CONF-871075--Vol.2

DE88 007806

CONF-871075--Vol.2

WASTE MANAGEMENT
Initiative
THE OAK RIDGE MODEL

1987 OAK RIDGE MODEL CONFERENCE

PROCEEDINGS

Environmental Protection
Volume II

sponsored by

The Department of Energy/Oak Ridge Operations

Research and Waste Management Division

and

Martin Marietta Energy Systems, Inc.

Prepared by
ANALYSAS CORPORATION

Printed by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY
under Contract No. DE-AC05-84OR21400

Oak Ridge Model Conference
Proceedings
Environmental Protection

Volume II

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The Clean Air/Water Agenda – What's New?

Presented by:

M. P. Mauzy, Roy F. Weston, Inc.

The Clean Air/Water Agenda - What's New

The Clean Air and Clean Water programs are the oldest media nationally based environmental programs addressing public concerns. Because of their longevity they are considered by many to be the most mature programs, however the problems and challenges are not solved and public priority and concerns remain high. The easy progress has been accomplished and the more dispersed and difficult problems remain. The Clean Water Act of 1987 establishes new national program directions. The Clean Air Act remains legislatively deadlocked but a new agenda is developing, with many components already in the implementation phase.

The emerging agendas in these elderly programs have far reaching implications to the regulated community, including federal government agencies. The options for implementation of toxic control, quality attainment, and pollution prevention will be discussed along with the probable impacts on those regulated by these programs.

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PROCEEDINGS PAPER NOT AVAILABLE
AT TIME OF PRINTING

RCRA Waste Oversight: Lead

Presented by:

W. A. Alexander, ORNL

RCRA WASTE OVERSIGHT: LEAD - W. A. Alexander, Oak Ridge National Laboratory*

Introduction

The Oak Ridge National Laboratory (ORNL) is a multipurpose research facility dedicated to the mission of expanding both basic and applied knowledge in the field of energy. ORNL accomplishes this mission through research in all fields of modern science and technology. ORNL's facilities include nuclear reactors, research laboratories, radioisotope production laboratories, and support facilities.

Historically, in the nuclear industry, water, concrete, steel, and lead have been common materials used for radiation shielding purposes. Lead, a high-density material, is a very effective shield for gamma radiation and has been utilized extensively at ORNL in association with radioisotope production and nuclear research. During these activities, lead became an inherent part of the radioactive waste and was disposed of in massive quantities by land burial.

Until recently, the disposal of lead by land burial was an accepted practice. However, the realization that lead in some forms is a

*Operated by Martin Marietta Energy Systems, Inc., for the U.S. Department of Energy under Contract No. DE-AC05-84OR21400

hazardous waste under the Resource Conservation and Recovery Act (RCRA) has resulted in a drastic change in the method of disposal, storage, and management of lead-containing materials and waste. Under the RCRA EP (Extraction Procedure) toxicity test (40 CFR 261.24) wastes are considered EP toxic and thus hazardous if they yield extracts containing lead equal to or greater than 5.0 milligrams per liter. The extraction procedure is defined by the Environmental Protection Agency and must be performed by this standard. EP toxicity tests at ORNL have shown that most forms of lead yield greater than this amount when the extraction procedure is performed. Also lead that is radioactively contaminated is defined as a "mixed waste" and must be managed accordingly. "Mixed waste" has its own problems because there is a lack of proper disposal methods for radioactively-contaminated lead and currently all such lead is being stored for future action.

Administrative and Physical Controls

At ORNL, an extensive program has been developed to eliminate lead from radioactive waste. This program involves the RCRA training of all ORNL workers with documented certification of training, the physical separation of lead from waste materials, the documentation and verification of a lead-free radioactive waste, and the operation of an aggressive field oversight program with a comprehensive reporting and follow-up program.

The RCRA training program is conducted for waste generators and focuses on the recognition of the many forms of lead-bearing materials and how to properly disposed of them. A combination of lectures and demonstrations are utilized to meet these objectives and to provide a basis for documentation for certification.

To provide documentation for the verification for a lead-free waste stream, each packet of waste is monitored for lead and a log-in sheet is completed for each packet. This activity can only be conducted by a waste generator that has been certified through the RCRA training program.

A field interface program has been developed to monitor waste streams for lead and other improper materials or practices. This program is described in the operational example section of this paper.

Operational Example

The potential for lead in nonradioactive waste streams was highlighted when a staff member of ORNL's Environmental Compliance and Health Protection Division was consulted to determine the proper disposal of lead-backed sheetrock. It was determined that lead-backed sheetrock had been utilized at ORNL for many years for the soundproofing of certain areas subject to high noise levels. Naturally, this issue resulted in an investigation into the generation and disposition of other lead-bearing materials and waste.

This investigation was conducted by staff members of ORNL's Department of Environmental Monitoring and Compliance as part of an on-going program titled "Field Interface and Remedial Response." The Field Interface and Remedial Response program involves conducting field inspections of construction and operating activities to prevent/detect potential environmental problems and to determine compliance to environmental laws and regulations. Field inspectors conduct "on-site" monitoring of all ORNL activities which provides an excellent opportunity to investigate the various uses of lead throughout the facility. One of the key components of this program is the reporting system which allows for the distribution of a "Site Inspection Report" to transfer information to a wide distribution throughout ORNL. Figure 1 is an example of a "Site Inspection Report" and how they are used to document the various uses of lead throughout ORNL.

Figure 1

Site Inspection Report

Location:	Building xxxx
Date:	9/2/87
Project Title:	Demolition of Building xxxx
Construction Eng:	John Doe
Contractor:	Number One Construction Company
Notes:	Staff members of the Environmental Monitoring and Compliance Department have been working with the contractor on the removal of lead from the waste material during the demolition of Building xxxx. Lead has been found in the form of lead anchors, lead roof flashing, and lead joints in the cast iron pipe. Attention must be paid to these sources of lead in all demolition work at ORNL.

During the investigation into the sources of lead-bearing material at ORNL, the following items or uses of lead were identified:

- Radiation shielding
- Lead-backed sheetrock
- Lead-backed ceiling tile
- Lead joints
- Automotive batteries
- Bases for equipment
- Weights
- Lead anchors
- Roof flashing
- Lead drains and pipes
- Lead solder
- Door stops
- Lead slag

Each of these lead-bearing materials or uses presents the potential for lead to be included in an inappropriate waste stream. Figure 2 is an example of lead shot which are utilized in scale and instrument calibration while Figure 3 identifies lead being improperly used as a base for a pencil sharpener. The use of lead as bases for small equipment, book ends, and door stops has been restricted due to safety concerns about workers being injured if a brick is dropped. Figure 4 details lead being used to join cast iron pipe and Figure 5 identifies lead anchors embedded in concrete. These are commonly used in buildings and must be considered in building demolition and the disposal of the waste materials. As indicated earlier, lead material is used with sheetrock and ceiling tile for soundproofing purposes and this must be considered when waste materials are involved. One of the largest uses of lead continues to be for the shielding for radioactive materials. Lead sheets and bricks are used to shield radioactive processes. Lead and lead-lined containers are used to transport radioactive materials and waste.

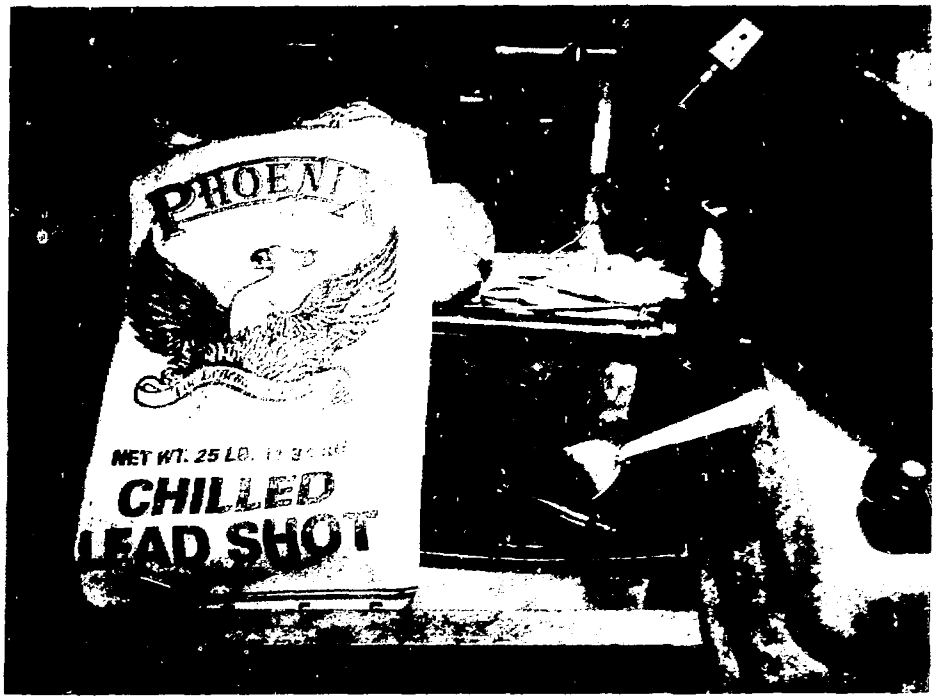


Figure 2. Lead in shot form is utilized in scales and instrument calibration

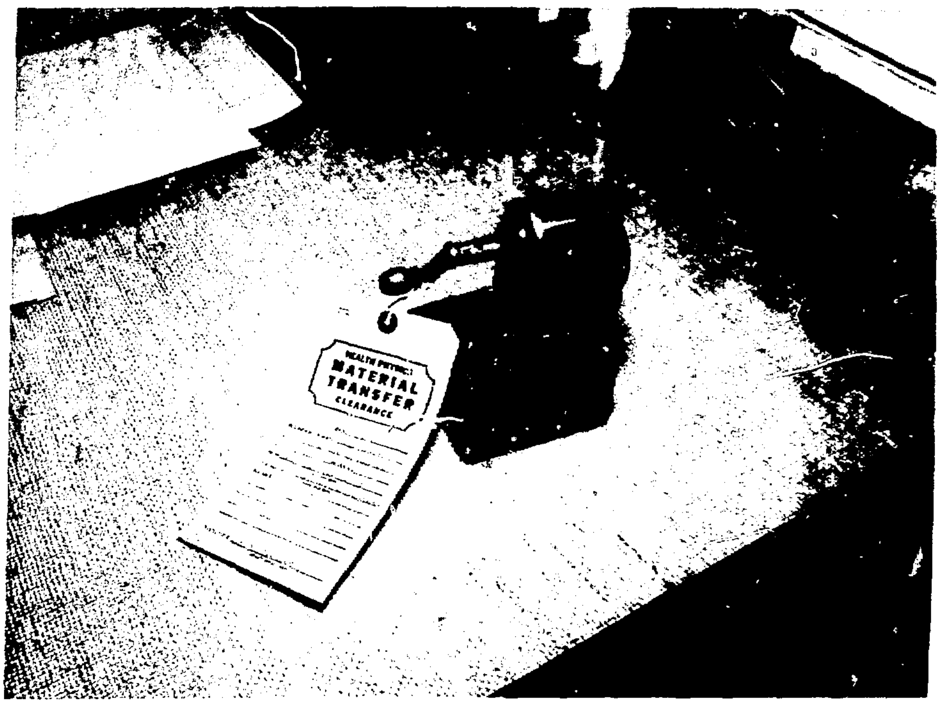


Figure 3. There are many uses of lead which are improper, including this example

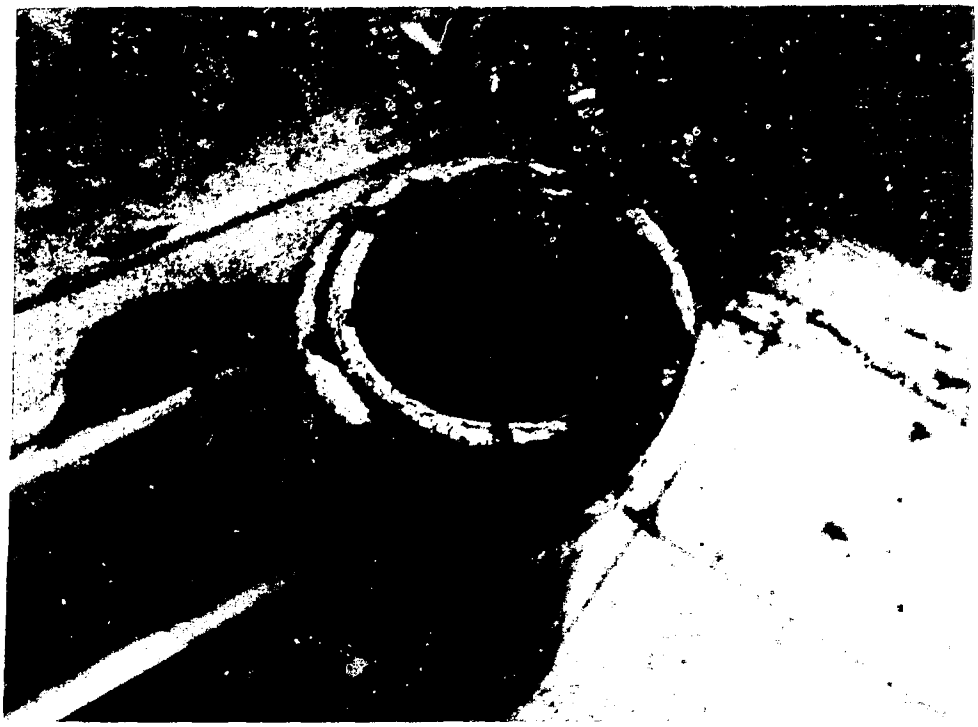


Figure 4. A common use of lead is to join sections of cast iron pipe

Figure 5. Lead anchors are ut'lized as fasterners in concrete

From these examples, it should be noted that lead and lead-bearing materials are utilized for many different purposes. This fact must be considered when there exists the potential for lead to be included in waste materials.

Summary

Now that various sources of lead have been identified, steps are underway to reduce the potential for lead to be included in ORNL waste streams.

Lead is only one example of RCRA waste that has the potential for being included in waste streams. The same training programs, waste certification, oversight, and management techniques can be utilized for other RCRA wastes that have the potential for being included undetected in waste streams. These include a RCRA training program for waste generators, waste certification, and a field oversight program. Also, new lead management techniques being utilized include the return of unused lead to the ORNL Lead Stores, the recycle of scrap lead, and a reduction in the purchase of new lead. Also improvements are being made in the storage of stock and waste lead to provide for the proper storage of RCRA material and waste. These activities are consistent with the Laboratory's waste minimization policy. Additional efforts are underway to investigate the existing technologies for the decontamination of lead that is radioactively contaminated to reduce the problems associated with the storage of "mixed waste."

Data Management for Site Investigations at the DOE Fernald, Ohio Plant (Feed Materials Production Center)

Presented by:

Dr. William J. Douglas, Roy F. Weston, Inc.

Data Management for Site Investigations at the DOE Fernald, Ohio PLANT (Feed Materials Production Center)

W.J. Douglas
D.R. Phoenix
L.A. Votta
J. Snyder
Roy F. Weston, Inc.

Site investigations of waste storage areas at the DOE Fernald FMPC were conducted over a period of 9 months. Data collection included geophysical and radiological surveys, soil sampling and chemical analysis, and aerial photogrammetry. Several hundred thousand data elements had to be stored and made accessible to produce map displays and statistical summaries of the data in twelve waste areas.

WESTON employed a VAX 11/785 based data management system and related micro-computer systems to support data management for the site characterization activities. WESTON'S Technical Information Management System (TIMS) employs an oracle DBMS, the CPS-1 numeric surface and graphics system, and SAS. This paper describes WESTON'S approach to data management for mixed waste site characterization, and the specific applications that were employed on the Fernald FMPC project.

DATA MANAGEMENT FOR SITE INVESTIGATIONS AT THE D.O.E. FEED MATERIAL PRODUCTION CENTER, FERNALD, OHIO

William J. Douglas, Ph.D., P.E.
Donald R. Phoenix, Ph.D.
Jerry K. Snyder, P.E.
Lisa Votta
Roy F. Weston, Inc.

1. INTRODUCTION

During the period 1 September 1986 to 1 June 1987, Roy F. Weston, Inc. (WESTON) conducted a characterization investigation study (CIS) in the Waste Storage area near the production area of the Feed Materials Production Center (FMPC) located near Fernald, Ohio, operated for the U.S. Department of Energy by Westinghouse Materials Company of Ohio (WMCO). This paper describes the WESTON Technical Information Management System (TIMS) and the specific aspects of data management that were applied to site investigations during the CIS.

Section 2 summarizes the WESTON TIMS data entry and reporting components in general terms.

Section 3 describes the data files and the reports developed to support WESTON scientists in conducting the CIS.

2. TIMS DESCRIPTION

The WESTON approach to site characterization is focused in the WESTON Technical Information Management System (TIMS), which has been designed specifically for application to site investigations. TIMS provides a means for entering data into a centralized data base for direct access by engineers and scientists who are concerned with various aspects of the site - geology, hydrology, topography, meteorology, etc.

The TIMS structure includes a unified site-related framework for storing information, and for assuring that it has undergone the appropriate level of quality assurance before it is accessible to users for reporting and analysis purposes. TIMS also includes file security procedures to ensure that client files maintain their integrity and confidentiality. The centralized data file is made accessible to users through the application of the following commercial software systems residing on the WESTON VAX computer network:

- ORACLE - Data Base Management System
- SAS - Statistical Analysis System
- CPS-1 - Numerical Surface/Graphics System
- GKS - Graphics Software
- DCL - User Interaction Software Shell

TIMS is menu-driven and permits users to select the appropriate files and produce a variety of report types, both tabular and graphical, that are an inherent part of the site characterization process.

There are four fundamental elements of the WESTON TIMS:

- o Cartographic Frame Subsystem
- o Field Observation Subsystem
- o Sampling and Laboratory Analysis Subsystem
- o Data Reporting and Analysis Subsystem

The first three of these are concerned with data entry into the TIMS ORACLE Data Base. The remaining subsystem relates to the extraction of data to create meaningful information summaries that guide decision makers in the site characterization process. Figure 1 illustrates the elements of TIMS in each of the four quadrants.

2.1 Cartographic Frame Subsystem

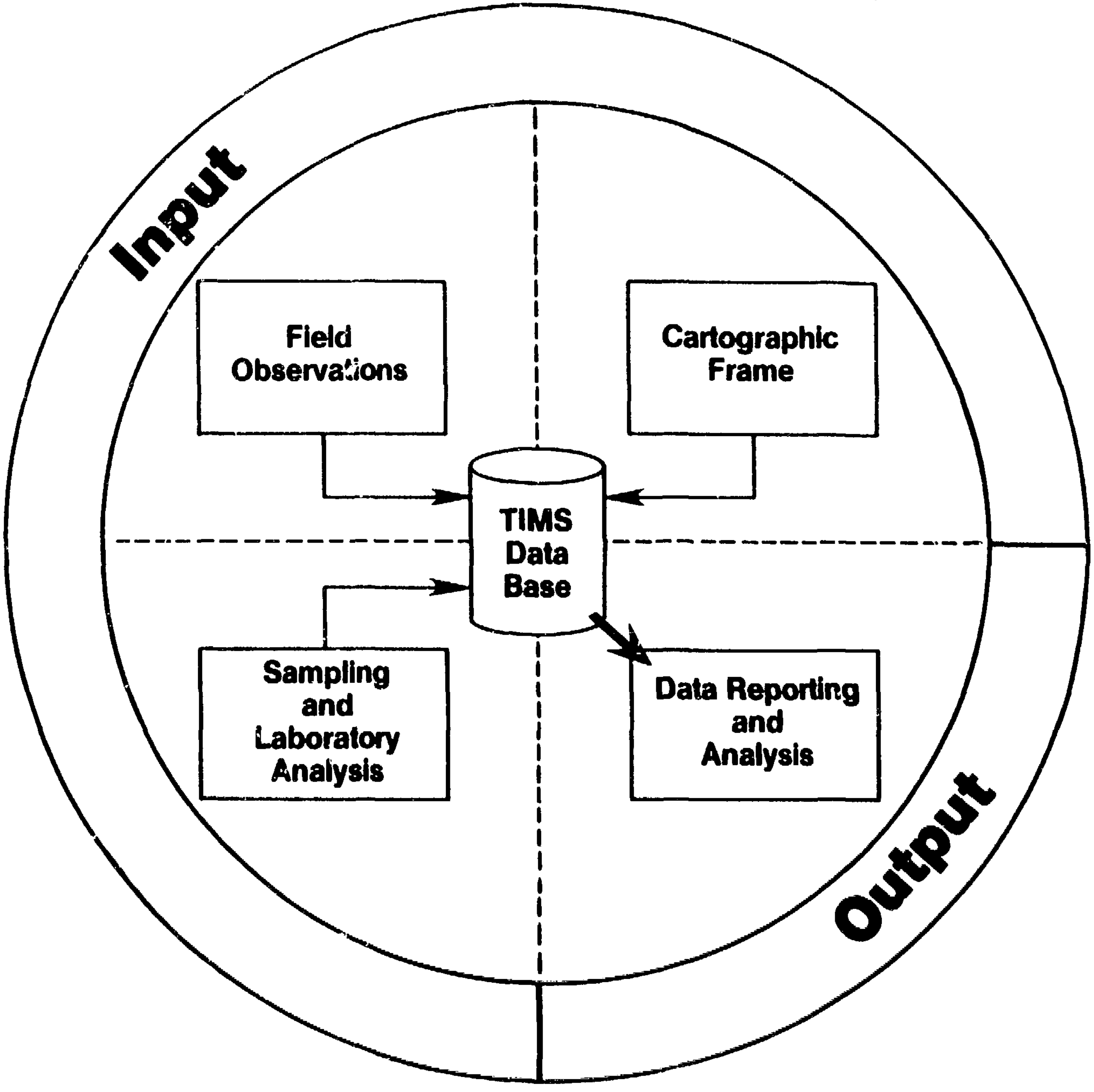
An essential element of the WESTON TIMS is the provision for geographic and spatial reference for data elements. This reference permits the use of spatially-based computer graphics in the interpretation of information. Figure 2 illustrates the process, which starts with an aerial photo survey of the site, complemented by standard land survey procedures to ensure that aerially-acquired data have been ground-truthed.

The survey results are entered into WESTON's automated mapping systems, which include Intergraph work stations interfacing with a VAX computer. A digitized base map is produced that includes natural and human-made features such as:

- o Buildings.
- o Roads.
- o Railroads.
- o Property lines.
- o Fence lines.
- o Topography.
- o Hydrology.
- o Gridding.
- o Sampling stations.

The digitized base map undergoes validation procedures, and a magnetic tape is created that is compatible with the TIMS CPS-1 numerical surface and object file format requirements. This tape is loaded onto the WESTON VAX system and is transferred into the TIMS Data Base.

WESTON Technical Information Management System



Cartographic Frame

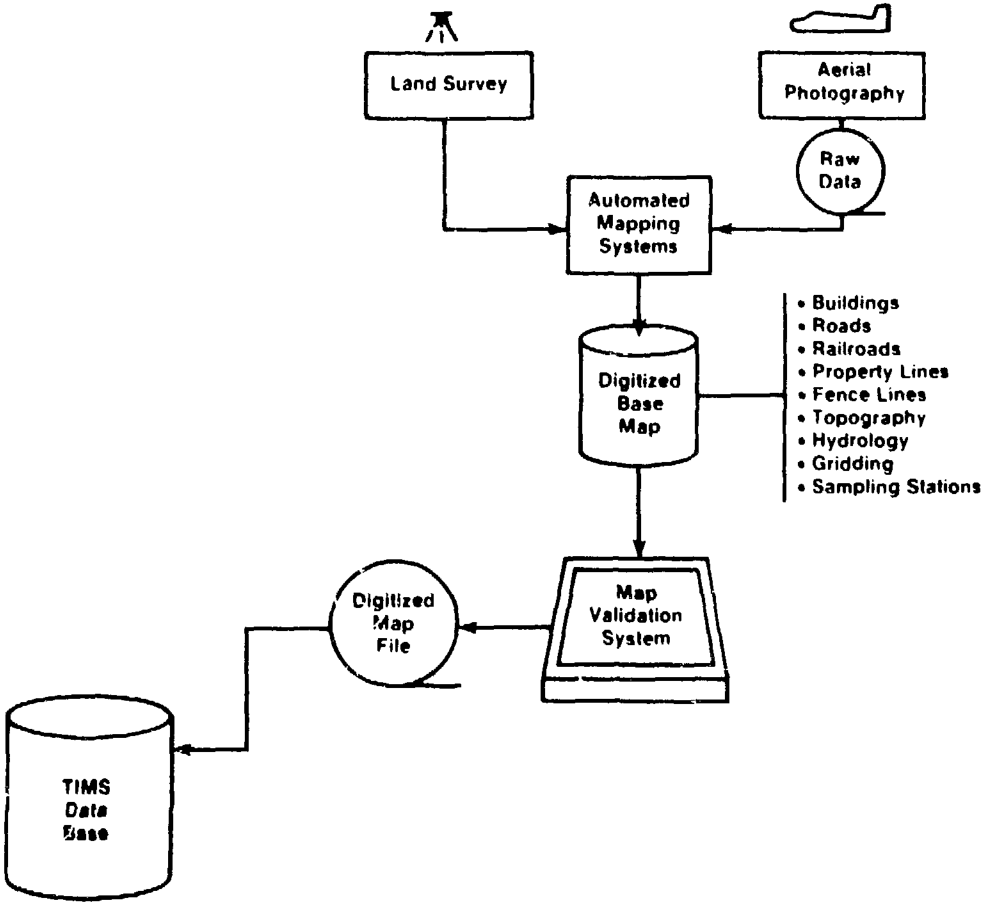


FIGURE 2

2.2 Field Observation Subsystem

The Field Observation Subsystem is illustrated in Figure 3. Field observations are generally recorded in field notebooks and serve as the principal, legally admissible source material relating to the site characterization process. Notebook data is coded on standard 1H data forms, or data forms may be used directly by field personnel to code information. The forms have been developed to capture all of the required information that is essential to a site characterization program. The data forms are submitted to data entry personnel, who employ standardized screens to complete the data entry process. The screen formats are very similar to the data forms, which assists the data entry process and reduces key entry errors. Data entered from field observations include:

- Site ID.
- Drilling logs.
- Lithology.
- Hydrologic observations.
- Meteorologic observations.
- Sampling location codes.

Preliminary data files are validated by the Project Data Base Administrator (DBA) and technical staff, ensuring that the original field observations have been accurately portrayed in the data base. A user access system precludes unauthorized personnel from using data that have not passed through the data validation process.

Geophysical and radiological surveys are also conducted by field crews as part of the site characterization process. The survey data may be recorded on magnetic tape or in hard copy notebooks. The data must pass through data validation and quality assurance before they are entered into the TIMS data base.

2.3 Sampling and Laboratory Analysis Subsystem

The Sampling and Laboratory Analysis Subsystem is described in Figure 4. It begins with the development of a sampling plan that is commensurate with the site attributes and the site characterization needs of the project. Samples of soil, air, water, sediments, and biota are extracted and logged onto chain-of-custody forms, and sent to the WESTON analytical laboratory. A portion of the samples may be sent to a subcontractor laboratory, depending on workload and turnaround time requirements for the project.

Field Observations

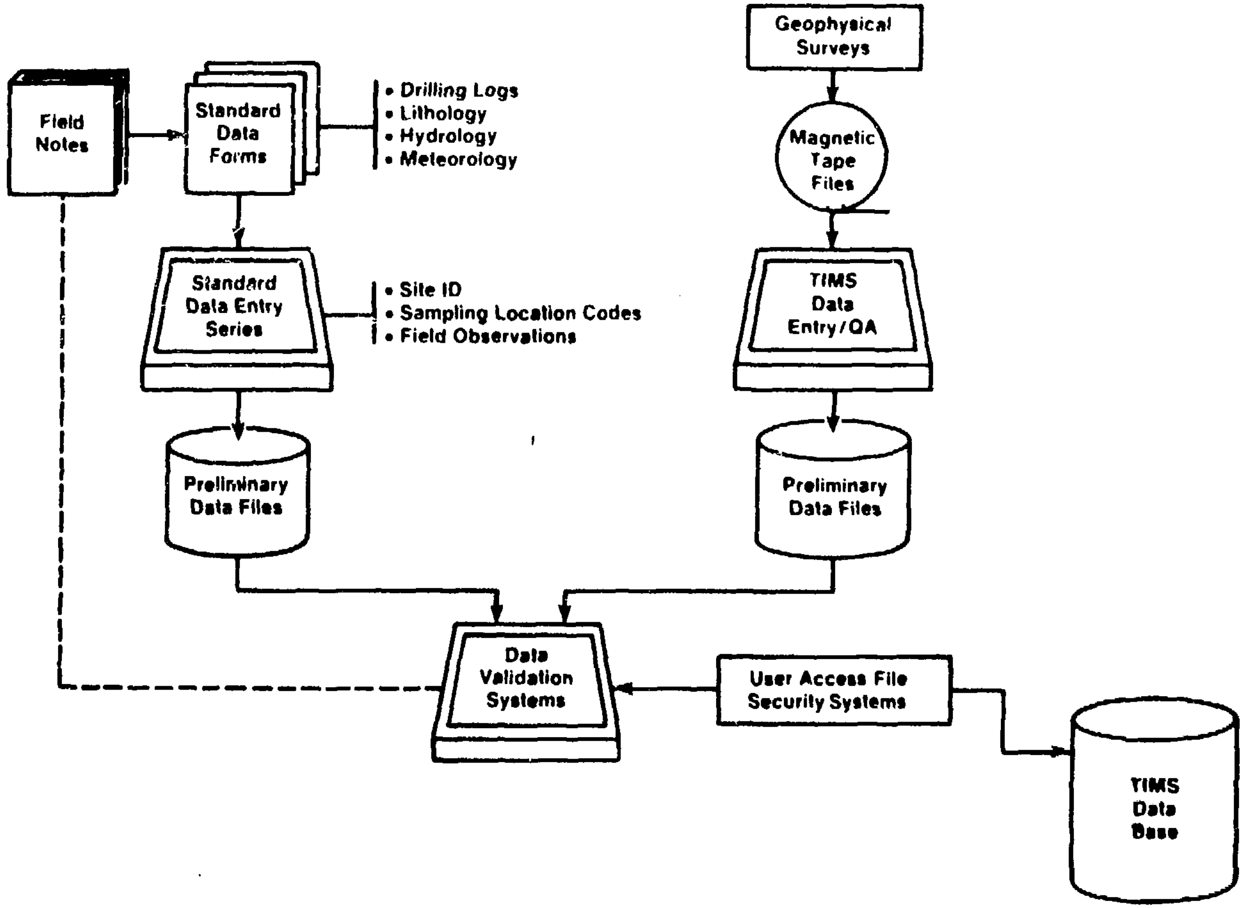


FIGURE 3

Sampling and Laboratory Analysis

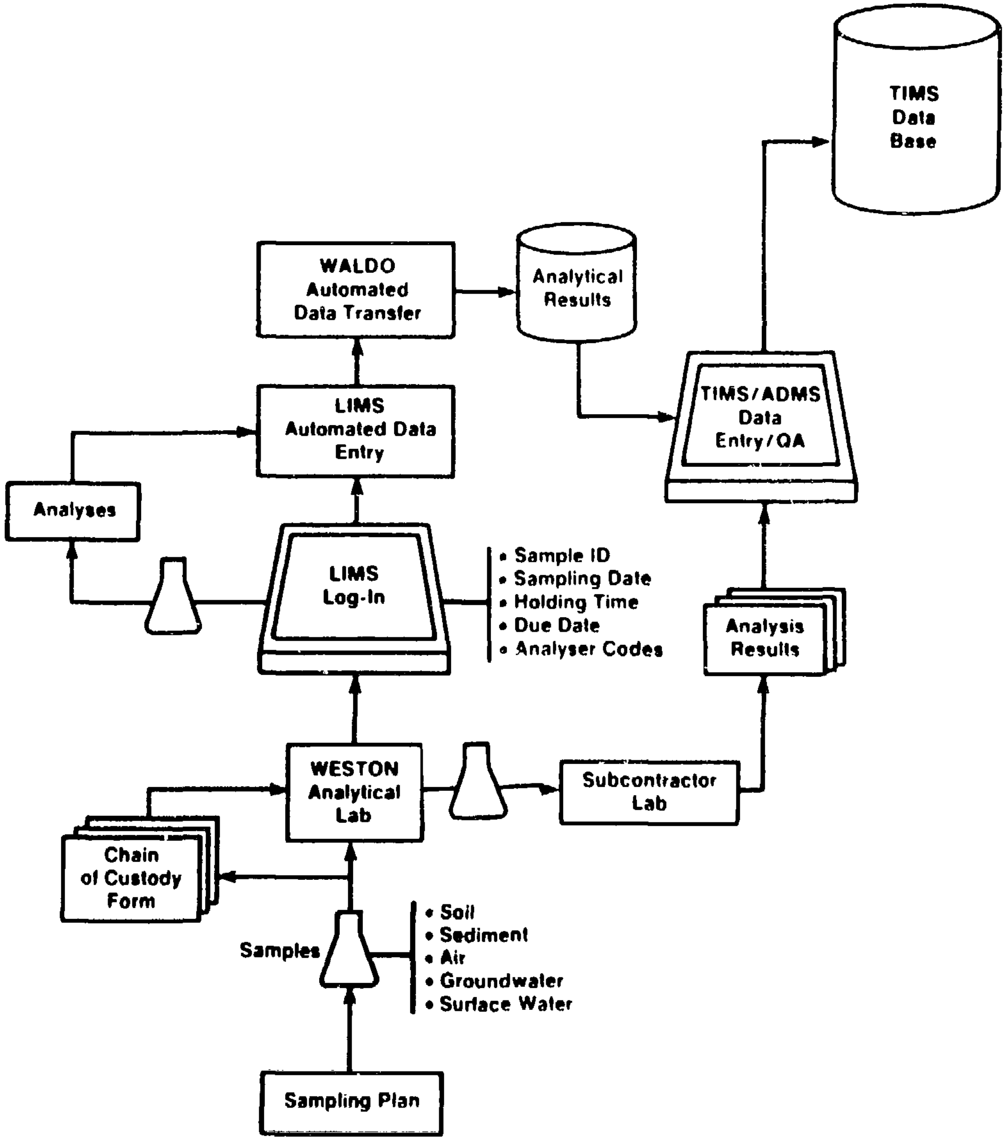


FIGURE 4

The information describing samples to be analyzed by WESTON are entered into the Laboratory Information System (LIMS). This includes:

- o Sample ID.
- o Sampling date.
- o Holding time.
- o Due date.
- o Analysis types.

The samples are then sent to the appropriate laboratory department for analysis - metals, organics, or inorganics.

The LIMS includes direct interfaces with laboratory measurement systems to provide automated entry of data into the LIMS computer files. The WESTON Analytical Data On-Line System (WALDO) creates preliminary files that include analytical results and sample status information. These results pass through a standardized QA procedure and are entered into the TIMS Data Base.

Samples sent to subcontractor laboratories are analyzed in accordance with the WESTON-defined schedule. WESTON makes available its Analytical Data Management System (ADMS) to subcontractor laboratories to produce dBaseIII diskettes containing sample results. The diskettes are entered into the WESTON TIMS after passing through the QA procedure. Data entry screens for analyte results are menu-driven and are designed to facilitate the data entry process.

2.4 Data Reporting and Analysis Subsystem

The principal objective of the first three elements of TIMS is to produce a consistent, quality-assured data base that can be applied by scientists and engineers to display site characteristics in a manner that provides visibility to the decision-making process. The Data Reporting and Analysis Subsystem described in Figure 5 is designed to bring the capabilities of proven, commercially-available software to the user in a manner that facilitates the application of these tools to the data base.

A set of menus within DCL provides users with a variety of choices relating to the types of reports to be produced and the parameters to be analyzed and displayed. The user selects an Installation that is of interest, which is a piece of geography (physical location/group of sites) that is being characterized. He/she also selects site codes (regions within the Installation), location codes (specific points where samples were taken or observations recorded), and dates that are of interest. The TIMS ORACLE procedures

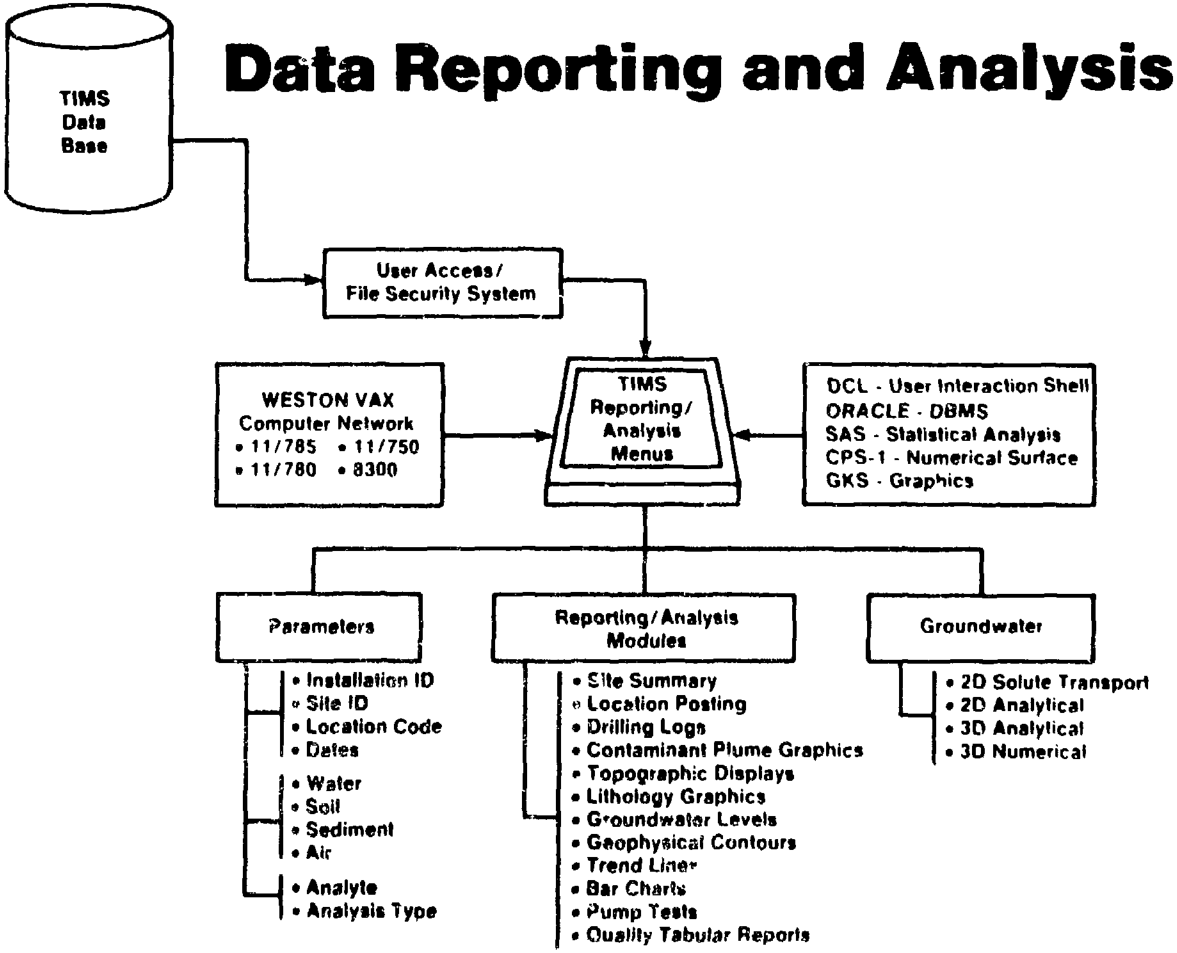

Data Reporting and Analysis
TIMS
Data
Base
User Access/
File Security System
WESTON VAX
Computer Network
• 11/785 • 11/750
• 11/780 • 8300
TIMS
Reporting/
Analysis
Menus
DCL - User Interaction Shell
ORACLE - DBMS
SAS - Statistical Analysis
CPS-1 - Numerical Surface
GKS - Graphics
Parameters
• Installation ID
• Site ID
• Location Code
• Dates
• Water
• Soil
• Sediment
• Air
• Analyte
• Analysis Type
Reporting/Analysis
Modules
• Site Summary
• Location Posting
• Drilling Logs
• Contaminant Plume Graphics
• Topographic Displays
• Lithology Graphics
• Groundwater Levels
• Geophysical Contours
• Trend Lines
• Bar Charts
• Pump Tests
• Quality Tabular Reports
Groundwater
• 2D Solute Transport
• 2D Analytical
• 3D Analytical
• 3D Numerical

FIGURE 5

extract the selected segment of the data base and prepare it for reporting. The selected reporting method - tabular, bar chart, time series, or a map - may be applied to a water quality data set or to a soil chemistry data set.

A variety of user-selected reporting and analysis modules are available in TIMS. These include:

- o Site Summaries
- o Location Posting
- o Drilling Logs
- o Contaminant Plume Graphics
- o Topographic Displays
- o Lithology Graphics
- o Groundwater Levels
- o Trend Lines
- o Time Series
- o Bar Charts
- o Pump Test Reports
- o Water Quality Tables
- o environmental measurement concentration isopleths

The user may select from the menu of available options to apply ORACLE, CPS-1, and SAS in a user-friendly, menu-driven mode. A more experienced user may elect to produce customized reports by accessing the data base with ORACLE queries that are outside the scope of the menu-driven set. He/she may also apply CPS-1 and SAS directly to produce the extensive reporting and information display capabilities of these systems. Furthermore, the base map layers are also available for map overlays in conjunction with user-defined spatial displays of information.

Finally, a set of groundwater models is available within TIMS to assist in analyzing the transport of solutes and radionuclides. These models interface with the TIMS Data Base to acquire the site variables that are inherent in the modeling process and merge them with the other required data elements to be entered by the user. They provide a means for

evaluating remediation alternatives to support the remediation of contaminated sites and for analyzing the long-term characteristics of aquifers in both saturated and unsaturated hydrological zones.

2.5 Summary

The complete WESTON TIMS (WTIMS) is illustrated in Figure 6, which incorporates the details of each of the subsystems. It is important to recognize that the WTIMS is not simply a software system. Rather, it includes:

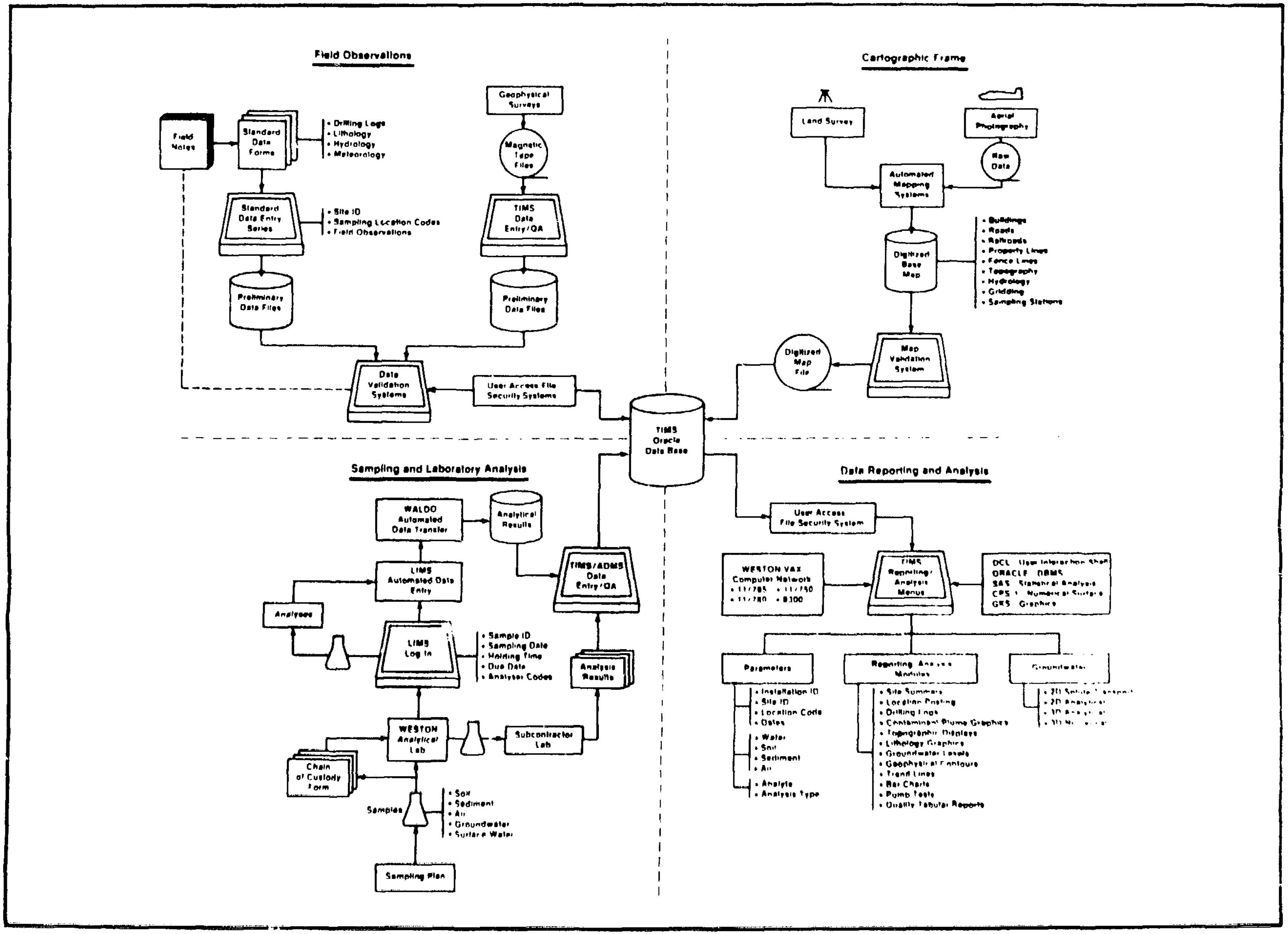


FIGURE 6 **WESTON Technical Information Management System**

- o Procedures.
- o Standards.
- o Software.

Each of these is an integral element of conducting a successful site characterization and investigation the WESTON Way.

3. DATA MANAGEMENT FOR FMPC CIS

The specific aspects of technical data management that were conducted for the Fernald CIS started with the development of a Cartographic frame. It also included support to three distinct analyses consisting of geophysical surveys, radiological surveys, and chemical radiological analyses of soil and water samples.

3.1 Cartographic Frame

In order to establish a basis for displaying technical information, an aerial survey of the FMPC was conducted. Survey data was digitized in Ohio State plane coordinates to produce a layered file structure of man-made and natural features within an area of six square miles. The digitized files were used to produce a variety of mylar maps using a Data General MV-4000 mini-computer and a Zeta 836 plotter for use by technical staff in conducting site characterization studies.

The cartographic files were converted to a CPS-1 compatible format, and loaded onto magnetic tapes at the WESTON cartographic center. The tapes were loaded onto disks for access by the VAX 11/785 processor for use in conducting site characterization studies. The layers included in the data base are shown in Table 1.

Table 1
Cartographic Layers

Layer	No. of Points
Hydrography	21,669
Buildings and Structures	16,007
Fences	4,519
Roads	28,489
Railroads	889
Approximate Pit Boundaries	474
Pipelines	31
Total	72,078

The files were used in conjunction with the CPS-1 numerical surface software to reproduce base maps and compare them with originals. After this QA procedure was completed, the files were made available to project staff to provide the cartographic frame for displaying the information collected in conducting the geophysical and radiological surveys, and the chemical and radiochemical laboratory analyses.

The large variety of available layers was reviewed for applicability to the project needs. Layers were selected for producing map products that would best represent the required attributes and provide assistance in interpreting technical information.

3.2 Geophysical Surveys

The results of the FMPC geophysical surveys are reported in Reference 1. The objectives of this study were to provide information that would assist in locating soil boring and groundwater monitoring wells, and to identify locations that could be hazardous to drilling operations due to the presence of buried drums containing hazardous or radioactive waste. Three geophysical measurement techniques were employed: magnetic (M), electromagnetic (EM), and ground penetrating radar (GPR).

A local base grid of 100 ft. x 100ft. measured as local Southing (SF) and Easting (EF) was used in the study area and related to the Ohio State plane coordinate system by conducting a land survey. A coordinate transformation was developed to convert the local values (EF, SF) into global (state planar) Easting and Northing coordinates (E,N). This transformation was computerized and used routinely to convert all field measurements into a global reference for the purpose of reporting study results consistently in the documentation of the investigations.

The magnetic survey consisted of approximately 1500 measurements conducted at 25 foot intervals, eight feet above ground surface, and stored in digital memory. The results were summarized to produce a data file that included:

local SF, EF coordinates (ft.)
magnetic intensity (gammas)

This file was corrected for diurnal variation and transformed to state planar coordinates. Table 2 illustrates a sample of the magnetic intensity data file.

Table 2

Magnetic Intensity Data (gammas)

State Plane Coordinates Northing (ft)	Easting (ft)	Total Magnetic Intensity (Uncorrected)	Correction for Diurnal Variation	Total Magnetic Intensity (Corrected)
481473.227	1377893.172	56017.0	.0	56017.0
481448.234	1377892.484	56007.0	.0	56007.0
481423.242	1377891.797	56029.0	.0	56029.0
481397.570	1377916.125	56350.0	.0	56350.0
481422.559	1377916.797	56042.0	.0	56041.0
481447.551	1377917.484	55993.0	.0	55993.0
481472.543	1377918.172	56019.0	.0	56018.0
481497.531	1377918.859	56028.0	-1.0	56028.0
481522.523	1377919.547	56032.0	-1.0	56032.0
481547.512	1377920.219	56040.0	-1.0	56040.0
481572.504	1377920.906	56060.0	-1.0	56060.0
481621.801	1377947.266	56045.0	-1.0	56044.0
481596.813	1377946.578	56047.0	-1.0	56046.0
481571.820	1377945.891	56028.0	-1.0	56027.0
481546.828	1377945.203	56021.0	-1.0	56019.0
481521.840	1377944.531	56026.0	-3.0	56023.0
481496.848	1377943.844	56033.0	-3.0	56030.0
481471.859	1377943.156	56026.0	-3.0	56023.0
481446.867	1377942.469	55965.0	-3.0	55962.0
481421.875	1377941.781	55941.0	-3.0	55938.0
481396.887	1377941.109	56004.0	-3.0	56001.0
481371.211	1377965.406	55977.0	1.0	55978.0
481396.203	1377966.094	55966.0	1.0	55967.0
481421.191	1377966.766	55972.0	1.0	55973.0
481446.184	1377967.453	55997.0	1.0	55998.0
481471.176	1377968.141	55965.0	1.0	55965.0
481496.164	1377968.828	56012.0	1.0	56013.0
481521.156	1377969.516	56033.0	1.0	56034.0
481546.145	1377970.188	56003.0	1.0	56004.0
481571.137	1377970.875	56004.0	1.0	56005.0
481596.129	1377971.563	56015.0	1.0	56017.0
481621.117	1377972.250	56000.0	2.0	56002.0
481646.109	1377972.922	55968.0	2.0	55970.0
481670.418	1377998.609	56014.0	2.0	56016.0
481645.426	1377997.922	56013.0	2.0	56015.0
481620.434	1377997.250	56009.0	2.0	56011.0
481595.445	1377996.563	55983.0	2.0	55986.0
481570.453	1377995.875	55956.0	2.0	55958.0
481520.473	1377994.516	56058.0	3.0	56060.0
481495.480	1377993.828	55999.0	3.0	56001.0
481470.492	1377993.141	56029.0	3.0	56032.0
481445.500	1377992.453	56012.0	3.0	56015.0
481420.508	1377991.766	55941.0	3.0	55944.0
481395.520	1377991.094	55938.0	3.0	55941.0
481370.527	1377990.406	55922.0	3.0	55925.0
481369.844	1378015.391	56496.0	3.0	56499.0
481394.836	1378016.078	55773.0	3.0	55777.0
481419.824	1378016.750	55963.0	4.0	55966.0
481444.816	1378017.438	56039.0	4.0	56043.0
481469.809	1378018.125	56015.0	4.0	56019.0

The results of the magnetic survey were processed using the CPS-1 numerical surface and graphical display software. As a quality control procedure, the data was posted in relation to the grid for review by geophysicists responsible for the survey. Files were corrected and edited, and then the data was displayed in the form of isopleths of constant magnetic intensity. The displays were varied by changing contour intervals, grid spacing, map scale, viewing window, and color codes to produce a variety of display alternatives. The results were overlayed onto the cartographic frame to provide additional interpretive capabilities to the survey results.

After an extensive period of data analysis, a set of data products was defined by the geophysicists to support the study documentation. These map displays were prepared in full map scale, and then the scale was reduced to provide computer-generated, multi-color map products in 8 1/2" x 11" format for direct use in the draft report. These products were then photocopied in color for inclusion in the final report for the study.

Figure 7 illustrates the total magnetic intensity data control point posting locations for the waste storage area. Full-size maps with posted values were used by the geophysicists to assist in data interpretation and quality control. Similar postings were provided for EM and GPR data.

Figure 8 illustrates the total magnetic intensity in the waste storage area. Figure 9 is a representation for a selected window that consists of Pit 1.

Electromagnetic (EM) terrain conductivity survey data was managed similarly to magnetic data. Approximately 2000 EM measurements were entered into the EM data file. Figure 10 is a posting of the EM control points in the Waste Storage Area, and Figure 11 is a plot of EM conductivity. A window showing the EM conductivity in Pit 2 is presented in Figure 12.

A total of 65 computer-generated figures such as these using CPS-1 were included in the Volume 1 Geophysical Survey Report for FMPC, including detailed windows for each of 19 sites consisting of waste pits, sludge ponds, fly ash piles, a sanitary landfill, and other selected areas.

FIGURE 7

TØTAL MAGNETIC INTENSITY DATA

CØNTRØL PØINT PØSTINGS MAP ØF THE WASTE STØRAGE AREA

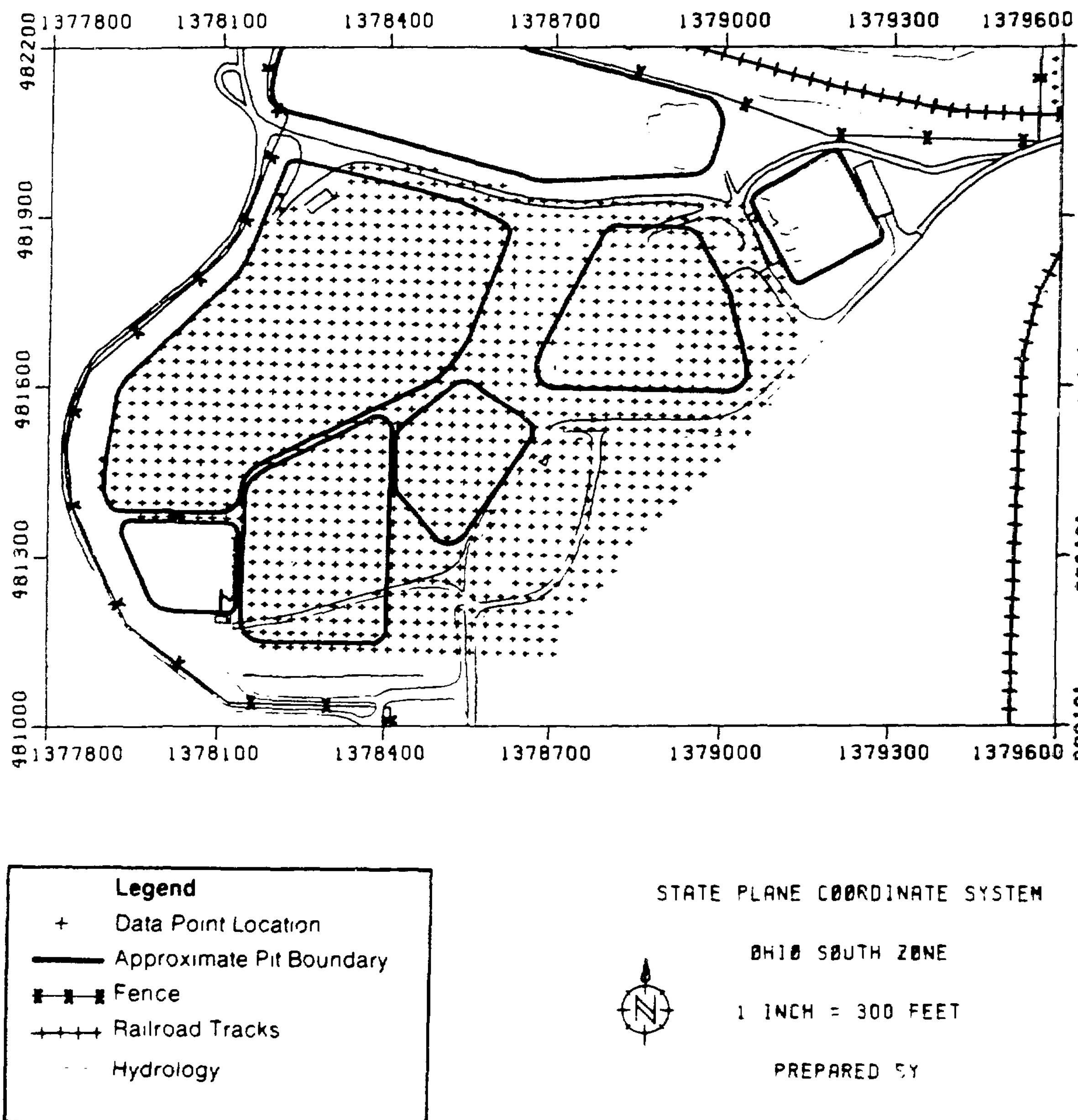
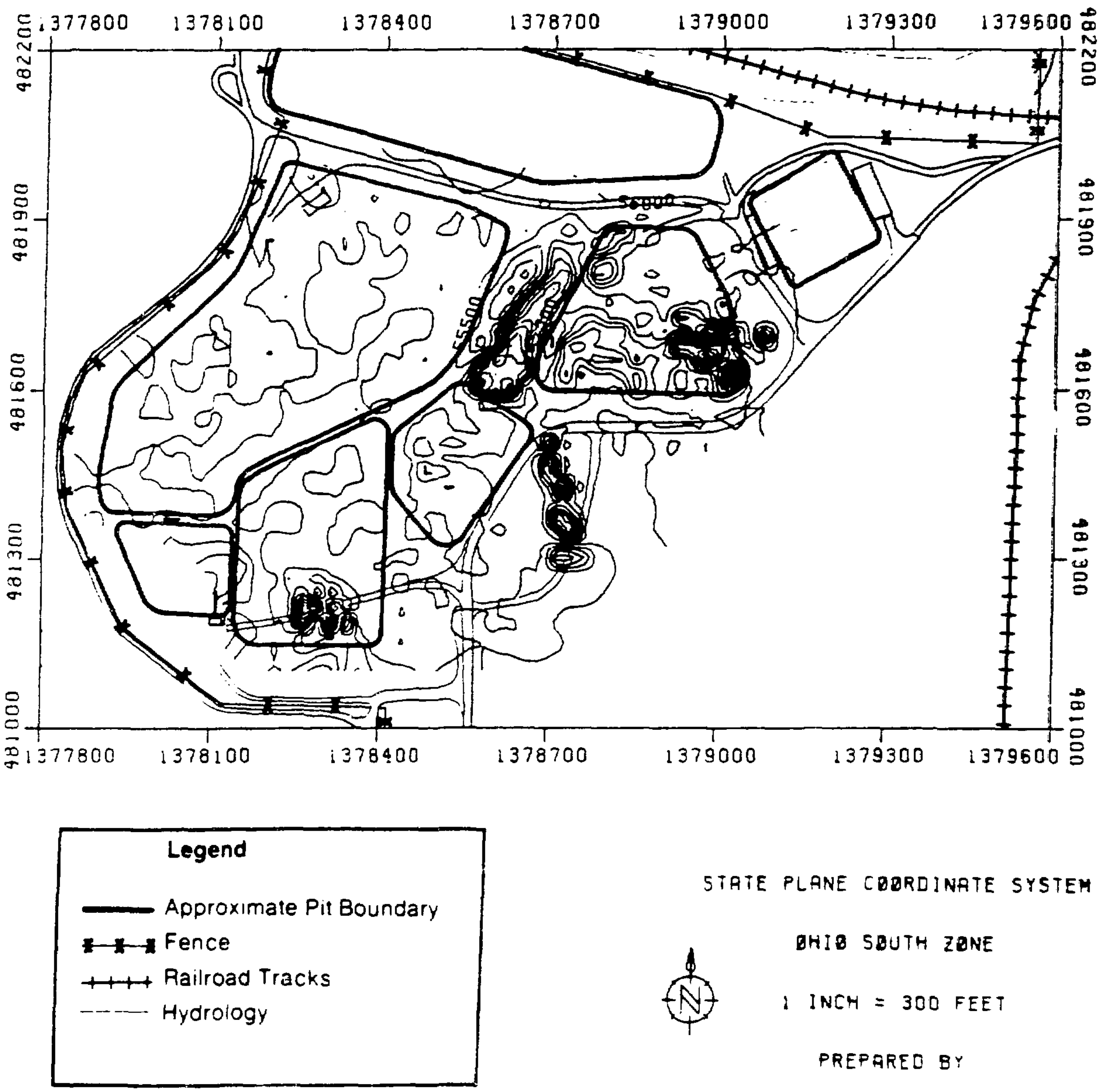


FIGURE 8

ØTAL MAGNETIC INTENSITY CØNTØUR MAP ØF THE WASTE STØRAGE AREA

CØNTØUR INTERVAL = 500 GAMMAS



STATE PLANE CØØRDINATE SYSTEM

ØHIØ SØUTH ZØNE

1 INCH = 300 FEET

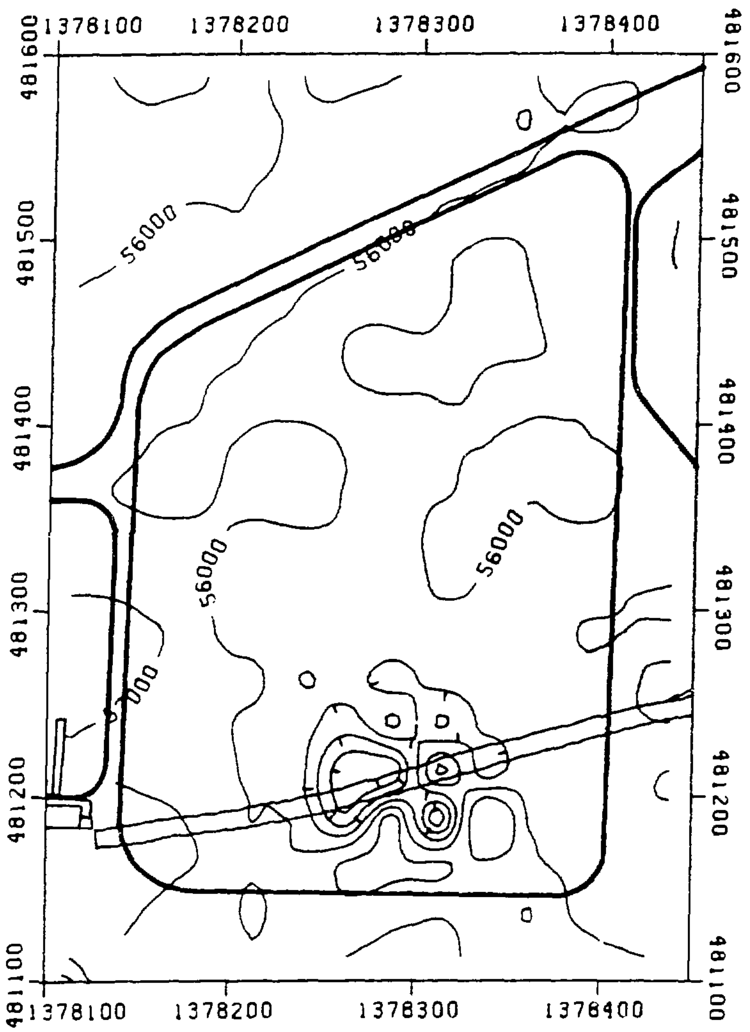
PREPARED BY

RØY F. WESTØN, INC. 9/1/87

FIGURE 9

TØTAL MAGNETIC INTENSITY CØNTØUR MAP ØF PIT ØNE

CØNTØUR INTERVAL = 1000 GAMMAS



STATE PLANE CØØRDINATE SYSTEM

ØHIØ SØUTH ZØNE

1 INCH = 100 FEET

PREPARED BY

RØY F. WESTØN, INC. 9/1/87

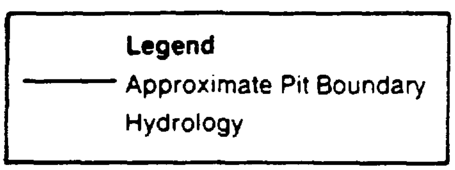
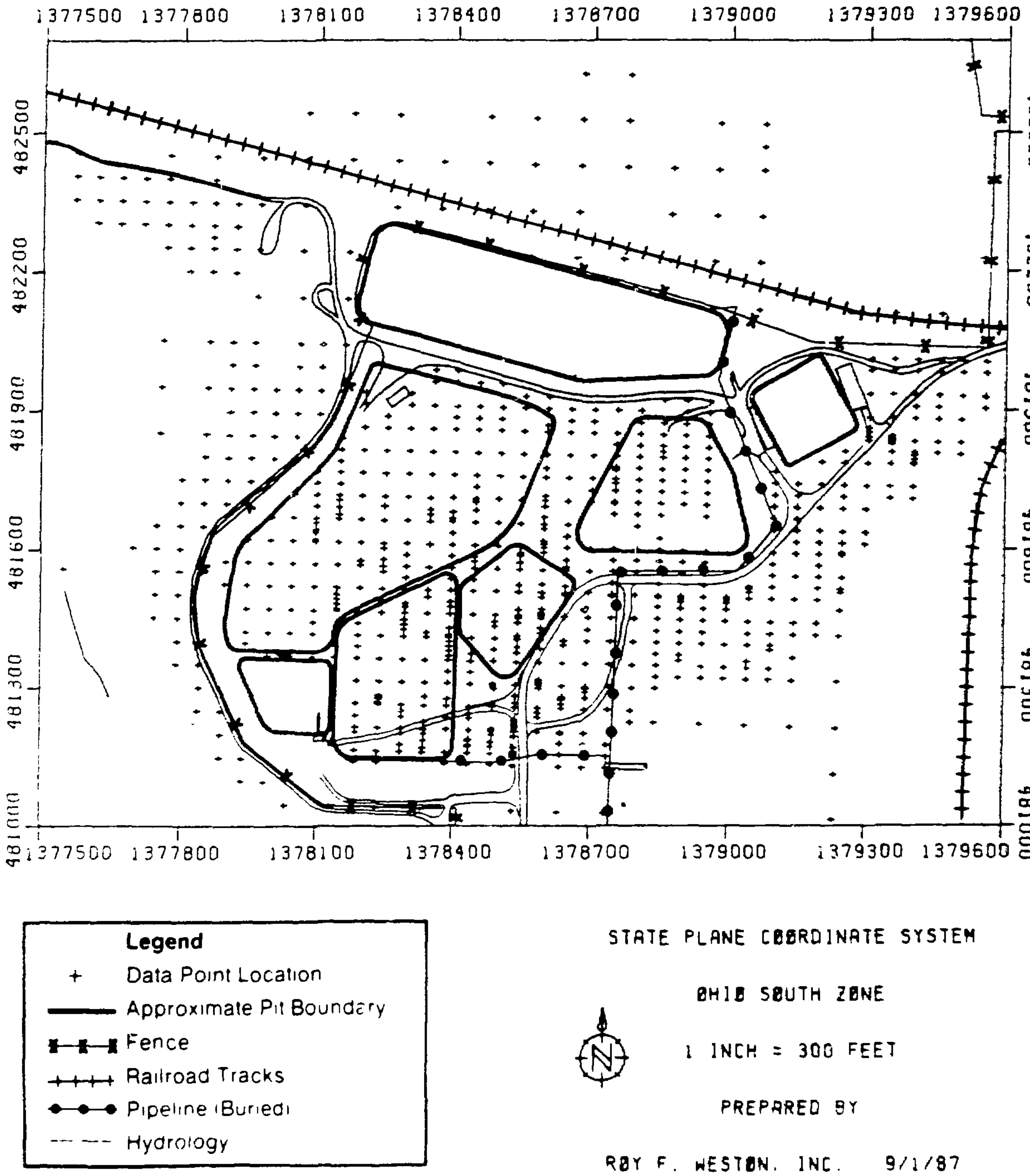


FIGURE 10

EM31 DATA CØNTRØL PØINT PØSTINGS MAP

ØF THE WASTE STØRAGE AREA



STATE PLANE CØØRDINATE SYSTEM

ØHIØ SØUTH ZØNE

1 INCH = 300 FEET

PREPARED BY

RØY F. WESTØN, INC. 9/1/87

FIGURE 11

EM31 HØRIZØNTAL DIPØLE APPARENT CØNDUCTIVITY CØNTØUR MAP ØF THE WASTE STØRAGE AREA

CØNTØUR INTERVALS = 20 MMHØS/M ANC 100 MMHØS/M

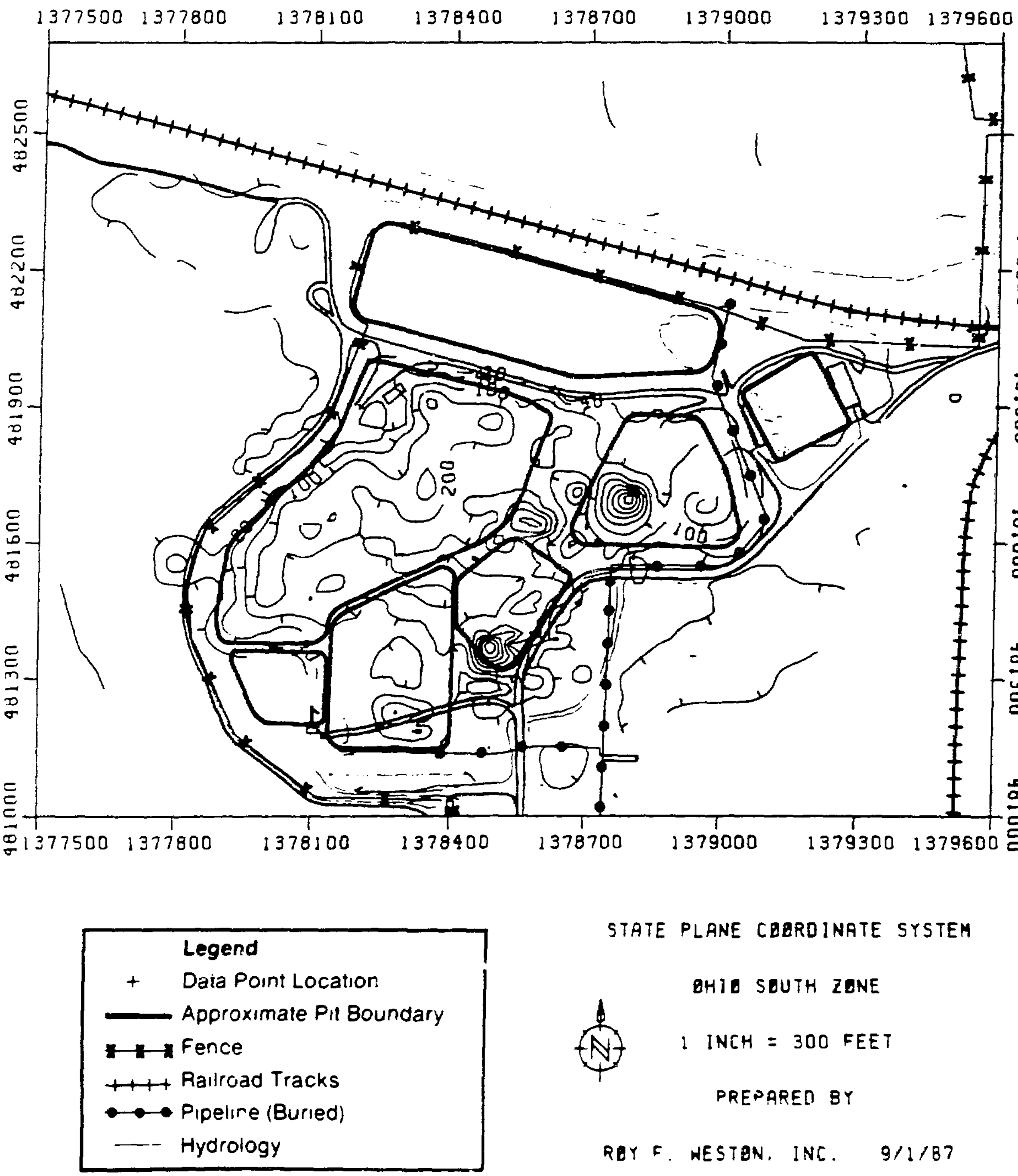
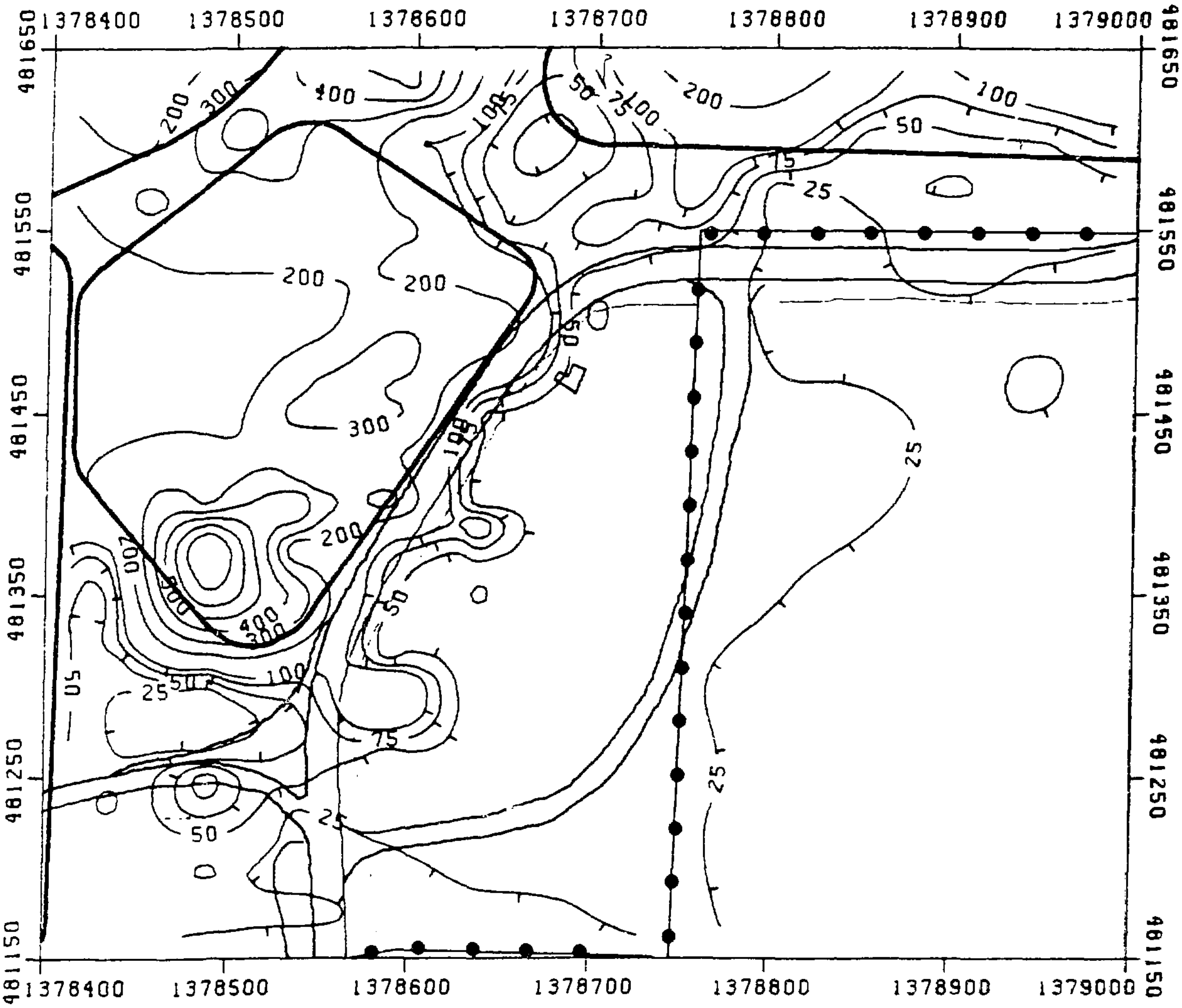


FIGURE 12

EM31 HØRIZØNTAL DIPØLE APPARENT CØNDUCTIVITY CØNTØUR MAP ØF PIT TWØ

CØNTØUR INTERVALS = 25 MMHØS/M AND 100 MMHØS/M



Legend

- Approximate Pit Boundary
- Pipeline (Buried)
- Hydrology

STATE PLANE CØØRDINATE SYSTEM

ØHIØ SØUTH ZØNE

1 INCH = 100 FEET

PREPARED BY

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3.3 Surface Radiation Surveys

As part of the CIS study at the FMPC site, it was necessary to characterize the surface radiation distributioon survey cons - 1) radiation count rate measurements, 2) dose rate measurements, 3) exposure rate measurements, and 4) surface and near-surface soil samples.

Radiation count rates in counts per minute (CPM) were measured with a Field Instrument for dicting low energy radiation or FIDLER. This instrument was used to measure gamma radiation in the range emitted from Th-234 of the U-238 decay chain (63 Kev).

Three separate FIDLER surveys were performed: a) a survey of 2,354 locations at 50 foot intervals was performed over the entire waste storage area, b) a qualitative "scan" of 3,802 blocks, 25 feet on a side, was performed of suspected hot spots, and c) a detailed survey of 15,912 locations in elevated radiation count rate areas at 6.25 foot intervals.

Dose rates from beta and gamma radiation in millirads per hour, mRad/hr, were measured at 2,300 locations on 50-foot grid intervals.

Exposure rates in microroentgens per hour, uR/hr, were measured at 130 separate locations. Surface and near-surface soil samples were collected at 2,500 locations where it was estimated, based on the FIDLER readings, that the U-238 concentration would be greater than 35 pCi/g. Soil samples were analyzed by gamma ray spectrometry for U-238 concentration.

3.4 Chemical and Radiochemical Characterization

The FMPC required a wide variety of soil and water sampling for the purpose of establishing the chemical and radiochemical characteristics of pit areas where waste products are stored. A sampling program was developed for 13 sites, requiring 67 borings and 10 surface water sampling locations. Soil samples were subject to extensive quality assurance procedures which included field blanks of the water used in the decontamination process, blind duplicates of soil samples sent to the laboratory for analysis, duplicate counts of every tenth sample passing through the laboratory, and a laboratory QA audit to ensure the procedures were being followed. The results of the chemical and radiochemical analyses are reported in Reference 2.

A wide variety of analytical studies were conducted by the WESTON Analytical Laboratory and subcontractor laboratories consisting of both RCRA characteristic and radiological parameters. The types of analysis and associated numbers of parameters are defined in Table 3.

Table 3
Parameter Types Analyzed

Type		Number of Analytes
EP-Toxicity Metals		8
HSL Organics		24
HSL Volatiles		35
HSL Semi Volatiles		65
HSL Pesticides		26
Appendix IX	Organics	224
	Metals	25
	Miscellaneous	4
Radiochemistry		16

The specific analysis requested for each sample were based on the sampling plan and were identified in the Chain-of-Custody forms submitted with each sample. The 28,000 results of the analyses were transferred to the Database Administrator via direct telecommunications from the WESTON laboratory for some parameters, and via hard copy and diskette for others. A significant effort was required to enter, validate, and quality assure the large quantity of data that had to be processed within a period of about six weeks. A first order reduction in the amount of data to be reported was achieved in deciding to report only those analytes which increase percent above detectable concentrations. The number of analytical values and the associated analysis types are illustrated in Table 4.

Table 4

Chemical Analysis for FMPC

Category	Number of Analyses Reported
Inorganic	1362
Organic	696
Radiochemical	919

As described in Section 3.2, a sample designation coding system was required. The coding elements used are shown in Table 5.

Table 5

Coding Element	Digits	Purpose
- Project ID	3	to segregate FMPC samples from others in the WESTON laboratory
- Measurement Type	2	to segregate soil sample depths, water, sediment, and air samples
- Site	2	to identify the waste pit or other site where the sample was taken
- Sample	3	identifies the location of the sample

Sample tracking reports were prepared to assist in identifying the samples that had been collected and analyzed by the laboratory. Table 6 is an example of a report from the Sample Tracking System.

The data management requirements of the FMPC CIS were to produce tabular listings of analytical results in order to assist in data interpretation and reporting for each of the waste areas. Table 7 is a typical inorganic data summary report illustrating the analytical results for the Burn Pit. The concentration values are reported along with the appropriate units of measure, borehole, and pit (site) code field sample I.D. and laboratory batch number. The inorganic data summary reports include only reported values exceeding instrument detection limits.

Organic data tables were prepared in the format illustrated in Table 8. These tables include a value qualifier, which indicates that the detection limit value has been used in selected analyte cases. A total of 34 organic and inorganic data summary tables were produced to support the data interpretation effort.

In addition to tabular data, cartographic displays were used to assist in data interpretation. Figure 13 illustrates the borehole locations in the seven of the sites in the Waste Storage Area.

Radiochemical analysis for 16 parameters were summarized in tabular form as illustrated in Table 9.

Table 6

Sample Tracking Report

FERNALD PLANT
DETAIL ANALYSIS REPORT
REPORT DATE: 4-JUN-87

CLIENT SAMPLE NUMBER	LAB SAMPLE NUMBER	DATE SAMPLED	DATE RECEIVED	SAMPLE COMPLETED DATE	PROMISED DATE	ANALYSIS TYPE
FMP-AR-02-003	8704-254-01900	23-APR-87	27-APR-87		25-MAY-87	PCBs
FMP-AR-04-009	8704-254-01400	23-APR-87	27-APR-87		25-MAY-87	PCBs
FMP-AR-07-007	8705-461-00500	06-MAY-87	21-MAY-87		18-JUN-87	PCBs
FMP-AR-24-007	8705-462-00400	12-MAY-87	21-MAY-87		18-JUN-87	PCBs
FMP-AR-27-041	8705-486-00600	22-MAY-87	26-MAY-87		23-JUN-87	PCBs
FMP-AR-28-007	8704-254-01300	23-APR-87	27-APR-87		25-MAY-87	PCBs
FMP-AR-45-002	8705-486-00200	18-MAY-87	26-MAY-87		23-JUN-87	PCBs
FMP-AR-46-021	8705-486-00500	15-MAY-87	26-MAY-87		23-JUN-87	PCBs
FMP-AR-49-007	8705-461-01800	04-MAY-87	21-MAY-87		18-JUN-87	PCBs
FMP-AR-54-018	8705-461-01700	04-MAY-87	21-MAY-87		18-JUN-87	PCBs
FMP-AR-P4-015	8704-254-00900	23-APR-87	27-APR-87		25-MAY-87	PCBs
FMP-FB-54-008	8704-236-00300	21-APR-87	23-APR-87		21-MAY-87	HSL Metals
FMP-FB-54-008	8704-236-00300	21-APR-87	23-APR-87		21-MAY-87	PCBs
FMP-FB-54-008	8704-236-00300	21-APR-87	23-APR-87		21-MAY-87	Inorganics
FMP-PS-01-058	8704-203-00600	16-APR-87	20-APR-87		18-MAY-87	HSL Metals
FMP-PS-02-038	8704-236-00200	20-APR-87	23-APR-87		21-MAY-87	HSL Metals
FMP-PS-02-038	8704-236-00200	20-APR-87	23-APR-87		21-MAY-87	PCBs
FMP-PS-02-026	8704-236-00100	20-APR-87	23-APR-87		21-MAY-87	Inorganics
FMP-PS-04-021	8704-254-00100	22-APR-87	27-APR-87		25-MAY-87	HSL Metals
FMP-PS-04-022	8704-254-00200	22-APR-87	27-APR-87		25-MAY-87	Inorganics
FMP-PS-04-022	8704-254-00200	22-APR-87	27-APR-87		25-MAY-87	PCBs
FMP-PS-07-033	8705-342-00300	05-MAY-87	07-MAY-87		04-JUN-87	HSL Metals
FMP-PS-07-033	8705-342-00300	05-MAY-87	07-MAY-87		04-JUN-87	PCBs
FMP-PS-07-033	8705-342-00300	05-MAY-87	07-MAY-87		04-JUN-87	Inorganics
FMP-PS-08-007	8704-254-00700	23-APR-87	27-APR-87		25-MAY-87	PCBs
FMP-PS-08-007	8704-254-00700	23-APR-87	27-APR-87		25-MAY-87	HSL Metals
FMP-PS-08-006	8704-254-00600	23-APR-87	27-APR-87		25-MAY-87	Inorganics
FMP-PS-24-014	8705-415-00400	13-MAY-87	15-MAY-87		12-JUN-87	HSL Metals
FMP-PS-24-011	8705-415-00100	12-MAY-87	15-MAY-87		12-JUN-87	PCBs
FMP-PS-24-068	8705-426-00200	14-MAY-87	18-MAY-87		15-JUN-87	Inorganics
FMP-PS-25-009	8705-466-00300	19-MAY-87	21-MAY-87		18-JUN-87	HSL Metals
FMP-PS-25-011	8705-466-00400	20-MAY-87	21-MAY-87		18-JUN-87	Inorganics
FMP-PS-49-032	8705-305-00200	30-APR-87	04-MAY-87		01-JUN-87	HSL Metals
FMP-PS-49-032	8705-305-00200	30-APR-87	04-MAY-87		01-JUN-87	Inorganics
FMP-PS-49-032	8705-305-00200	30-APR-87	04-MAY-87		01-JUN-87	PCBs
FMP-SW-05-002	8705-426-00800	15-MAY-87	18-MAY-87		15-JUN-87	HSL Metals
FMP-SW-05-002	8705-426-00800	15-MAY-87	18-MAY-87		15-JUN-87	Inorganics
FMP-SW-05-002	8705-426-00800	15-MAY-87	18-MAY-87		15-JUN-87	PCBs
FMP-SW-06-001	8704-203-01500	13-APR-87	20-APR-87		18-MAY-87	HSL Metals
FMP-SW-06-002	8704-203-00200	15-APR-87	20-APR-87		18-MAY-87	Inorganics
FMP-SW-06-005	8705-342-00600	05-MAY-87	07-MAY-87		04-JUN-87	PCBs
FMP-SW-08-002	8705-359-00200	07-MAY-87	11-MAY-87		08-JUN-87	Inorganics

TABLE 7

BURN PIT INORGANIC DATA SUMMARY

PIT NO	BOREHOLE	SAMPLE ID	BATCH NUMBER	PARAMETER	CONCENTRATION	UNIT OF MEASURE
07	01	FMP-PS-07-001	8704-286-0010	ALUMINUM, TOTAL		MG/KG
				CALCIUM, TOTAL		MG/KG
				CHROMIUM, TOTAL		MG/KG
				COPPER, TOTAL		MG/KG
				IRON, TOTAL		MG/KG
				LEAD, TOTAL		MG/KG
				MAGNESIUM, TOTAL		MG/KG
				MANGANESE, TOTAL		MG/KG
				POTASSIUM, TOTAL		MG/KG
				VANADIUM, TOTAL		MG/KG
				ZINC, TOTAL		MG/KG
			8704-286-0080	BARIUM, EP LEACHATE		UG/L
	02	FMP-PS-07-003	8704-286-0020	ALUMINUM, TOTAL		MG/KG
				BARIUM, TOTAL		MG/KG
				CADMIUM, TOTAL		MG/KG
				CALCIUM, TOTAL		MG/KG
				CHROMIUM, TOTAL		MG/KG
				COPPER, TOTAL		MG/KG
				IRON, TOTAL		MG/KG
				LEAD, TOTAL		MG/KG
				MAGNESIUM, TOTAL		MG/KG
				MANGANESE, TOTAL		MG/KG
				POTASSIUM, TOTAL		MG/KG
				VANADIUM, TOTAL		MG/KG
				ZINC, TOTAL		MG/KG
			8704-286-0090	BARIUM, EP LEACHATE		UG/L
				MERCURY, EP LEACHATE		UG/L
	03	FMP-PS-07-026	8704-286-0030	ALUMINUM, TOTAL		MG/KG
				BARIUM, TOTAL		MG/KG
				CADMIUM, TOTAL		MG/KG
				CALCIUM, TOTAL		MG/KG
				CHROMIUM, TOTAL		MG/KG
				COBALT, TOTAL		MG/KG
				COPPER, TOTAL		MG/KG
				IRON, TOTAL		MG/KG
				LEAD, TOTAL		MG/KG
				MAGNESIUM, TOTAL		MG/KG
				MANGANESE, TOTAL		MG/KG
				MERCURY, TOTAL		MG/KG
				NICKEL, TOTAL		MG/KG
				POTASSIUM, TOTAL		MG/KG
				SODIUM, TOTAL		MG/KG
				VANADIUM, TOTAL		MG/KG
				ZINC, TOTAL		MG/KG
			8704-286-0100	BARIUM, EP LEACHATE		UG/L

TABLE 8

PIT TWO ORGANIC DATA SUMMARY

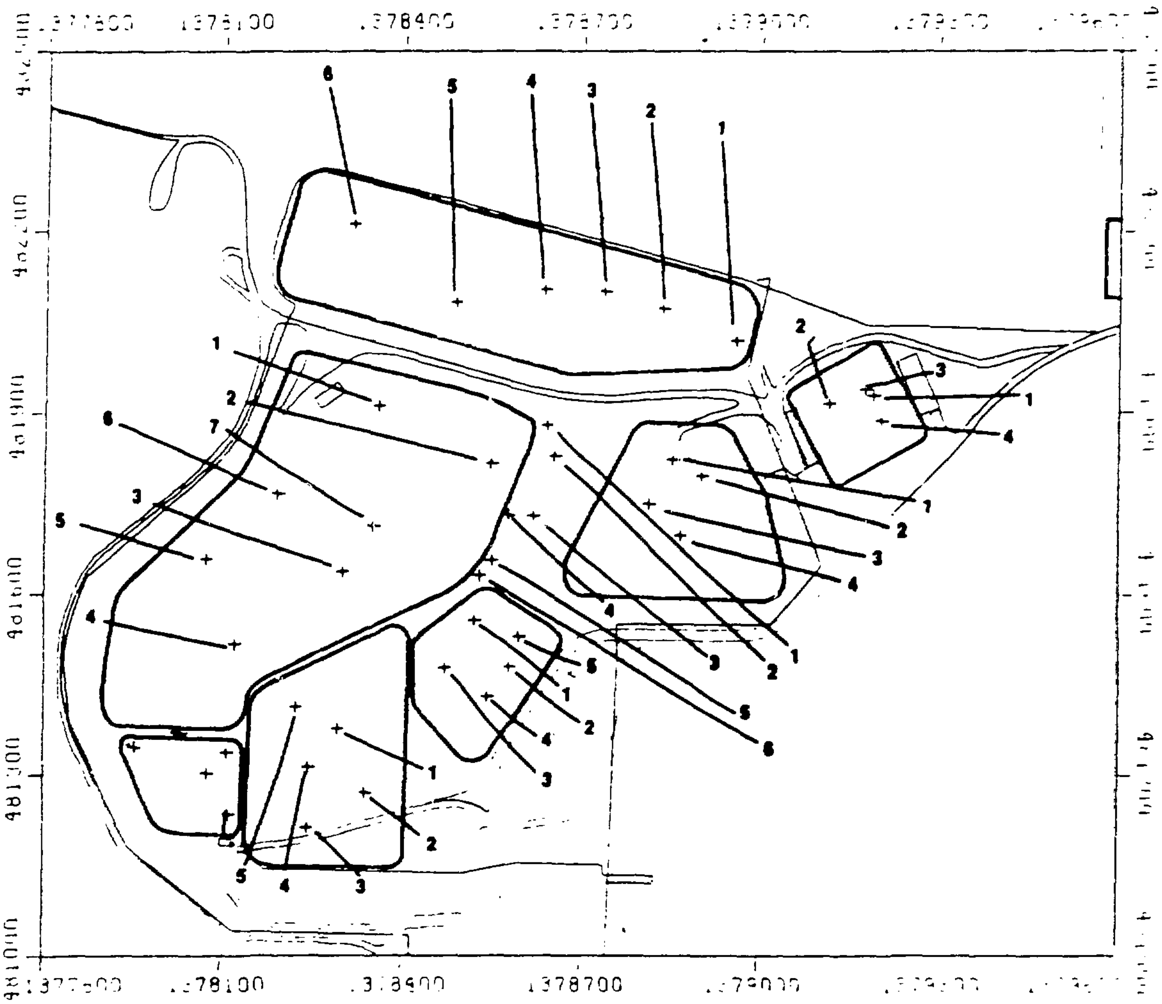
ORGANIC CHEMICAL DATA SUMMARY FOR FMPC

BOREHOLE NUMBER	SAMPLE ID	BATCH NUMBER	PARAMETER	CONCENTRATION	UNIT OF MEASURE	QUALIFIER
02-01	FMP-PS-02-007	8704-203-0070	BENZO(A)PYRENE		UG/KG	J
02-01	FMP-PS-02-007	8704-203-0070	4,4-DDT		UG/KG	
02-01	FMP-PS-02-007	8704-203-0070	BENZO(K)FLUORANTHENE		UG/KG	J
02-01	FMP-PS-02-007	8704-203-0070	FLUORANTHENE		UG/KG	
02-01	FMP-PS-02-007	8704-203-0070	2-BUTANONE		UG/KG	*
02-01	FMP-PS-02-007	8704-203-0070	PHENANTHRENE		UG/KG	J
02-01	FMP-PS-02-007	8704-203-0070	ANTHRACENE		UG/KG	J
02-01	FMP-PS-02-007	8704-203-0070	BENZO(A)ANTHRACENE		UG/KG	J
02-01	FMP-PS-02-007	8704-203-0070	PYRENE		UG/KG	J
02-01	FMP-PS-02-007	8704-203-0070	1,1,1-TRICHLOROETHANE		UG/KG	J
02-01	FMP-PS-02-007	8704-203-0070	AROCLOR-1260		UG/KG	
02-01	FMP-PS-02-007	8704-203-0070	DI-N-OCTYL PHTHALATE		UG/KG	J*
02-01	FMP-PS-02-007	8704-203-0070	BENZO(B)FLUORANTHENE		UG/KG	J
02-01	FMP-PS-02-007	8704-203-0070	CHRYSENE		UG/KG	J
02-01	FMP-PS-02-007	8704-203-0070	BIS(2-ETHYLHEXYL)PHTHALATE		UG/KG	J*
02-01	FMP-PS-02-007	8704-203-0070	DI-N-BUTYL PHTHALATE		UG/KG	J*
02-03	FMP-PS-02-017	8704-203-0080	DI-N-BUTYL PHTHALATE		UG/KG	J*
02-03	FMP-PS-02-017	8704-203-0080	DI-N-OCTYL PHTHALATE		UG/KG	J*
02-03	FMP-PS-02-017	8704-203-0080	BENZO(B)FLUORANTHENE		UG/KG	
02-03	FMP-PS-02-017	8704-203-0080	ACENAPHTHENE		UG/KG	J
02-03	FMP-PS-02-017	8704-203-0080	FLUORANTHENE		UG/KG	
02-03	FMP-PS-02-017	8704-203-0080	DIBENZOFURAN		UG/KG	J
02-03	FMP-PS-02-017	8704-203-0080	FLUORENE		UG/KG	J
02-03	FMP-PS-02-017	8704-203-0080	BENZO(G,H,I)PERYLENE		UG/KG	J
02-03	FMP-PS-02-017	8704-203-0080	INDENO(1,2,3-CD)PYRENE		UG/KG	J
02-03	FMP-PS-02-017	8704-203-0080	BENZO(K)FLUORANTHENE		UG/KG	
02-03	FMP-PS-02-017	8704-203-0080	PYRENE		UG/KG	
02-03	FMP-PS-02-017	8704-203-0080	NAPHTHALENE		UG/KG	J
02-03	FMP-PS-02-017	8704-203-0080	ETHYLBENZENE		UG/KG	J
02-03	FMP-PS-02-017	8704-203-0080	PHENANTHRENE		UG/KG	
02-03	FMP-PS-02-017	8704-203-0080	CHRYSENE		UG/KG	
02-03	FMP-PS-02-017	8704-203-0080	BENZO(A)PYRENE		UG/KG	
02-03	FMP-PS-02-017	8704-203-0080	VINYL CHLORIDE		UG/KG	
02-03	FMP-PS-02-017	8704-203-0080	4,4-DDT		UG/KG	
02-03	FMP-PS-02-017	8704-203-0080	ANTHRACENE		UG/KG	J
02-03	FMP-PS-02-017	8704-203-0080	BENZO(A)ANTHRACENE		UG/KG	
02-03	FMP-PS-02-017	8704-203-0080	AROCLOR-1260		UG/KG	
02-03	FMP-PS-02-017	8704-203-0080	2-BUTANONE		UG/KG	*
02-03	FMP-PS-02-018	8704-203-0090	PYRENE		UG/KG	
02-03	FMP-PS-02-018	8704-203-0090	DIBENZOFURAN		UG/KG	
02-03	FMP-PS-02-018	8704-203-0090DIL	PHENANTHRENE		UG/KG	
02-03	FMP-PS-02-018	8704-203-0090	FLUORENE		UG/KG	
02-03	FMP-PS-02-018	8704-203-0090DIL	FLUORANTHENE		UG/KG	
02-03	FMP-PS-02-018	8704-203-0090	BENZO(K)FLUORANTHENE		UG/KG	
02-03	FMP-PS-02-018	8704-203-0090DIL	DI-N-BUTYL PHTHALATE		UG/KG	J*
02-03	FMP-PS-02-018	8704-203-0090	BENZO(A)PYRENE		UG/KG	
02-03	FMP-PS-02-018	8704-203-0090	ACENAPHTHENE		UG/KG	
02-03	FMP-PS-02-018	8704-203-0090	DI-N-OCTYL PHTHALATE		UG/KG	J*
02-03	FMP-PS-02-018	8704-203-0090	CHRYSENE		UG/KG	
02-03	FMP-PS-02-018	8704-203-0090	AROCLOR-1260		UG/KG	J
02-03	FMP-PS-02-018	8704-203-0090	ANTHRACENE		UG/KG	
02-03	FMP-PS-02-018	8704-203-0090	2-METHYLNAPHTHALENE		UG/KG	

J=COMPOUND IS PRESENT BUT CONCENTRATION IS UNCERTAIN; *=COMMON LABORATORY CONTAMINANT

FIGURE 13

BOREHOLE SAMPLE LOCATIONS IN THE WASTE STORAGE AREA



STATE PLANE COORDINATE SYSTEM

OHIO SOUTH ZONE

1 INCH = 300 FEET

PREPARED BY

ROY F. WESTON, INC. 9/1/87

SAMPLE ID	COORD'S EAST	SOUTH	START DEPTH (FEET)	END DEPTH (FEET)	COLL. DATE DD-MMM-YY	DRY WEIGHT (GRAMS)	V Q	U-234 (PCI/G)	UNCER.	V Q	U-235 (PCI/G)	UNCER.	V Q	U-238 (PCI/G)	UNCER.	V Q	TH-228 (PCI/G)	UNCER.
FMP-PS-01-002	1750.0	1360.0	0	12	13-APR-87	737												
FMP-PS-01-017	1680.0	1325.0	0	12	14-APR-87	693												
FMP-PS-01-034	1800.0	1465.0	0	12	15-APR-87	628										L		
FMP-PS-01-049	1705.0	1525.0	0	12	15-APR-87	714												
FMP-PS-01-060	1705.0	1425.0	0	12	16-APR-87	656												
FMP-PS-02-002	2035.0	1250.0	0	10	14-APR-87	179												
FMP-PS-02-009	1975.0	1175.0	0	8	16-APR-87	561												
FMP-PS-02-019	1925.0	1255.0	0	10	17-APR-87	648										L		
FMP-PS-02-028	2000.0	1300.0	0	10	20-APR-87	554												
FMP-PS-02-040	2035.0	1200.0	0	10	20-APR-87	637												
FMP-PS-03-002	1800.0	825.0	0	4	03-APR-87	515												
FMP-PS-03-009	1750.0	1100.0	0	20	06-APR-87	238												
FMP-PS-03-030	1575.0	1225.0	0	20	08-APR-87	268												
FMP-PS-03-048	1575.0	1225.0	17	18	08-APR-87	265												
FMP-PS-03-053	1525.0	1085.0	0	20	09-APR-87	344												
FMP-PS-03-074	1640.0	975.0	0	14	10-APR-87	593										L		
FMP-PS-03-080	1640.0	975.0	6	7	10-APR-87	173												
FMP-PS-03-091	1925.0	917.0	0	20	10-APR-87	617										L		
FMP-PS-03-111	1800.0	1025.0	0	12	13-APR-87	551												
FMP-PS-04-003	2300.0	900.0	0	20	22-APR-87	724												
FMP-PS-04-023	2350.0	925.0	0	20	22-APR-87	550												
FMP-PS-04-040	2262.0	975.0	0	20	24-APR-87	627												
FMP-PS-04-063	2315.0	1025.0	0	20	05-MAY-87	783												
FMP-PS-05-002	1750.0	525.0	0	12	13-MAR-87	92												
FMP-PS-05-013	1925.0	650.0	0	15	19-MAR-87	92												
FMP-PS-05-026	2075.0	625.0	0	29	23-MAR-87	84												
FMP-PS-05-046	2175.0	625.0	0	28	25-MAR-87	91												

4. DATA BASE TRANSFER

As of the date of writing this paper, two of the three CIS final report volumes have been drafted, and the third was in preparation. On completion of the final volume, WESTON will complete the loading of the TIMS database files, and will transfer data files to WMCO for continuing use in conducting the Remedial Investigation and Feasibility Study (RI/FS) for the FMPC. The transfer is being made by developing magnetic tape files containing both cartographic data and study results in accordance with specified formats.

5. REFERENCES

1. D.O.E. Characterization Investigation Study, Volume 1: Geophysical Survey, September 1987.

2. U.S. D.O.E. Characterization Investigation Study, Volume 2: Chemical and Radiological Analysis of the Waste Storage Pits.

Data Management for the DOE Environmental Survey

Presented by:

P. Bridges,

Science Applications International Corporation

DATA MANAGEMENT FOR THE DOE ENVIRONMENTAL SURVEY

Jon Goyert, Kevin Newman,
Science Applications International Corporation, and
Karen Daniels, and Paul Kanciruk, Oak Ridge National Laboratory

The Department of Energy (DOE) is conducting a DOE-wide survey of 41 sites to identify potential environmental problems and areas of environmental concern at DOE facilities, and prioritize them Department-wide using a consistent risk-based ranking methodology. This ranking will enable DOE to more effectively establish priorities for addressing environmental problems and to more efficiently allocate the resources necessary to correct these problems.

The data base structure developed by the participating laboratories is designed to meet the sampling and analysis phase requirements of the DOE Environmental Survey. It provides a common and consistent structure for all participating laboratories for data storage, processing, and reporting, and provides a well-documented and easily usable database for future DOE needs.

This paper describes: 1) the evolution, philosophy, and final decisions reached on the data management structure, 2) the contents, analysis methods, and reporting requirements, and 3) the quality assurance procedures developed for verification and validation of the data.

PROCEEDINGS PAPER NOT AVAILABLE AT TIME OF PRINTING

What Happens Following a Tank Release?

Presented by:

John M. Wilson, NUS Corporation

ABSTRACT

WHAT HAPPENS FOLLOWING A TANK RELEASE?

John M. Wilson, CPG

Remediation of contamination resulting from releases from underground storage tank (UST) systems is the newest program in the environmental field. EPA regulations are out in draft form; many states have already set into motion their own underground tank programs. EPA's clean-up criterion will probably be 5 ppb benzene. Some states are proposing even lower levels (e.g., Florida - 1 ppb benzene). It is questionable whether current technology, given variable site hydrogeologic conditions, can effectively clean the ground water at these sites to these stringent requirements.

This paper details the procedures required for remediation activities following verification of a release from a system. Included are subsurface site investigation, contamination plume assessment, remediation equipment system installation, effectiveness of typical equipment, and approximate cost of systems. Information given is based on NUS Corporation experience in remediation of contamination from UST releases at over 100 sites in 16 states.

PROCEEDINGS PAPER NOT AVAILABLE
AT TIME OF PRINTING

Contingency Planning and Emergency Response in Construction Activities: Training the Construction Worker

Presented by:

Edith Jones, ORNL

CONTINGENCY PLANNING AND EMERGENCY RESPONSE IN CONSTRUCTION ACTIVITIES: TRAINING THE CONSTRUCTION WORKER - Edith Jones, Technical Resources and Training Group, Environmental Compliance and Health Protection Division, Oak Ridge National Laboratory,* Oak Ridge, Tennessee 37831

ABSTRACT

Construction activities have been identified as having the potential for environmental and/or health impacts at Oak Ridge National Laboratory, particularly as site cleanup and restoration plans are initiated. In addition to other control measures, ORNL has chosen to institute special training for all construction workers and related contractors. Individuals are given training to help them understand how construction activities at ORNL can potentially have adverse effects on the environment and their health and to teach them how to respond to potential chemical and radiation hazards.

Workers are given a review of basic information on radiation and chemicals in a framework that emphasizes the situations in which workers or the environment may be exposed to potential risk. Specific instructions are presented on what to do when contamination is suspected, with identification of emergency procedures and response personnel.

Courses are designed to meet the needs of different audiences:

- Construction workers
- Construction supervisors
- Project and contractor managers

The courses are implemented at different levels of detail, based on projections of potential for exposure. Over 460 persons have been trained this fiscal year.

INTRODUCTION

The Oak Ridge National Laboratory (ORNL) is a multiprogram laboratory that conducts research and development activities for DOE and other U.S. government agencies as well as for private industry and institutional organizations. Programs at ORNL cover almost all areas of science and technology. Supporting these programs are

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*Operated by Martin Marietta Energy Systems, Inc., for the U.S. Department of Energy under Contract No. DE-AC05-84OR21400.

facilities such as nuclear reactors, radiochemical laboratories, accelerators, hot cells, chemical and biological research laboratories, and waste treatment facilities.

While special research facilities are important, the people who work on site are an even more valuable resource. Some years ago, ORNL initiated a general employee training program designed to make employees more aware of the health, safety, and environmental risks associated with the laboratory's operation, and to outline the efforts being made to protect the employees and the environment through procedures and controls.

The need to verify that similar information was being offered to subcontractor personnel, such as construction workers and well drillers, became apparent. Because of the history of the Laboratory and of the technologies used, potential environmental and occupational health concerns are being identified. Decommissioning, demolition, replacement, and upgrade of both production facilities and waste handling systems have been expanding over the past several years. In the area of environmental health and safety, ORNL has a responsibility **for** all persons on site, as well as a responsibility **to** all employees.

A release of radioactive material from a ventilation improvements project in 1985 and other environmental concerns prompted a decision that specific training in the recognition and prevention of unplanned releases should be given to all personnel involved in construction projects.[1] The Environmental Compliance and Health Protection (EC&HP) Division was assigned the responsibility for developing, implementing, and managing an environmental health and safety training program for construction workers.

In addition to meeting the need to inform construction workers about environmental health and safety issues, the training program had to meet several other program requirements. Various levels of training were needed: managers, construction engineers, and construction workers. The program had to be flexible enough to properly train the workers as a necessary prerequisite for construction projects. The training programs also needed to be in place as soon as possible.

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[1] Investigation Report of the Release of Strontium-90 from the Building 3517 Cell Ventilation Improvements Construction Site on November 29, 1985, ORNL/M 111/R1 (January 21, 1986).

PROGRAM DEVELOPMENT

OBJECTIVES

After a preliminary needs assessment, the curricula for the construction worker program was developed to ensure that construction workers perform their duties safely, to increase worker awareness of risks and hazards, to outline ORNL's efforts to protect construction workers, and to reduce the number of incidents involving potential impact to the workers or the environment. To accomplish these objectives the training program addressed:

- Identification of the types of hazards present;
- Review of the correct work procedures for handling potentially hazardous materials;
- Outline of the correct procedures to follow if worker suspects the presence of hazardous materials; and
- Review of the worker's responsibility to protect self and the environment.

CONTENT

The basic training program covered the above objectives with subject modules on hazardous material control, radiation protection, responsibilities of the worker, actions to take if questionable material found, and some operational requirements while working on the ORNL site.

In the development of the course material, an effort was made to determine the most effective way to present the training material. The literature confirmed that adult students are more likely to learn information if they can see a fairly immediate use for the new material in their own experiences. Adults remember longest the learning experience that is interesting, vivid, and intense.[2] The Technical Resources and Training (TRT) Group's task was to

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[2]NAPCAE, Tested Techniques for Teachers of Adults, Washington: National Association for Public Continuing and Adult Education, 1972.

present "the right material at the right time in the right amount so that motivation would be maintained."[3]

For the construction workers to really understand why an environmental health and safety training program was important to them, they first had to know what type of facilities and materials ORNL staff had been working with for the past 40 years. Therefore, after a brief introductory segment outlining the program, a videotape was shown of actual facilities and activities at ORNL. This overview helped the workers better understand the reasons for implementation of certain ORNL health and safety procedures and guidelines. Although many of the construction workers would never work in all of the areas shown in the videotape, they did have a better understanding of the type of facilities that might be located in the vicinity of their work area.

In the next phase of training development, other special training modules were developed for supervisors and managers of construction projects, as well as for other special contractor groups. The training program for supervisors and managers of construction projects emphasized project planning and potential problem analysis.[4,5] These areas are an integral part of compliance with environmental health and safety guidelines because these planning skills and techniques allow for better control of radioactivity and other hazardous materials.

Additional training modules are being developed to address job-specific needs such as: correct contamination zone clothing and work practices, proper disposal of wastes, containment measures, and spill control and prevention.

MEDIA

Various media were developed to be used in the training program: transparencies; flipcharts; color videotapes; handouts, including 3 x 5 in. pocket cards printed with emergency numbers and special instructions; and an

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[3]Curtis Ulmer, Teaching the Disadvantaged Adult, Washington: National Association for Public School Adult Education, 1969.

[4]Kepner-Tregoe, Problem Analysis and Decision Making, New Jersey: Princeton, 1979.

[5]Charles H. Kepner and Benjamin B. Tregoe, The New Rational Manager, New Jersey: Princeton (198[illegible]).

awareness review quiz to be completed at the end of the training program. The pocket cards (see Fig. 1) were developed to encourage the construction workers to carry the information with them (i.e., in a coverall pocket) for immediate access in case of an incident. The videotape was prepared in four segments. The first segment, as previously discussed, explains the potential hazards found on the ORNL site; the second, discusses the worker's responsibility to protect him or herself and the environment and some reminders when working on the ORNL site; the third segment was filmed at various construction projects and highlights worker protection techniques; and the fourth, contains construction examples of previous practices and a summary of current site status. The third segment is used as a tool to facilitate discussion on good work practices, protective clothing and equipment, warning signs and zones, prevention and containment of spills, and identification of correct procedures and incorrect procedures. The fourth segment is used in the management training program as a project planning activity. The managers are encouraged to identify the steps necessary to safely direct construction activities on this site.

SUMMARY

ORNL has established a comprehensive training program to fulfill its environmental health and safety responsibility for construction-related training. During this fiscal year, approximately 40 training programs have been conducted, reaching approximately 460 trainees. These trainees represent 30 subcontractor organizations working on a wide variety of construction projects at ORNL.

Special attention has been paid to enhancing the effectiveness of the training project. Emphasis has been given to the importance of safeguarding the health of all employees and subcontract personnel working on site as well as safeguarding the integrity of the environment.

DO'S AND DON'TS WHEN WORKING ON ORNL SITE

- Do Wear Your Badge at all Times.
- Do Practice Good Work Habits.
- Do Use Available Control Measures and Protective Equipment.
- Do Observe ALL Warning Signs and Zones.
- Do Dispose of All Wastes as Instructed.
- Do Contact Your Health Physicist if You Suspect a Problem.
- Do Practice Good Personal Hygiene.
- Do NOT Eat, Drink, or Smoke Where Hazardous Materials are Suspected.

ACTIONS TO TAKE IF QUESTIONABLE MATERIAL IS FOUND DURING CONSTRUCTION/WELL-DRILLING ACTIVITIES

- STOP ALL OPERATIONS
- Move Away From Suspect Contamination But Don't Leave Work Site.
- Notify Your Supervisor of Potential Problem.
- If Health Physicist is On Site, Follow His/Her Instructions.
- If No Health Physicist is Present, Call 911.
- Notify Project Engineer.
- Stand By and Follow Instructions.

Fig. 1. Handout Used in Construction Worker Training Program.

Application of Monoclonal Antibodies to Environmental Monitoring

Presented by:

Joseph Paladino,

Westinghouse Bio-Analytic Systems Co.

APPLICATION OF MONOCLONAL ANTIBODIES TO ENVIRONMENTAL MONITORING -
Joseph Paladino, Product Manager, and Kenneth W. Hunter III, Scientific Director, Westinghouse Bio-Analytic Systems Company, Madison, PA.

ABSTRACT

The Westinghouse Bio-Analytic Systems Company (WBAS) is developing a monoclonal antibody-based immunoassay for the quantitative analysis of pentachlorophenol in environmental samples. The method offers high throughput and reasonable sensitivity for the analysis of aqueous samples. The pentachlorophenol immunoassay can detect as little as 25 micrograms/liter in water directly without sample concentration. The U.S. EPA Environmental Monitoring Systems Laboratory in Las Vegas, Nevada, is examining the immunoassay for consideration as an approved aqueous analytical method. WBAS is also developing expedient soils extraction methods to permit using the immunoassay for site characterization.

The pentachlorophenol immunoassay can offer savings in the time and cost of sample analysis. Sufficient testing will show immunoassays to be effective analytical tools available to the environmental chemist. WBAS will continue to develop them for the analysis of additional toxic compounds.

INTRODUCTION

Antibody-based analytical methods are useful for the environmental monitoring of organic chemical compounds. Considerable work has already been accomplished by a number of investigators, especially in the area of pesticide residue analysis, in developing methods that can detect and quantify environmental contaminants (1,2,3). Research has demonstrated that these methods can offer the sensitivity, precision and reproducibility of conventional methods, such as gas/liquid chromatography. They can be implemented with conventional methods to reduce the overall cost and effort of chemical analysis in programs involving, for example, the monitoring of water (including potable, surface and ground waters), industrial effluents, and organisms (such as for worker exposure assessment), as well as site characterization. The usefulness of this analytical approach is gaining increased recognition as is evidenced by 1) recent requests-for-proposal for antibody-body based methods by the U.S. Food and Drug Administration, the U.S. Dairy Association, and the U.S. Environmental Protection Agency, 2) the development of methods for pesticide monitoring in a joint program involving the University of California and the California Department of Food and Agriculture and 3) the emergence of new companies attempting to commercialize antibody-based products with applications to environmental chemistry.

All of the methods incorporate antibodies derived from evolving immunochemical techniques. Antibodies are protein molecules produced by an animal's immune system which serve to defend against invading substances such as viruses and bacteria. When a foreign substance or antigen, enters an animal, specialized cells, called B lymphocytes, produce antibodies that bind to the invader tagging it for destruction by the immune system. The protein structure of the antibody bears sites which recognize in very specific ways the chemical structure of the antigen. The binding is the result of various noncovalent interactions and complementary chemical structure.

Each B lymphocyte produces a distinct type of antibody. Following immunization, B lymphocytes can be extracted and fused to myeloma cells to produce hybridomas, cells with virtually unlimited growth potential. Each hybridoma produces the antibody of the parent B lymphocyte. Hybridomas producing antibodies with the desired characteristics of affinity and specificity can be selected and propagated (cloned). The resulting antibodies, termed monoclonal since they derive from a single clone of B lymphocytes, are homogeneous exhibiting constant analytical behavior. These antibodies may then be employed in chemical sensing devices ranging from field portable kits to fully quantitative, lab-based systems

The Westinghouse Bio-Analytic Systems Company (WBAS) is developing technology utilizing monoclonal antibodies for trace organic chemical analysis. The first product developed by WBAS is a competitive inhibition enzyme immunoassay (CIEIA) for pentachlorophenol analysis. Pentachlorophenol, a toxic wood preservative, is an EPA priority pollutant and a major contaminant found at many hazardous waste sites including several of those on the National Priorities List. WBAS has chosen pentachlorophenol as a lead compound to demonstrate the utility of immunoassays for quantitative environmental analysis. The CIEIA procedure can be used to detect any organic compound for which antibodies are produced.

This paper describes the CIEIA and presents data, developed in a cooperative program with the U.S. EPA Environmental Monitoring System Laboratory (EMSL) in Las Vegas, Nevada, comparing the method to gas chromatography-mass spectrometry for determining pentachlorophenol concentrations in samples. The utility of antibody-based methods will also be discussed in light of the advantages and limitations of the technology. Although additional development of these analytical methods is necessary, especially in the area of sample preparation, we believe that the technology has immediate application to environmental contaminant monitoring. The overall reduction in the cost of sample analysis offered by the technology certainly [illegible] their use.

DESCRIPTION OF THE CIEIA

The CIEIA is performed using a plastic, 96-well microtiter plate to which standard solutions of pentachlorophenol, prepared samples, and reagents are added in a stepwise manner. Reagents are delivered to the microtiter plate by a multi-channel micropipettor as shown in Figure 1. The entire procedure requires approximately 2.5 hours and results in a color change occurring within each well of the plate that is inversely proportional to the concentration of pentachlorophenol. A microtiter plate spectrophotometer is used to determine the optical density values of the microtiter plate wells. Also, a software program calculates the concentration of pentachlorophenol in each sample by reference to a calibration curve generated using the standard solutions. Since a large part of the procedure involves incubation after each step several plates may be run concurrently.

CIEIA Procedure

The CIEIA procedure is schematically presented in Figure 2. Prior to performing the immunoassay, each microtiter plate is precoated with pentachlorophenol-protein conjugate molecules that adhere permanently to the well surfaces. A competitive inhibition reaction occurs when samples or standard solutions are incubated with anti-pentachlorophenol antibodies during the first step of the procedure. The reaction is allowed to proceed for one hour, and then the plate is rinsed, leaving behind surface-bound antibodies. Pentachlorophenol in the aqueous phase will inhibit the binding of the antibody to the conjugates on the well surfaces. Therefore, the level of bound antibody is inversely proportional to the pentachlorophenol concentration of the standard solutions and samples. To determine the amount of antibody bound to each of the well surfaces, an enzyme-protein complex is added after the first step resulting in that molecule binding directly to each of the surface-bound antibodies. After one hour, the plate is again rinsed and the enzyme substrate is added to each well. The surface-bound enzymes react with the colorless substrate to yield a yellow-colored product. The enzymatic reaction results in the development of color that is directly proportional to the amount of surface-bound antibody. Therefore the color intensity developed within each well is inversely proportional to the pentachlorophenol concentration of each sample or standard. The enzymatic reaction is allowed to proceed for 30 minutes, at which time the microtiter plate is placed in an automated microtiter plate spectrophotometer that determines the optical density of all 96 wells. The equipment used to perform the pentachlorophenol immunoassay includes a spectrophotometer, personal computer, and printer, shown in Figure 3, as well as micropipettors and other volumetric ware.

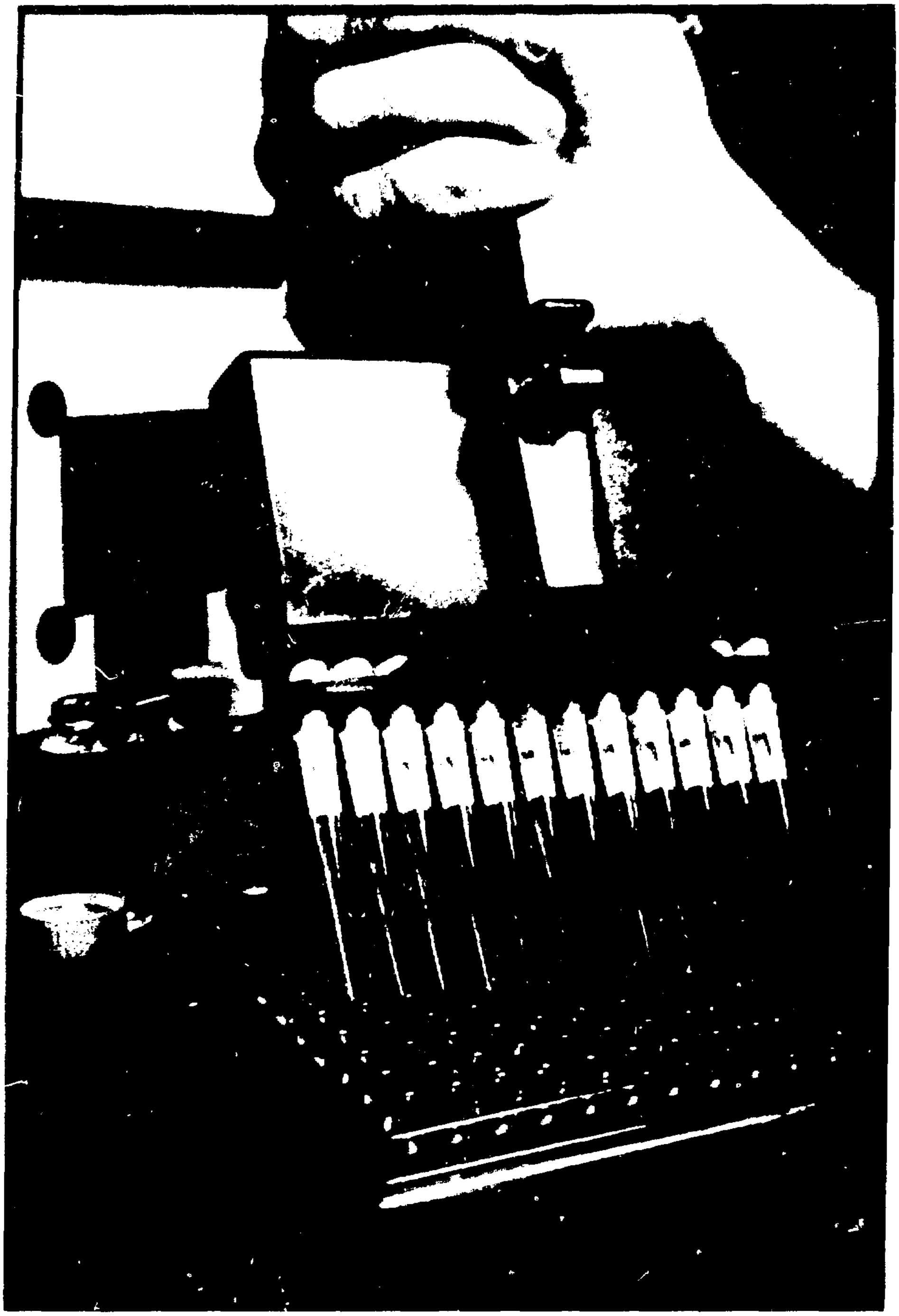


Figure 1. Delivery of Reagents to a Microtiter Plate

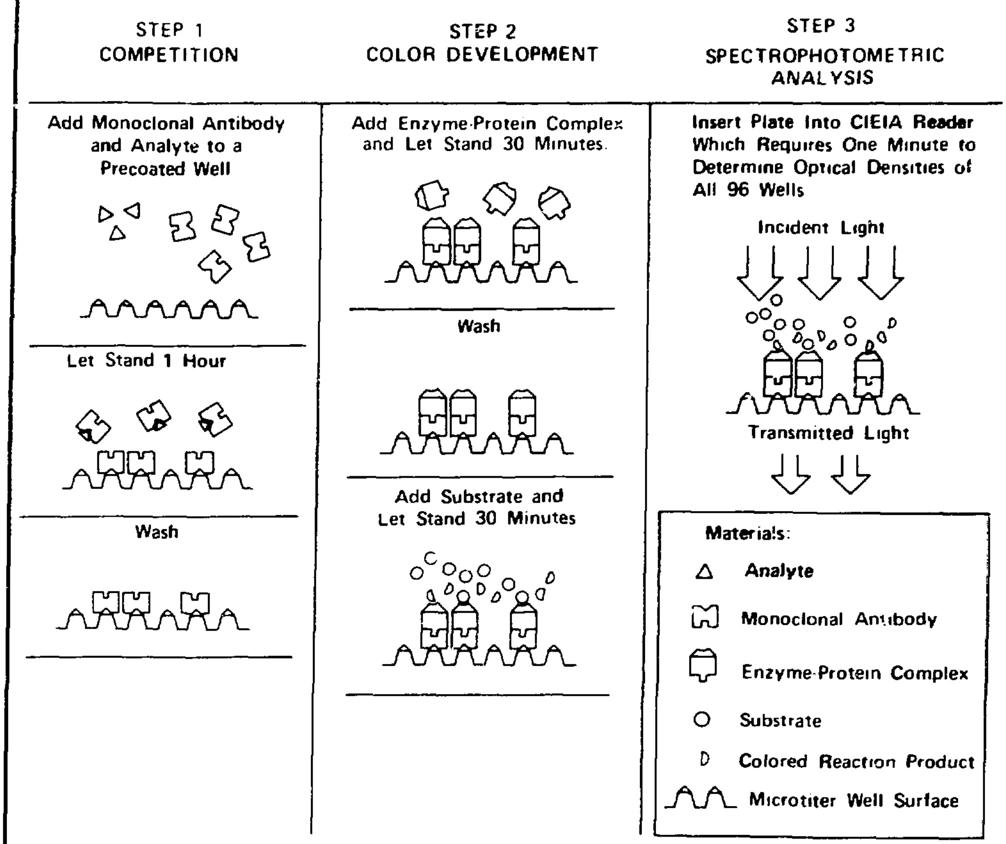


Figure 2. CIEIA Procedure

767472-2Aa

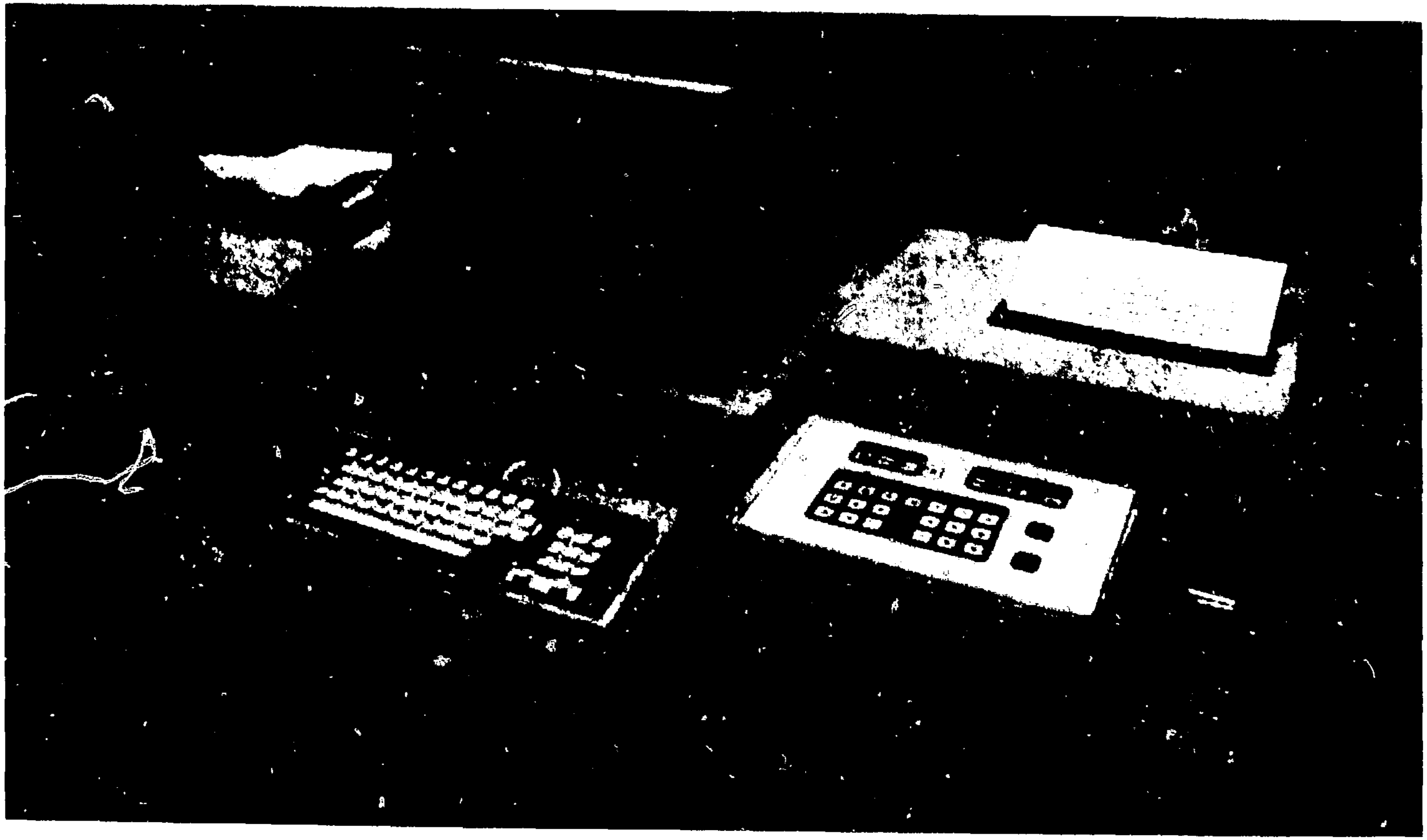


Figure 3. Computer, Printer and Spectrophotometer

CIEIA Results

Samples and standard solutions can be added to a microtiter plate according to a format desired by the analyst. As an example, the results of 24 sample analyses using the CIEIA are shown in Table 1. Standard solutions of pentachlorophenol, ranging from 627.940 to 1.963 parts-per-billion, were added to wells B1-3 to H1-3. Three wells (A1-3), serving as blanks, received all the reagents except pentachlorophenol; they, therefore, represented a zero level of analyte. The remaining 72 wells were used for sample analysis. Each sample was tested in triplicate.

The standard curve is useful for determining the dynamic range of the system's response to pentachlorophenol. In this example, the minimum level of detection is considered to be approximately 13.5 ppb representing a concentration causing 90% peak absorbance. Since the standards and samples are diluted by the addition of reagents, sample concentrations must be multiplied by 3 to determine actual values.

The analyst may use additional wells for range finding either by dilution or concentration. He may also wish to incorporate internal spikes to determine the possibility of any interference posed by the sample matrix.

CIEIA Method Comparison

The results of a preliminary study performed in cooperation with EPA-EMSL, involving the analysis of pentachlorophenol in ground, surface and drinking waters, are presented in Table 2. Spiked samples were analyzed by CIEIA directly, by CIEIA after EPA method 604 extraction, by CIEIA after extraction by solid phase (phenyl) columns, and by gas chromatography-mass spectrometry after EPA method 604 extraction.

The data shows that the immunoassay can be used to quantitate pentachlorophenol in water to levels in the low parts-per-billion range. Also, the accuracy and precision of the CIEIA compares favorably with GC-MS analysis. When considering the high sample throughput capacity of the immunoassay, it appears that the CIEIA offers considerable savings in time and cost over conventional methods, especially when applied to aqueous analysis.

Efforts to develop additional data are ongoing in the joint program. Future work will focus on groundwater samples obtained from pentachlorophenol-contaminated sites, as well as, the potential of the immunoassay for soils analysis as it relates to site characterization.

TABLE 1
CIEIA RESULTS

-Plate Absorbance-

	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	
-A-	0 120	0 123	0 122	0 376	0 379	0.415	1 016	0 927	0 761	0 868	0 767	0 950	-A-
-B-	0 301	0 316	0 303	0 359	0 372	0 382	0 513	0 516	0 591	0.512	0 573	0 583	-B-
-C-	0 344	0 346	0.359	0 661	0 627	0 623	0 990	0 967	1 038	0 992	1 051	1 078	-C-
-D-	0 444	0 470	0 440	0 434	0 442	0 417	0 531	0 422	0 540	0 532	0 581	0 585	-D-
-E-	0 613	0 627	0 636	0 842	0 852	0 807	0 594	0 574	0 667	0 962	1 032	1 060	-E-
-F-	0 759	0 783	0 772	0 492	0 494	0 484	0 428	0 414	0 466	0 514	0 550	0 504	-F-
-G-	0 821	0 955	0 925	1 153	1 115	1 086	0 830	0 815	0 903	1 013	1 106	1 068	-G-
-H-	0 983	0 962	1 086	0.670	0 658	0 634	0 480	0 481	0 538	0 575	0 601	0 566	-H-

-Plate Format-

	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	
-A-	BLK	BLK	BLK	*1	*1	*1	*9	*9	*9	*17	*17	*17	-A-
-B-	S1	S1	S1	*2	*2	*2	*10	*10	*10	*18	*18	*18	-B-
-C-	S2	S2	S2	*3	*3	*3	*11	*11	*11	*19	*19	*19	-C-
-D-	S3	S3	S3	*4	*4	*4	*12	*12	*12	*20	*20	*20	-D-
-E-	S4	S4	S4	*5	*5	*5	*13	*13	*13	*21	*21	*21	-E-
-F-	S5	S5	S5	*6	*6	*6	*14	*14	*14	*22	*22	*22	-F-
-G-	S6	S6	S6	*7	*7	*7	*15	*15	*15	*23	*23	*23	-G-
-H-	S7	S7	S7	*8	*8	*8	*16	*16	*16	*24	*24	*24	-H-

-Standard Curve Data-
Four Parameter Logistic

Conc.	o.d.	o.d.	o.d.	Mean o.d.	% cv	Calc Conc	% diff
627 940	0 179	0.194	0 181	0 185	4.403	574 552	-8 50
313.970	0.222	0.224	0 237	0 228	3.572	328.487	4 62
156 980	0.322	0.348	0.318	0 330	4 941	161 821	3.08
78 490	0 491	0.505	0.514	0.504	2 301	74.839	-4.65
39.250	0 637	0.661	0.650	0 650	1 849	40 711	3 72
19.630	0.699	0.833	0.803	0 779	9.031	19 486	-0.74
1 963	0 861	0 840	0 964	0.889	7 468	1 745	-11 12

Regression Parameters:

a	0 1406
b	-1.3241
c	4 2601
d	0 8942
R-sqr	0 9757
Sterr	0 0297

-Blanking Data-

o.d.	o.d.	o.d.	Mean o.d.
0 120	0 123	0 122	0 122

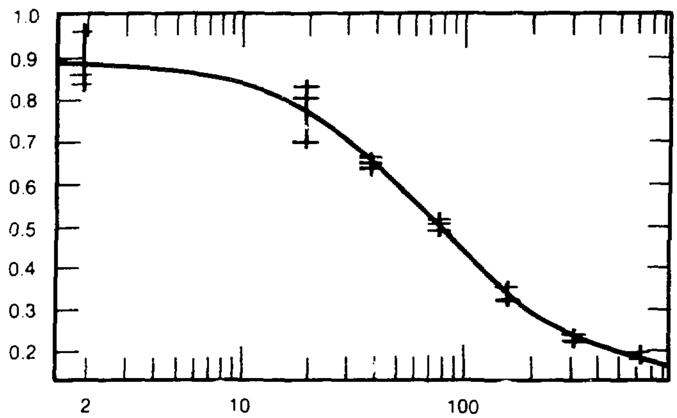
TABLE 1 (Continued)
CIEIA RESULTS

-Sample Results-
Conc units = ppb

#	o.d.	o.d.	o.d.	Mean o.d.	% cv	Conc.	#	o.d.	o.d.	o.d.	Mean o.d.	% cv	Conc.
1	0.254	0.257	(*)	0.256	0.829	258.107	13	0.472	0.452	0.545	0.490	9.990	79.067
2	0.237	0.250	0.260	0.249	4.625	271.753	14	0.306	0.292	0.344	0.314	8.560	176.024
3	0.539	0.505	0.501	0.515	4.052	71.418	15	0.708	0.693	0.781	0.728	6.469	27.350
4	0.312	0.320	0.295	0.309	4.127	181.121	16	0.358	0.359	0.416	0.378	8.783	127.349
5	0.720	0.730	0.685	0.712	3.319	29.876	17	0.746	0.645	0.828	0.740	12.387	25.404
6	0.370	0.372	0.362	0.368	1.436	133.266	18	0.390	0.451	0.461	0.434	8.849	99.367
7	1.031	0.993	0.964	0.996	3.372	(H)	19	0.870	0.929	0.956	0.919	4.787	(H)
8	0.548	0.536	0.512	0.532	3.443	66.711	20	0.410	0.459	0.463	0.444	6.642	95.291
9	0.894	0.805	(*)	0.850	7.405	8.734	21	0.840	0.910	0.938	0.896	5.632	(H)
10	0.391	0.394	0.469	0.418	10.564	106.374	22	0.392	0.428	0.382	0.401	6.033	114.739
11	0.868	0.845	0.916	0.877	4.132	4.214	23	0.891	0.984	0.946	0.941	4.971	(H)
12	0.409	(*)	0.418	0.414	1.538	108.463	24	0.453	0.479	0.444	0.459	3.960	89.683

(*) = edited (H) = too high (L) = too low (n.a.) = not applicable

Standard Curve



O.D. vs. Concentration (ppb)

Fitting Method:
Four-Parameter

Regression Parameters:
a = 0.1406
b = -1.3241
c = 4.2501
d = 0.8942
R-sqr = 0.9757
Sterr = 0.0297

Calculated Concentrations.
Concentration at mid-point of O.D range = 70.8199
Concentration at 10% of O D range = 372.2487
Concentration at 90% of O D range = 13.4734

TABLE 2 - METHOD COMPARISON: PENTACHLOROPHENOL IN DRINKING WATER SOURCES, ppb

SAMPLE[a]	EXPECTED LEVEL ppb	CIEIA DIRECT EPA	CIEIA DIRECT WBAS	CIEIA AFTER EPA METHOD 604 EXTRACT	CIEIA AFTER SOLID PHASE EXTRACT	GC/MS EPA	GC/MS WBAS
G-1	0	NR[b]	<89	< 7	< 33	12	< 25
G-2	100	128	145(15)[c]	62(7)	100(11)	105	104
G-3	400	546	364(14)	391(18)	298(12)	319	386
G-4	1000	1138	853(11)	988(8)	1079	790	984
G-5	4000	4531	3650(25)	3696(21)	3835(17)	3914	2200
G-6	20000	23958	18500(9)	20600(18)	24500(27)	23466	11000
S-1	0	NR	< 89	< 7	< 33	3	< 10
S-2	100	< 89	< 89	113(37)	135(9)	54	83
S-3	400	282	412	220(36)	435(14)	273	394
S-4	1000	1211	1036	517(24)	1079(21)	892	1100
S-5	4000	4073	4478	4145(14)	3521(13)	4308	1800
S-6	20000	20180	19900	17900(32)	21100(9)	12828	18000
T-1	0		< 89	< 7	< 33	< 1	< 10
T-2	100	< 89	127	116(18)	92(16)	2624	56
T-3	400	561	317	298(21)	364(46)	3349	293
T-4	1000	790	972	712(29)	938(20)	669	700
T-5	4000	4063	4105	3372(20)	3835(17)	NR	2300
T-6	20000	25400	18800	17200(9)	18400(23)	16256	37000

a. G = ground water, S = surface water, T = tap water

b. NR = no result due to procedural error.

c. Parenthetic numbers indicate % variation for multiple runs.

ADVANTAGES AND LIMITATIONS: APPLICATIONS

The advantages and limitations of immunochemical methods of analysis are based largely on the properties of the antibodies they employ. Table 3 lists the advantages and limitations of the technology in regards to its present status. In general, many of the limitations can be overcome by an innovative application of the technology Perhaps most compelling to the notion of adopting such methods are their low cost and sample throughput capacity.

The properties of specificity (chemical selectivity) and affinity (sensitivity) can, in part, be manipulated by the immunologist when developing antibodies for particular applications. The specificity of the anti-pentachlorophenol antibody was determined by examining its reaction with compounds of similar structure, as summarized in Table 4. The cross-reactivity can be explained by examination of the immunogen used to induce antibodies. Molecules with molecular weights less than approximately 10,000 atomic mass units must be attached to a large molecule, such as a protein, to render them capable of initiating an immune response. The production of antibodies for pentachlorophenol required the synthesis of the immunogenic structure shown in Figure 4. In this case, the small molecule (analyte structure) is termed the hapten and the hapten-protein conjugate is termed the immunogen. Via hybridoma technology, immunologists can produce antibodies that are specific for the haptenic structure making it possible to design an immunoassay capable of detecting either a single analyte or a class of compounds sharing a structural moiety.

Immunoassays operate in aqueous conditions with only certain concentrations of polar solvents being compatible. Therefore, if the chemical is in a water matrix with substantially no organic phase, the immunoassay may be run directly. This attribute enables the technology to be applied in the near-term to monitoring, for example, ground, surface and drinking waters, industrial effluents, and organisms (e.s., blood, urine, saliva, and sweat). As a means to clean-up and concentrate aqueous samples, the use of small, disposable chromatography columns available with reverse-phase, ion exchange and adsorption packings are quite effective. For aqueous analysis, therefore, immunoassays can be used to process large volumes of samples while providing savings in time and cost.

The advantages afforded by the immunoassay are diminished if much of the time from sampling to analyis is spent in sample extraction and cleanup. Incompatible liquid matrices and all solid matrices will require extraction into a solvent compatible with the immunoassay. Examples of acceptable solvents are methanol, isopropanol, acetonitrile and dimethyl sulfoxide. If necessary, extraction by conventional methods and exchange into a compatible solvent will have

TABLE 3 - Advantages/Limitations of Antibody-Based Methods for Environmental Analysis

Advantages	Limitations
Minimal sample preparation required for aqueous analysis	Development of sample preparation methods required for most matrices
Low reagent costs	Analysis cost will vary according to the extent of sample preparation required
Highly specific	Difficult to apply to multianalyte problems
Analysis of large compounds	Difficult to develop antibodies for compounds with molecular weight less than approximately 100-200 amu
Quantitative analysis	Cross-reactivity and interference

TABLE 4

SPECIFICITY OF ANTI-PENTACHLOROPHENOL ANTIBODY DETERMINED BY CROSS-REACTIVITY TESTING

Compound	Molar IC_{50}[a]	Percent Cross-Reactivity With PCP[b]
Pentachlorophenol	2.2 (+/- 0.3) x 10^{-6}	---
2,3,5,6-Tetrachlorophenol	5.3 (+/- 0.6) x 10^{-6}	42.0
2,4,6-Trichlorophenol	1.8 (+/- 0.3) x 10^{-5}	12.0
2,3,6-Trichlorophenol	2.5 (+/- 0.1) x 10^{-5}	8.8
2,6-Dichlorophenol	1.2 (+/- 0.1) x 10^{-4}	1.8
Tetrachlorohydroquinone	2.8 (+/- 0.1) x 10^{-4}	0.8
2,3,4-Trichlorophenol	4.5 (+/- 0.3) x 10^{-4}	0.5
2,3,5-Trichlorophenol	4.3 (+/- 0.3) x 10^{-4}	0.5
2,4-Dichlorophenol	NI[c]	0
2,5-Dichlorophenol	NI	0
3,5-Dichlorophenol	NI	0
3,4-Dichlorophenol	NI	0
2,3-Dichlorophenol	NI	0
4-Chlorophenol	NI	0
Phenol	NI	0
Pentachloroaniline	NI	0
Pentachlorobenzene	NI	0
2,3-Dinitrotoluene	NI	0
2,4-Dinitrotoluene	NI	0
2,4,5-Trichloronitrobenzene	NI	0

[a] Molar concentration of compound that inhibits 50% antibody binding in CIEIA.

[b] [IC_{50} PCP/IC_{50} compound] x 100

[c] NI = Not Inhibitory; 1.0 x 10^{-3} M

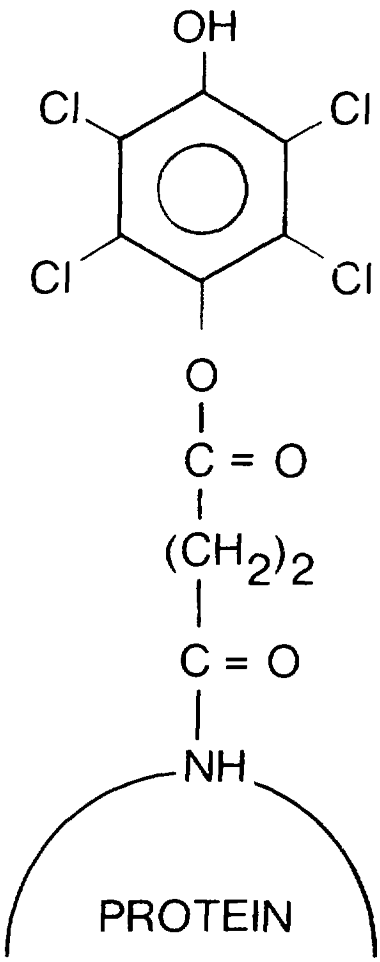


Figure 4. Pentachlorophenol Conjugate

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to be performed. The utility of this technology to characterizing contaminated sites will require, therefore, the development of expedient extraction and cleanup methods.

Immunoassays are essentially single analyte methods. In some cases, they may be used with conventional methods to more fully examine environmental problems. For example, if a toxic waste site has been characterized by conventional methodologies and found to contain many toxic compounds, it may be useful to utilize immunoassays to monitor the extent of the problem and the success of the cleanup effort. One might use the concept of sentinel species, one or two carefully chosen contaminants with appropriate physical and chemical characteristics (i.e., soil adsorption, water solubility, recalcitrance to biological degradation, etc.), to quickly and cost-effectively determine via immunoassay the status of the cleanup effort, rates of migration and impact on target organisms.

FUTURE DEVELOPMENTS

The useful application of immunochemical methods to environmental monitoring will require additional development of cleanup and extraction procedures for the range of sample matrices encountered by the analyst, as well as the designing of methods that complement traditional approaches. Acceptance of the technology will depend upon its ability to provide convenience, cost-savings, and enhanced problem solving capability.

One device being developed by WBAS, the capacitive affinity sensor, represents the coupling of antibody molecules through a transduction mechanism to a solid state electronic device to permit near-instantaneous, quantitative measurement of chemical compounds. This device when combined with a suitable sample preparation system is expected to allow continuous, on-line monitoring of aqueous streams, such as industrial effluents. It may also be configured to permit rapid and inexpensive single-point analysis for site screening or water monitoring.

Other devices and kits are being produced by a number of small innovative companies. As these products become field-tested useful applications of the technology will become apparent.

The authors greatfully acknowledge the contributions of Drs. Alan Brimfield, Steven Soileau and Peter Cheung of WBAS and Drs. Llewellyn Williams and Jeanette Van Emon of the EPA-EMSL, Las Vegas, NV.

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Classification and Reporting of Chemical Accidents

Presented by:

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CLASSIFICATION AND REPORTING OF CHEMICAL ACCIDENTS - *J. Andrew Walker, Richard E. DeBusk, Gretchen S. Bingman, and Cheryl L. Stovall; Management Systems Laboratories, Virginia Polytechnic Institute and State University, Blacksburg, Virginia*

ABSTRACT

Chemical accident response requires the joint effort of facility operators and local governments. During an accident, a gap frequently exists between the actions of facilities and local governments. A classification and reporting system for chemical accidents helps close that gap.

We illustrate the importance of a classification and reporting system and present a model system for facilities and local governments planning for chemical accidents. We distinguish between emergency and non-routine accidents and explain why the difference is important.

A CLASSIFICATION AND REPORTING SYSTEM IS NEEDED

There have recently been serious chemical accidents in Bhopal, India; Institute, West Virginia; and along the Rhine River in West Germany. These accidents dramatically illustrate both the threat of hazardous chemicals and the need for improved emergency management measures in areas surrounding chemical facilities. Partially in response to such accidents, the United States initiated new policies to improve such comprehensive planning. The Emergency Planning and Community Right-to-Know Act of 1986 requires hazard disclosure and improved planning and documentation by chemical facilities. In addition, state and local emergency planning commissions must be formed to cooperate with facilities in this effort. However, the 1986 Act lacks implementation guidance for emergency planners beyond these preliminary steps.

Developing linkages between facilities and local governments will improve cooperative planning and help bridge the gap between onsite and offsite information processing and response actions. A chemical accident classification system provides one method for bridging this gap. We use the term *accident* to mean any unplanned, unwanted event--something that happens which everyone wishes hadn't.

WHAT THE SYSTEM WILL DO

Facility operators have historically been slow to provide local governments with accident data. The consequences at both Institute and Bhopal resulted from failures in timely notification and subsequent offsite response actions. Effective response is founded on effective planning. Planning must include the development of a method to classify, report, and respond promptly to accidents. A chemical accident classification and reporting system is an information sharing tool that translates onsite accident data into meaningful accident information. Local governments can use this information to protect facility neighbors and support the response.

HOW TO DEVELOP A SYSTEM

There are five elements to a chemical accident classification system: distinguishing between emergency and non-routine accidents; establishing levels of accident severity within the broader categories of emergency and non-routine accidents; developing technical or other criteria for accident classification, planned response actions, and time constraints for notification.

Emergency and Non-Routine Accidents - A chemical classification and reporting system should include a distinction between emergency and non-routine accidents. We define emergency accidents as any significant deviation from planned or expected behavior or course of events that could endanger or adversely affect people, property, or the environment. Non-routine accidents are of such nature and severity as to fall below the emergency definition but still represent violations of regulatory laws or have public or press interest. Major accidents that clearly fall into the emergency accident category are rare. Rather, routine industrial mishaps occur regularly. A system that includes both categories of accidents provides appropriate levels to classify accidents and expedite the sharing of vital information. In this way, accidents that are not emergencies do not weaken the system by obscuring the truly important information.

Levels of Accident Severity - We need more detailed classification levels within the broader categories of emergency and non-routine accidents. These classification levels are defined in terms of reductions in facility safety and offsite impact. For the emergency accident category, we suggest using the classification levels developed by the Nuclear Regulatory Commission (NRC). These radiological emergency classification levels include Unusual Event, Alert, Site Emergency, and General Emergency. For non-routine accidents, we suggest a simple, two-level subdivision into Reportable Accidents and Loggable Accidents. Each level is linked to planned response actions.

Criteria for Classification - The NRC classification levels include technical definitions in terms of radiation exposure which in turn drive each classification level. A similar system for the chemical industry would be far more difficult to develop because of its many and varied chemical hazards. There is also no central regulatory authority to mandate standards. Facilities and local governments lack the resources to provide technical definitions and cannot formulate national standards.

It is possible, however, to develop emergency planning programs that include a classification system without precise technical definitions. We suggest structuring the judgment of facility operators until more precise methods can be developed. Factors in structuring judgment should include consideration of the following:

who was involved?
what kind of material?
how much material?
what was damaged?
where did it happen?
what do regulations or agreements say?
what is the impact?
what are the circumstances?

These general questions can guide facility operators and emergency managers in classifying accidents. The general guide suffices in the absence of exact measurements, which are often not available. The need for immediate response action is often more important than exact measurement of accident characteristics.

Planned Response Actions - Facility and local government response actions must be predetermined. Training, including joint exercises, ensures the response actions can be implemented and government and industry can cooperate. The chemical accident classification system helps ensure that initial notification conveys the right information in an easily understood format.

Time Constraints - Mandated notification times for prompt reporting by facility operators are important. However, because of differences in specific hazards and facility siting (relative to offsite populations and environmental considerations), reporting times for each level of accident should be developed between facility operators and offsite organizations. In addressing time constraints, the system must recognize and balance the competing needs for completeness and precision of information on the one hand, and for timeliness on the other.

To illustrate a classification and reporting system, we provide Figure 1, Example Chemical Classification System: Emergency Accidents; and Figure 2, Example Chemical Classification System: Non-Routine Accidents.

BENEFITS OF THE SYSTEM

The three benefits of a classification and reporting system are as follows:

Shared Understanding - The system provides a uniform, shared understanding of accident severity among all response groups. Accident classification levels are based on successive levels of reduction in facility safety and increased offsite impact.

Planned Response - In an accident, the time between discovery and the need to make critical decisions is short. Therefore, planning to establish predetermined response actions is critical. By defining categories of actions, local governments can make critical decisions: to shelter or evacuate, to request additional resources, etc. A chemical accident classification system must balance onsite and offsite information needs. Facility operators need precise data to identify and correct the source of the accident. Local government actions are based on a more general description of the situation provided by immediate notification. A chemical accident classification system must balance these dual needs.

Facility Credibility - A chemical accident classification system enhances the credibility of industry and local governments. Local governments are protecting their citizens; industry is a responsible neighbor. Cooperative planning reassures facility neighbors that competent authorities are concerned with their safety and are planning to assure their safety even in an accident.

Emergency Accident Classifications	General Criteria	Guidelines For Classification	Response Actions: Onsite	Response Actions: Offsite
Unusual Event	- Potential reduction of plant safety - No potential for offsite release	Judgment Factor Checklist ● Personnel involved - severity of injury or exposure - number of people involved - sensitivity of incident ● Material involved - type of material - amount of material ● Damage level - what was damaged - how badly ● Location of incident - onsite - offsite - circumstances ● Regulations and Agreements - compliance with all applicable regulations and agreements ● Impact - potential for worsening - potential as a catalyst for another event ● Circumstances - unrelated circumstances that heighten the sensitivity of an event	- Notify plant management - Notify local governments; regulatory agencies - Consider activating Emergency Response Team - Consider partial staffing of Emergency Operations Center	- Notify applicable municipal, county authorities
Alert	- Actual or potential substantial reduction of plant safety - Offsite release not expected to exceed permissible limits		- Notify plant management - Notify local governments; federal and/or state regulatory agencies - Activate Emergency Response Team, Emergency Operations Center - Evacuate/shelter plant workers or take other protective action	- Notify applicable municipal, county authorities - Activate local government, volunteer mutual aid responders (fire, emergency medical, etc.) if requested by plant - Consider partial staffing of Emergency Operations Center - Place police, fire, medical, engineering, etc. on stand-by
Site Emergency	- Actual or likely substantial reduction of plant safety - Potential for offsite releases to exceed permissible limits		- Notify plant management - Notify local government; federal and/or state regulatory agencies - Activate Emergency Response Team, Emergency Operations Center - Activate Joint Public Information Center (with counties and state officials) - Evacuate/shelter plant workers or take other protective action	- Notify applicable municipal, county authorities - Send representative to Joint Public Information Center - Prepare for field operations - Activate local government, volunteer mutual aid responders - Begin preparation of Emergency Broadcast System (EBS) messages, if needed
General Emergency	- Actual or imminent reduction of plant safety - Offsite releases are expected to exceed permissible limits		- Notify plant management - Notify local governments; federal and state regulatory agencies - Management confers with local government and determines need for shelter or evacuation siren activation to protect local residents - Management directs plant evacuation, sheltering, or other protective action - Activate Emergency Response Team, Emergency Operations Center, Joint Public Information Center	- Notify applicable municipal, county authorities - Activate EBS with plant evacuation/shelter sirens - Activate field operations, Emergency Operations Center, Joint Public Information Center - Open evacuation shelters if needed - Request state, federal assistance if needed

Figure 1. Example Chemical Classification System: Emergency Accidents

Non-Routine Accident Classifications	General *Criteria*	Guidelines *For Classification*	Response Actions *Onsite*	*Offsite*
Reportable Accident	- Regulatory reporting required - Potential for public/press sensitivity	Judgment Factor Checklist • Personnel involved - severity of injury or exposure - number of people involved - sensitivity of incident • Material involved - type of material - amount of material • Damage level - what was damaged - how badly • Location of incident - onsite - offsite - circumstances • Regulations and Agreements - compliance with all applicable regulations and agreements • Impact - potential for worsening - potential as a catalyst for another event • Circumstances - unrelated circumstances that heighten the sensitivity of an event	- Notify plant management - Notify local governments; regulatory agencies - Consider press statement or release	- Notify applicable regulatory agencies - Notify applicable municipal, county authorities
Loggable Accident	- No external reporting required	• A non-routine event that does not qualify as a reportable event using the judgment factors	- Assure event recorded - Conduct event trend analysis during periodic management reviews	- No action required

Figure 2. Example Chemical Classification System: Non-Routine Accident

CONCLUSION

Industry and local government can work together to develop an effective chemical accident classification system. This system can save lives. Should a central ciassification system be mandated later with precise technical criteria, the system can be adapted. It is the cooperation and systematic view of emergency management that is important. Industry and local government must work together; this need is more urgent now than ever before.

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The Role of Modeling in Emergency Response

Presented by:

M. J. Sale, ORNL

THE ROLE OF MODELING IN EMERGENCY RESPONSE[1]

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Appropriate response to environmental emergencies, such as spills of hazardous materials, requires predetermined information and understanding of the environmental setting, transport mechanisms of contaminants, and system sensitivities of any particular receiving system. Computer simulation models play a very important role in organizing the large array of information needed and in developing an understanding of system dynamics. For the past 18 months, we have been developing a set of simulation models to predict the fate of waterborne contaminants accidentally released into the White Oak Creek watershed. The models include surface water runoff from the watershed, reservoir regulation at White Oak Lake and other detention basins within the Oak Ridge National Laboratory (ORNL) reservation, flow routing within the Clinch River-Watts Bar Reservoir system, and transport and mixing processes controlling the dispersion of contaminants released downstream from White Oak Dam. The suite of models has been organized into an effective tool for use in managing environmental problems at ORNL. Experience with a number of different such problems demonstrates the value of these tools for mitigating the effects of spills and other accidental releases to the aquatic environment.

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[1] Based on work performed at Oak Ridge National Laboratory, operated by Martin Marietta Energy Systems, Inc., under contract DE-AC05-84OR21400 with the U.S. Department of Energy.

PROCEEDINGS PAPER NOT AVAILABLE
AT TIME OF PRINTING

Forecasting Contaminant Concentrations: Spills in the White Oak Creek Basin

Presented by:

Dennis M. Borders, University of Tennessee

FORECASTING CONTAMINANT CONCENTRATIONS: SPILLS IN THE WHITE OAK CREEK BASIN - Dennis M. Borders, The University of Tennessee, Knoxville, Tennessee; David W. Hyndman, Oak Ridge Associated Universities, Oak Ridge, Tennessee; Dale D. Huff, Environmental Sciences Division, Oak Ridge National Laboratory (operated by Martin Marietta Energy Systems, Inc., under contract DE-AC05-84OR21400 with the U.S. Department of Energy), Oak Ridge, Tennessee.

INTRODUCTION

The Streamflow Synthesis and Reservoir Regulation (SSARR) model has been installed and sufficiently calibrated for use in managing accidental release of contaminants in surface waters of the White Oak Creek (WOC) watershed (Figure 1) at ORNL. The model employs existing watershed conditions, hydrologic parameters representing basin response to precipitation, and a Quantitative Precipitation Forecast (QPF) to predict variable flow conditions throughout the basin. Natural runoff from each of the hydrologically distinct subbasins is simulated and added to specified plant and process water discharges. The resulting flows are then routed through stream reaches and eventually to White Oak Lake (WOL), which is the outlet from the WOC drainage basin. In addition, the SSARR model is being used to simulate change in storage volumes and pool levels in WOL, and most recently, routing characteristics of contaminant spills through WOC and WOL.

The Discharge Forecast Modeling Project originated as a result of the Strontium-90 Action Plan, a response to the abnormal release of radionuclides that occurred from WOC during late November and early December 1985. Excavation activities in the vicinity of the Building 3517 (Fission Products Development Laboratory, FPDL) construction site, combined with heavy rainfall, initiated the release into WOC. The incident occurred when a broken storm drain resulted in contact between ^{90}Sr-contaminated soil and storm runoff, which subsequently entered the storm and sanitary drainage systems. Several notable problems became obvious during ORNL's response to this release: (1) no predetermined criteria existed for the operation of White Oak Dam (WOD) in response to spills, (2) the hydrodynamics of contaminant transport and dispersion within the WOC watershed and downstream were not adequately understood to support requests for modified reservoir releases, and (3) real-time data on streamflow, precipitation, and water quality within the watershed were not readily available in sufficient quantity and usable format. The modeling study was initiated to help address these problems.

ORNL-DWG 86-9445

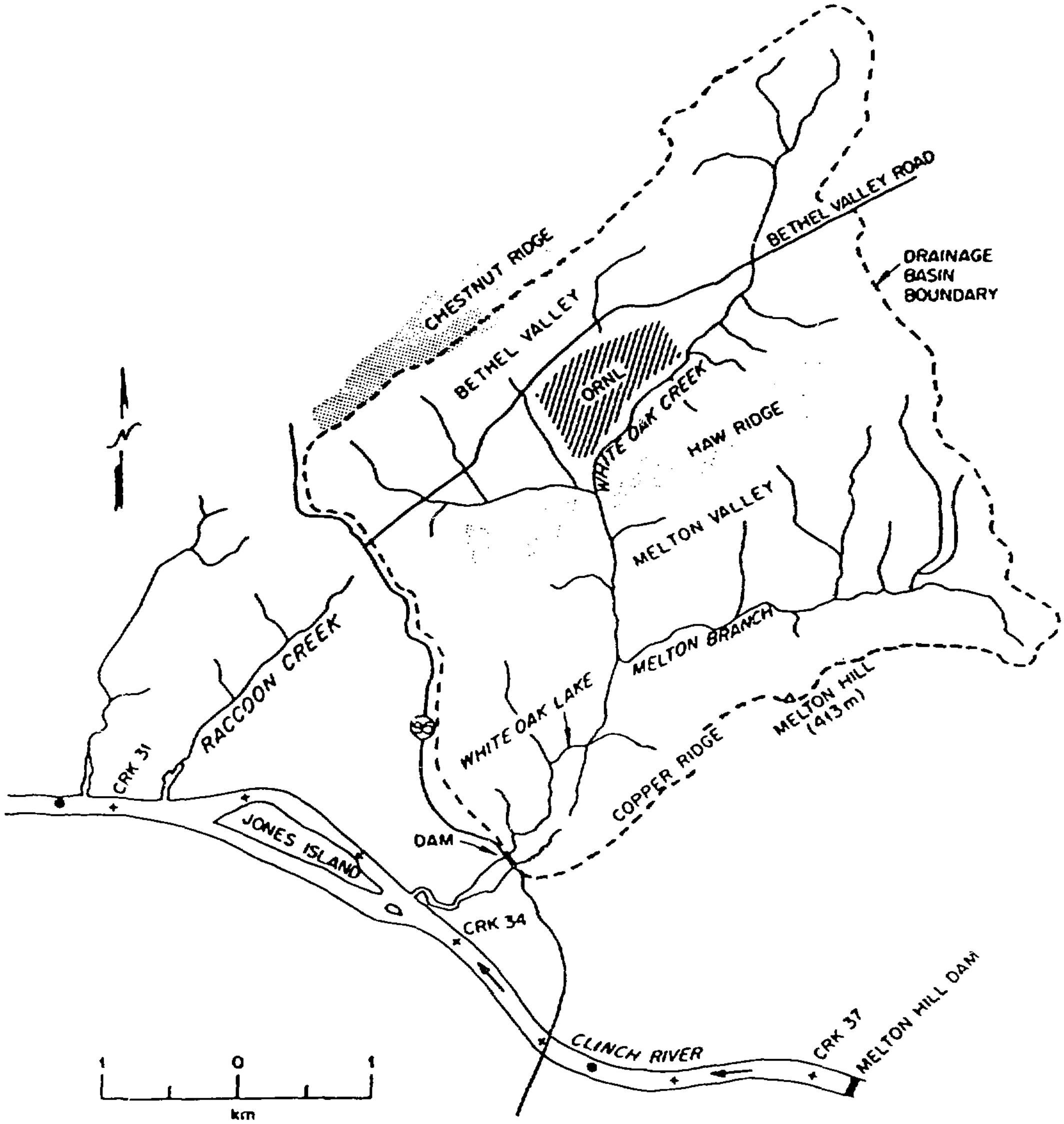

Figure 1. White Oak Creek drainage basin map.

DATA ACQUISITION AND EVALUATION

ORNL Monitoring Data

Perhaps the most important element involved in hydrologic modeling and discharge forecasting is the data base available to support the calibration and development of hydrologic simulations. The SSARR model has helped to identify limitations in the present data collection process and provide a framework for organizing and using the data that are gathered. Various organizations have been involved in data collection within the ORNL reservation, and historically each organization has dealt with its data according to specific needs. In addition, the projects for which hydrologic data were collected have not had coordinated data management procedures. Because of the diversity of data types needed for discharge forecast modeling and overlapping collection responsibilities, data management was a major task.

The initial forecast modeling required continuous flow records and climatic data at short time intervals for small sub-catchments within the WOC watershed. Several important gaps in WOC hydrologic monitoring were identified in the process of data acquisition. For example, there were no instruments for monitoring the water surface elevation of WOL and there were no gaging stations located upstream from the ORNL main plant area. Most of the problems have been or are being corrected as part of a continuing effort to improve and expand the current basin monitoring network.

In order to make timely forecasts for emergency response, it is necessary to access real-time data on streamflow and precipitation at a number of stations within the drainage basin. ORNL's Department of Environmental Monitoring and Compliance (EMC) began acquiring real-time data for WOC, Melton Branch (MB) and WOD in October, 1986. Then, as part of planned improvements, EMC installed a new Data Acquisition System (DAS) and installed more powerful data concentrators at the ambient water monitoring stations in June, 1987. With the application of this system, near real-time data signals are available at the three ambient monitoring stations on the new VAX 11/750 digital computer system. The system is equipped with a means of data verification which flags invalid values as well as system alarms for identifying values which fall outside acceptable ranges. Plans are being made to acquire a dedicated phone line within the Environmental Sciences Division (ESD) for direct access to all needed data available within the system. This will allow a direct link from the EMC computer data base to PCs in ESD where data can be continuously downloaded for input to SSARR modeling.

USGS Hydrologic Data

The U.S. Geological Survey (USGS) continues to work with ORNL to establish and maintain surface-water recording stations in and around the WOC watershed. Data from the following new stations have recently become available: First Creek monitoring station above WOC, the Parshall flume on WOC in the main plant area, and a satellite link (data collection platform, DCP) reporting near real-time flow and precipitation data at the 7500 Bridge monitoring station. A telecommunications link with the USGS data base in Nashville enables direct access of these data for present and future application to SSARR modeling.

The satellite link at 7500 Bridge became operational in April 1987, making flow data available on a near real-time basis. Under normal operating conditions, data are available no later than four hours after values are recorded. At stages of three feet or higher, the signal is reported every 15 minutes, but this situation occurred once in the initial days of site operation, and has not been verified recently. In September, 1987, a precipitation sensor was added to the DCP system, and these data are now available on the same basis as the streamflow records. In the future, an air temperature sensor may be installed at the 7500 Bridge station to supply modelers with near real-time temperature data (required for the new version of the SSARR model). USGS flow data from 7500 Bridge were invaluable as a substitute for WOC data when the record at that station (MS3) was missing.

Quantitative Precipitation Forecasts

ORNL staff have visited the Atmospheric Turbulence and Diffusion Laboratory (ATDL) in Oak Ridge to discuss the status of the emergency response forecast information service. The ATDL can now supply 48-hour (Day 1 and Day 2) QPFs (necessary for SSARR model discharge forecasting) with a breakdown for Knoxville every 6 hours. These forecasts are available as FAX System Products and are updated twice a day (12-h updates). Efforts are also being made to establish a modem link to enable ORNL direct access to the FAX system. In addition, the system is due to be upgraded soon to provide an expanded selection of QPF products. In the event that a QPF cannot be obtained from the ATDL, The National Weather Service (NWS) also maintains a 24 h/d QPF center which can provide 6-h QPFs for two days in advance. In addition, a staff member in the Energy Division, ORNL, obtains QPFs on a daily basis and can provide this information if necessary.

SSARR FORECAST MODELING

Water Quality Modeling

For spill response applications, the model has been adapted to the simulation of ^{90}Sr discharges from a combination of non-point and point-source releases. Strontium-90 has been the primary contaminant studied because it is regarded as one of the most likely candidates to cause an emergency incident by accidental release into WOC. It is also conservative and highly stable. Records of average monthly ^{90}Sr concentrations in WOC for calendar year 1986 as well as records of Solid Waste Storage Area no. 4 (SWSA-4) surface water flows and ^{90}Sr concentration versus flow for November 1985 to March 1987 have been collected. The flow versus ^{90}Sr relationship for SWSA-4 for this period of record has been scaled to represent background contaminant in WOC as a conservative estimate of average observed concentration. Therefore, background concentration is now continuously simulated as a function of flow for the WOC watershed. This relationship will be refined in the future as justified by the collection of samples from WOC at various flows.

Though simulation of background contaminant flux is important to water quality modeling, the major concern lies in forecasting the fate of hazardous substances released into the WOC system. Specific questions which must be addressed include "How long does it take a contaminant released from the main plant area to reach White Oak Dam (WOD)?", "What is the dilution of the contaminant as it travels through WOL?", and "How long will it take before the entire pulse of contaminant has passed through the dam?". Obviously, the answers to these questions vary considerably according to flow conditions and the regulation of the gates at WOD.

In addition, the character of the contaminant has an affect on its residence time within the watershed. Non-conservative (i.e. biodegradable) contaminants, such as ethylene glycol, react differently than ^{90}Sr under similar conditions. Modeling the basin response to this type of pollutant will require development of unique parameters for each contaminant considered, including decay coefficients, sediment partition coefficients, etc.

Recently, water quality modeling has been directed toward the development of procedures to simulate basin response to significant contaminant releases (particularly ^{90}Sr) into WOC from the main plant area at ORNL. A basic relationship was developed to route a contaminant spill through WOL assuming constant flow into the lake. According to this scheme, spills are routed coincident to, but independent from, basin model flows with theoretical reach and reservoir routing functions to simulate travel time and dispersion through WOC and WOL to subsequent output at WOD. Contaminant mass flux in WOC and WOL must be simulated as a relationship which is a function of the flows occurring simultaneously within the watershed. The emergency response to a simulated accidental spill (environmental drill) followed this type of procedure for forecasting the release of contaminants from WOD.

Environmental Drill

To test the emergency response of the SSARR modelers to a simulated contaminant release from the main plant area, an environmental drill was planned for June 1987.

To prepare for simulating the response to an actual contaminant release on WOC, a standard procedure was developed to follow each time an incident occurred. A procedure has been established to obtain timely information during emergency conditions on expected flow conditions, time of travel of contaminants, concentrations at key locations, and the consequences of alternative release procedures at WOD. A chart was prepared (Table 1) listing the steps to be taken upon notification of a spill. Included in this chart are the input data necessary for each step as well as all possible sources of this data. This procedure is subject to revision pending further model development and methods of data acquisition. Figure 2 illustrates a more comprehensive view of the sequence of events and the interaction which takes place between the discharge forecast and dispersion modeling groups. The dispersion modelers are concerned with the dispersion of contaminants downstream from WOD in the Clinch River system. When a spill is reported, data on flow conditions and lake elevation are needed to make an initial estimate of storage availability on WOL. This initial estimate will inform forecast modelers and management how long the gates on the dam can be closed, under existing conditions, until action is required to avoid overflow conditions at WOD. With the acquisition of all data including a QPF, SSARR model "backup" calculations (a routine which matches model simulations with current conditions), and simulation of the various scenarios (best and worst cases) can begin. At the same time, the dispersion modelers are engaged in modeling Clinch River flows and velocities. After modeling the various possible scenarios to determine timing and concentration of flows at WOD, a transfer of information can take place between the two modeling groups. At this point decisions must be made on the strategy to be employed for the regulation of the gates at WOD and notification of those responsible for the intakes downstream on the Clinch River.

On June 25, Discharge Forecast modelers simulated the following hypothetical spill scenario:

> At 5:30 a.m., assume a waste storage tank ruptured and approximately 30,000 gallons of waste, containing 100,000 Becquerels per liter (Bq/L) was released. By 7:30 am, assume all the waste had entered White Oak Creek near the process waste treatment plant.

The response to this scenario followed the steps set forth in the procedure previously described. The previous day's data was retrieved from the Waste Operation Control Center's operator by phone; however, the flow record at Melton Branch (MB) was incomplete. An ESD data

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PROCEDURE FOR RESPONSE TO CONTAMINANT RELEASE

STEP	INPUT DATA	SOURCE
1. UPDATE COMPUTER DATA	FLOW (MS3, MS4, MS5, 7500 BRIDGE) PRECIP. (WOD, MELTON VALLEY)	WOCC OPERATOR USGS DATA BASE EMC
2. GATHER FIELD DATA	SAME	FIELD VERIFICATION
3. OBTAIN QPF	QUANTITATIVE PRECIPITATION FORECAST	ATDL OR NWS
4. MAKE INITIAL ESTIMATE OF WOL STORAGE	FLOWS, LAKE ELEVATION	EMC
5. PROCESS DATA SSARR FORMAT		
6. SPILL DESCRIPTION	SPILL (CONTAMINANT DISCHARGE - TIME AND VOLUME)	
7. RUN SSARR MODEL BACKUP	FLOW, PRECIPITATION, UPDATED MODEL RUN	PREVIOUS
8. ENTER SPILL DATA		
9. SIMULATE VARIOUS SCENARIOS (BEST, WORST CASES)	SPILL, QPF LAKE REGULATION	PREVIOUS
10. DETERMINE WOL STRATEGY - PASS INFORMATION TO DISPERSION MODELERS	FORECAST AND DISPERSION GROUPS	

Table 1. Procedure for response to contaminant release.

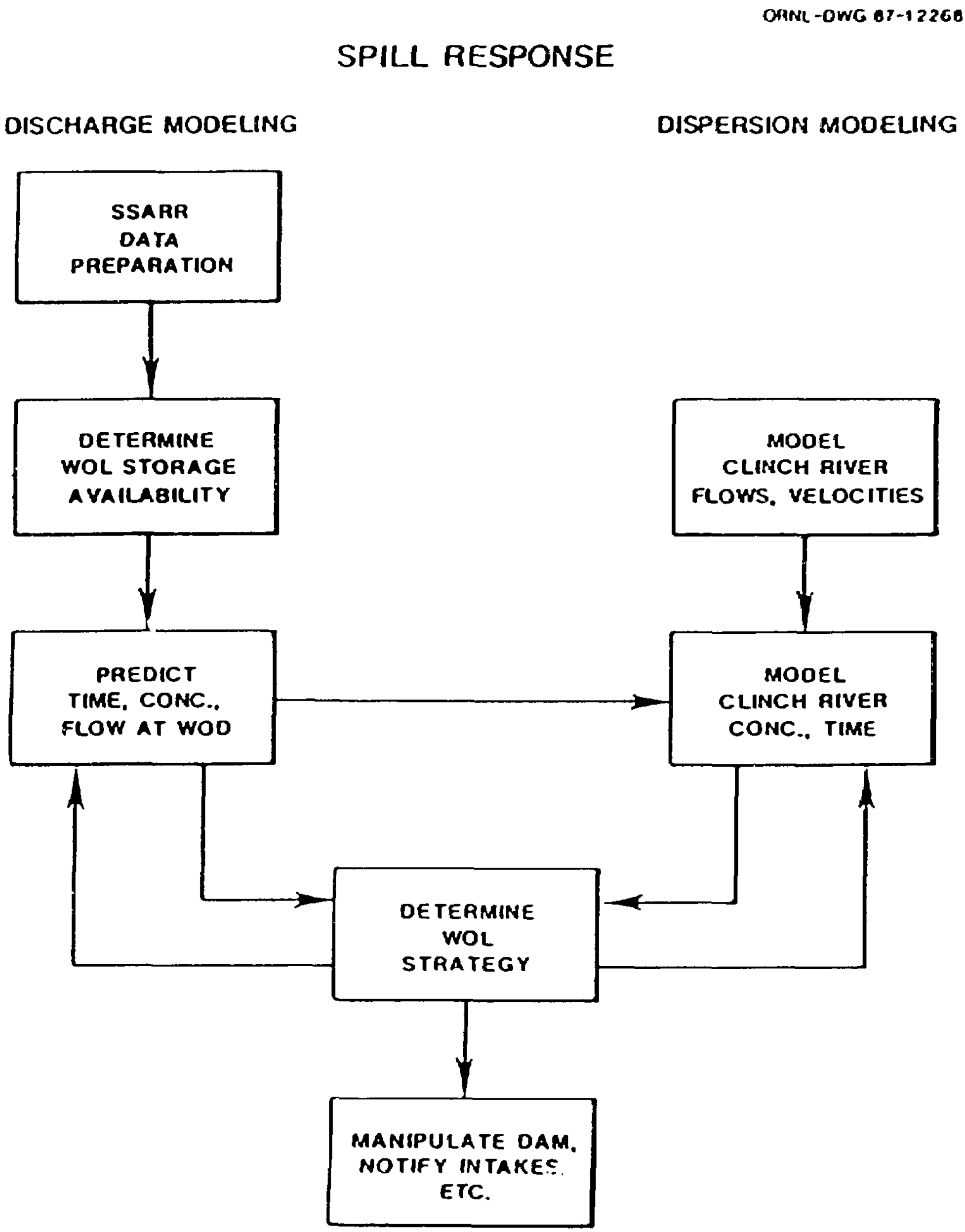


Figure 2. Flowchart of events and interaction between Discharge Forecast and Dispersion modelers.

logger, which was placed on MB in May, provided a means to avoid a data gap. A QPF was acquired by phone through the Atmospheric Turbulence and Diffusion Lab in Oak Ridge. The SSARR model backup calculation had been roughly prepared in advance, as part of an effort to test a new version of the model that was not yet operational. The spill data were entered into the model in units of Bq/s. The model forecast was simulated under the best case scenario (no rain over the period of forecast) assuming the gates of WOD were left open. Figure 3 illustrates the simulated basin response to the hypothetical spill through WOL and the contaminant discharge at WOD. A peak waste concentration of 292 Bq/L (59,540 Bq/s at an average flow of 7.2 cfs) was predicted at the dam approximately 48 hours after the assumed spill was released into WOC.

Upon obtaining results such as these, the predicted flows and concentrations at WOD would be passed on to the dispersion modelers. Output from dispersion modeling would include time and concentrations at the Oak Ridge Gaseous Diffusion Plant (K-25) water intake and downstream at Kingston. It should be noted that the results from the discharge forecast modeling represent only the best case scenario at constant flow conditions. Additional scenarios include variable flow conditions (precipitation over the forecast period), as well as all flow conditions with and without regulation of the gates at WOD.

Current Model Applications

The SSARR model was not developed specifically to simulate and forecast water quality in units of mass flux, only flow in units of volume per increment of time (e.g. ft^3/sec [cfs]). Therefore, contaminant releases must be transformed into units of flow (cfs) and added to surface water in order for the model to recognize them. The current model configuration is made up of two integral components: a flow routing branch (Figure 4) and a contaminant routing branch for modeling background contaminant concentration plus spills released from point or non-point sources. Under this scheme, background from each subbasin is continuously modeled as a function of basin flow while spills are added to model simulations, when they occur, according to their character and point of release to the flow system. The two branches of the model combine (Figure 5) above all routing reaches and reservoirs of the contaminant branch. Basin flows are added to contaminants prior to routing reaches and reservoirs in order for time of travel and dispersion of contaminants to be simulated as a function of the actual flow conditions occurring at that time. After routing flow plus contaminants through a reach or reservoir in the contaminant branch, basin flows are subtracted back out and transformed, leaving routed contaminant mass flux at any given location in the surface water system.

When representing contaminant mass flux in units of flow (cfs) in order to add to basin flows for purposes of routing through stream reaches and reservoirs, it is essential to scale all contaminant values down to

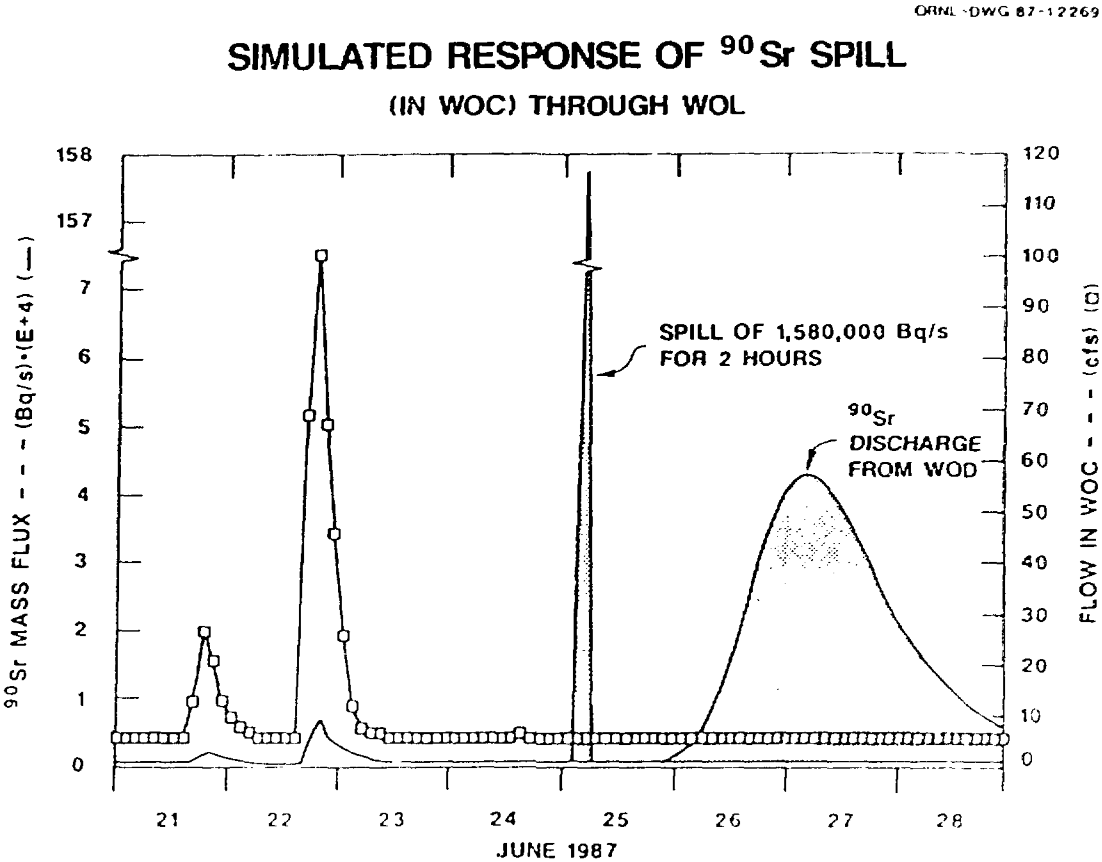
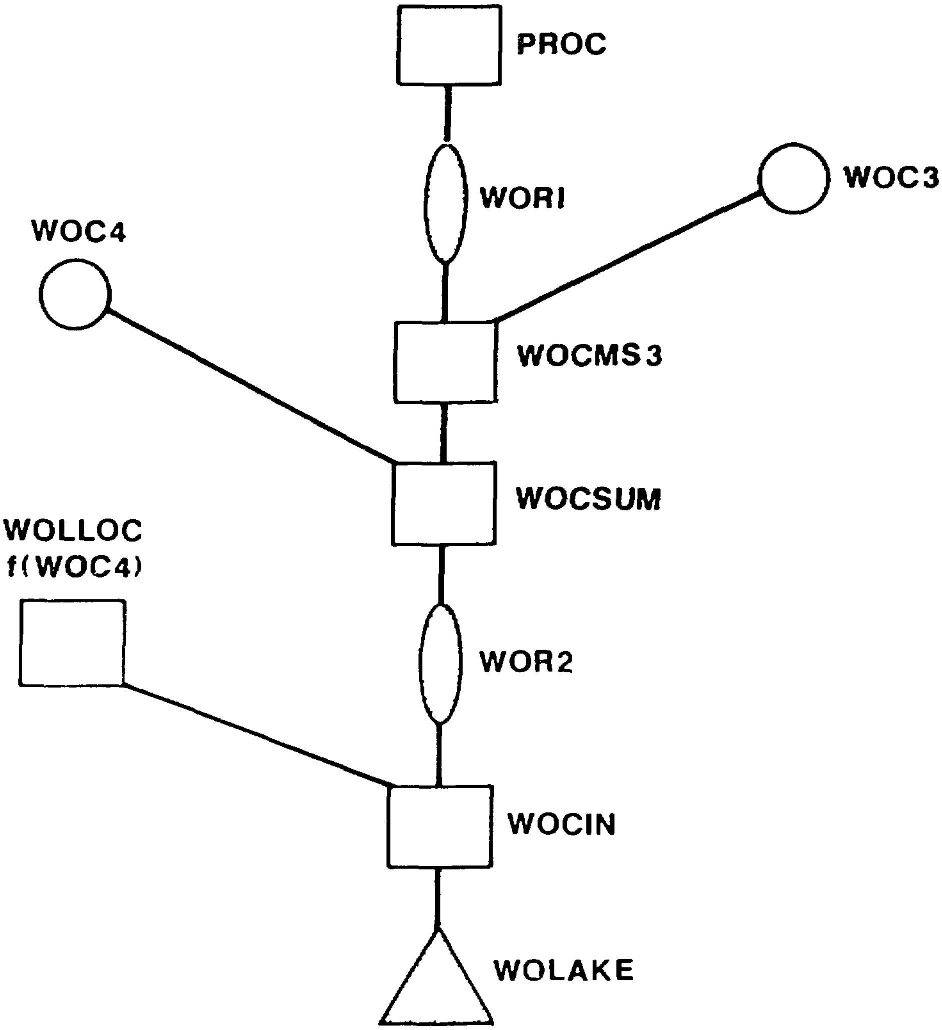


Figure 3. Simulated response of ^{90}Sr spill in White Oak Creek and discharge through White Oak Dam.

ORNL-DWG 87-15526

WHITE OAK CREEK FLOW MODEL (WOCMOD)



PROC – PROCESS INFLOWS TO WHITE OAK CREEK
WOR1 – WHITE OAK CREEK ROUTING REACH NO. 1
WOC3 – BASIN RUNOFF FROM WHITE OAK CREEK SUBBASIN
WOC4 – BASIN RUNOFF FROM MELTON BRANCH SUBBASIN
WOCSUM – SUMMATION OF FLOWS FROM MELTON BRANCH AND WHITE OAK CREEK
WOR2 – WHITE OAK CREEK ROUTING REACH NO. 2
WOLLOC – WHITE OAK LAKE LOCAL INFLOW
WOCIN – TOTAL INFLOW TO WHITE OAK LAKE
WOLAKE – WHITE OAK LAKE RESERVOIR

Fig. 4. White Oak Creek Flow Routing Model Configuration.

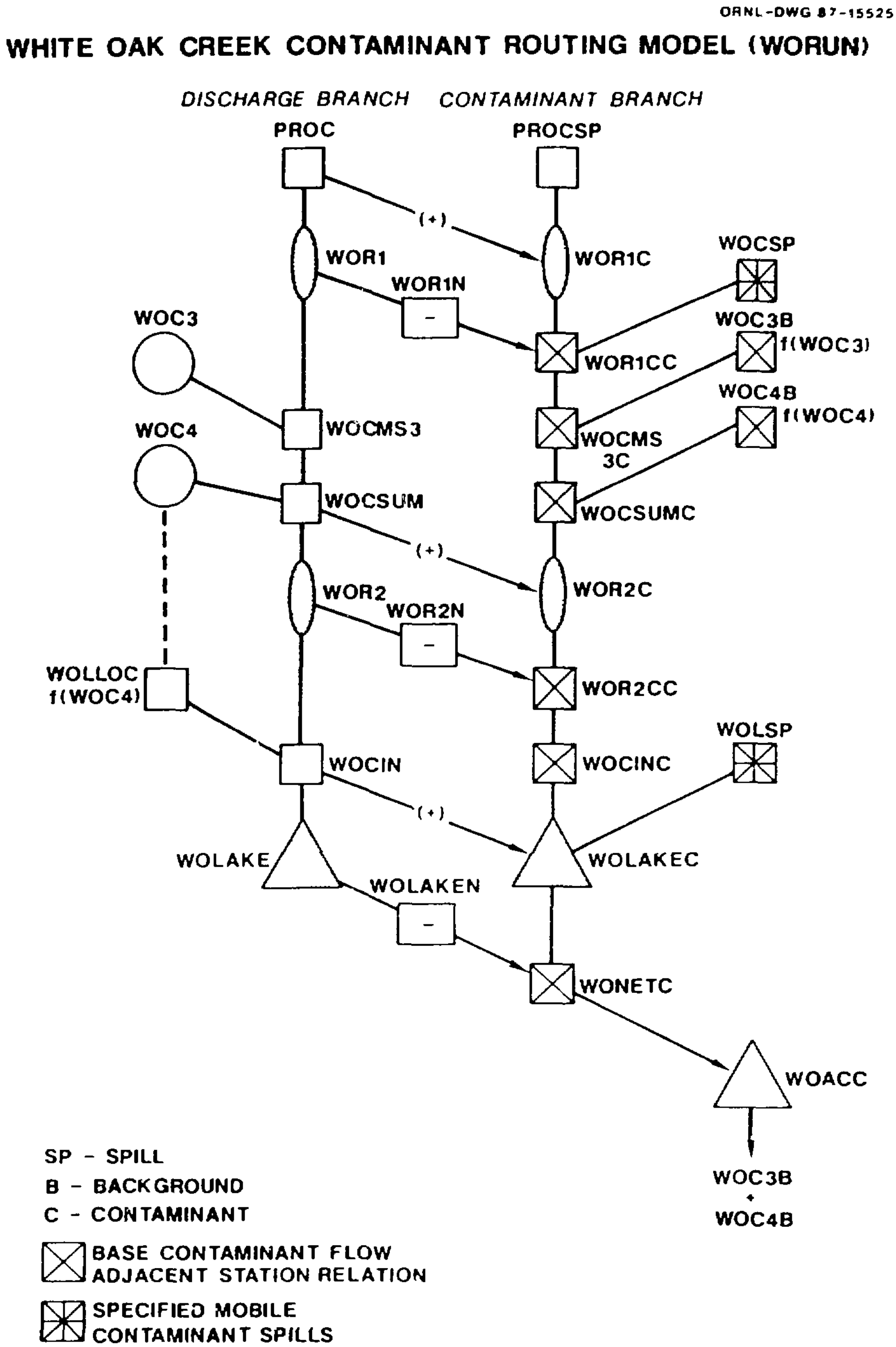


Fig. 5. White Oak Creek Contaminant Routing Model Configuration.

a proper level to reduce the impact on natural routing characteristics. For example, given a curve for time of travel versus flow (Q) for a stream reach (Figure 6), a contaminant release of one unit (C = 1) added to each of flows Q_1 and Q_2 results in substantially different impacts to the natural flow routing character of the stream:

$Q_1 = 5$ Travel time = 1.6
$Q_1 + C = 6$ Travel time = 1.8

$Q_2 = 1$ Travel time = 4.6
$Q_2 + C = 2$ Travel time = 3.3

The addition of this contaminant release to Q_1 increases the time of travel by 11% while the same value added to Q_2 results in a 28% decrease. Errors of this magnitude could cause gross misrepresentation of basin response as well as loss of model capability to maintain conservation of mass of a contaminant released into the system. Therefore it is necessary to scale contaminant concentrations approximately two orders of magnitude lower than expected basin flows.

DYE TRACER STUDY

In September 1987, staff at ORNL performed a dye tracer study to further characterize surface waters of the WOC basin and to modify the SSARR model calibration. The present calibration of the flow model is based on the estimation of time of travel versus flow for various reaches in the watershed under varying conditions of flow. The dye study supplied real values for travel times under a base flow (low flow) condition. These values will enable the modification of both the flow and contaminant branches of model calibration. Real travel time will enable the flow model to more accurately represent the basin response to rainfall. At the same time, travel times and dispersion characteristics will enable the calibration of the contaminant portion of the model and begin to answer the questions previously asked concerning the fate and consequences of hazardous contaminants released into the WOC system. In addition, the knowledge of defined flow paths through WOL could help to expedite sampling and cleanup efforts in the event of a contaminant spill.

Prior to releasing dye into WOC above WOL, drogues (plastic milk jugs nearly full of water) were released below WOC into the headwaters of WOL. This was done to determine flow paths of water entering the lake and to facilitate calculations for quantity of dye to release upstream. The drogues proved to be an excellent indicator of flow paths through WOL.

On September 14, at 11:45 a.m., approximately 1.25 gallons of a 20% solution of Rhodamine WT dye were instantaneously injected into WOC just below the water monitoring station (MS3) above the confluence with Melton Branch, 1.02 miles upstream of WOD. Automatic samplers were placed along WOC below the dye injection point and just above the lake.

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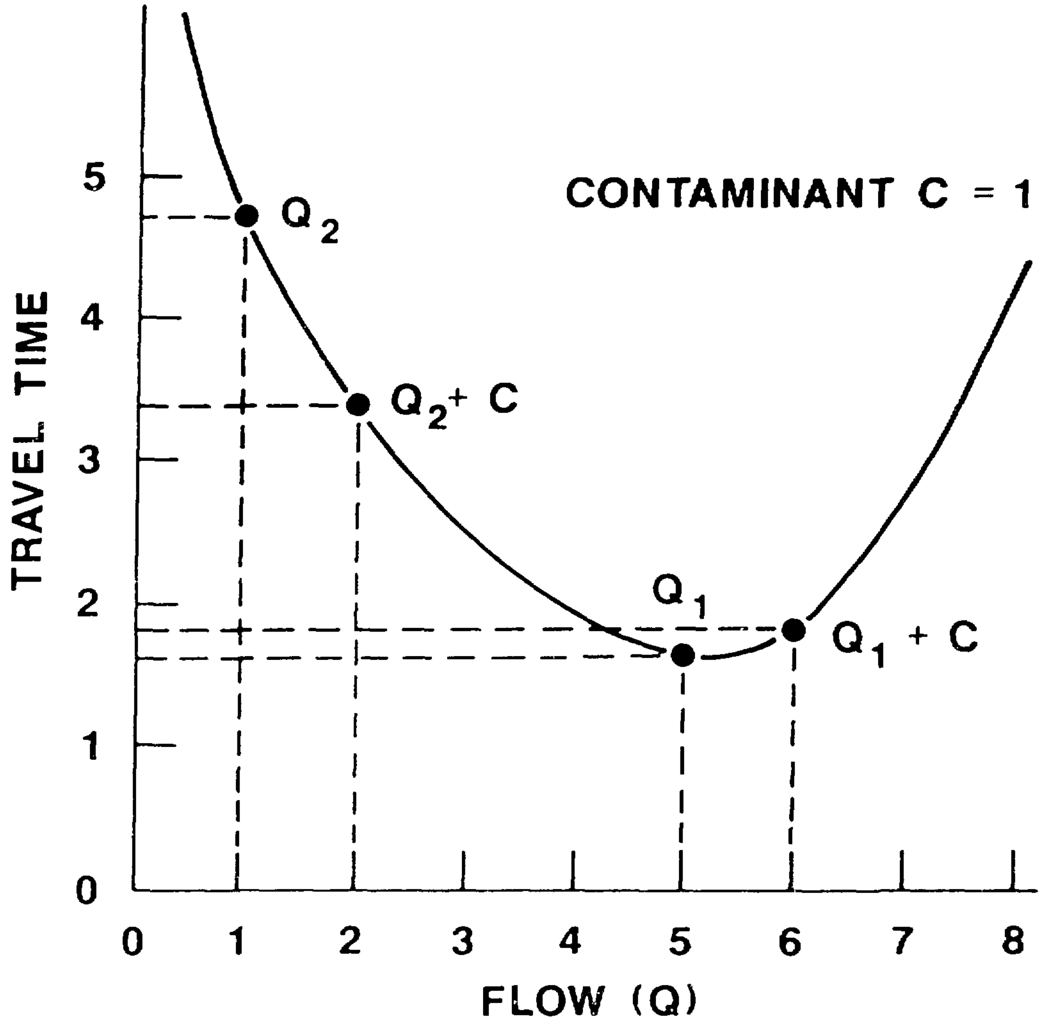
ROUTING REACH - TRAVEL TIME VERSUS FLOW RATE



$Q_1 = 5$ TRAVEL TIME = 1.6
$Q_1 + C = 6$ TRAVEL TIME = 1.8

$Q_2 = 1$ TRAVEL TIME = 4.6
$Q_2 + C = 2$ TRAVEL TIME = 3.3

Fig. 6. Stream Reach Time of Travel Versus Flow.

on the North and South banks of WOL about half the distance to the dam, and at WOD (Figure 7). This sampling was done to develop an understanding of flow paths, time of travel, and dispersion characteristics through WOL. The dye was also visually tracked and timed at various points to verify results.

Visual observation indicated that the dye reached the upper portion of the lake at about 1:15 p.m. Initially, the dye appeared to stay in a fairly concentrated plume as it traveled over the shallow sediment bar which extends through the upper reaches of the lake. As it reached the deeper water of the lake, which is warmer than the WOC water, the dye appeared to sink and disappear from sight. Upon returning to the lake on the morning of Sept. 15 (day 2), the dye had reappeared along the south bank and had followed a distinct flow path to the old dam outlet structure, and then along the face of the dam (northward along highway 95) to the new outlet structure. At the same time, waters along the north bank of the lake appeared to be relatively free of dye. However, by the morning of the 16th (day 3), the dye appeared to be evenly dispersed throughout the lower reaches of the lake.

From the time of injection, it took approximately 90 minutes for the leading edge of the plume to reach the headwaters of WOL and another 45 minutes for the peak concentration to be reached at this site. Measured peak to peak, travel time for this section of the creek is 2 hours and 15 minutes. A dilution factor of 2.9 was calculated between these two sites by comparing the peak of 4673 parts per billion (ppb) observed just below MS3 to the peak of 1613 ppb observed at the headwaters of the lake (Figure 8). From the time of injection, the leading edge of the dye plume (detectable concentrations) reached the dam in approximately 6 hours but less than 0.5 ppb of dye was recorded until approximately 12 hours after injection. The peak concentration measured at the dam was 22.5 ppb and was recorded 29 hours after the initial dye injection. Therefore, the time of travel through the lake is approximately 27 hours measured peak to peak under a low flow condition (Figure 9). A dilution of 72 times was calculated between the headwaters of the lake and the dam.

A second portion of the dye study is planned for further characterization of WOC above MS3. It will involve the injection of dye into WOC near the main plant area because this is the most likely area for an accidental release of contaminants to occur. Melton Branch (MB) will also be studied with dye tracer tests because of its effect on WOC and the possibility of a contaminant release from the High Flux Isotope Reactor (HFIR) located 0.95 miles upstream from WOC.

ORNL-DWG 66-9445

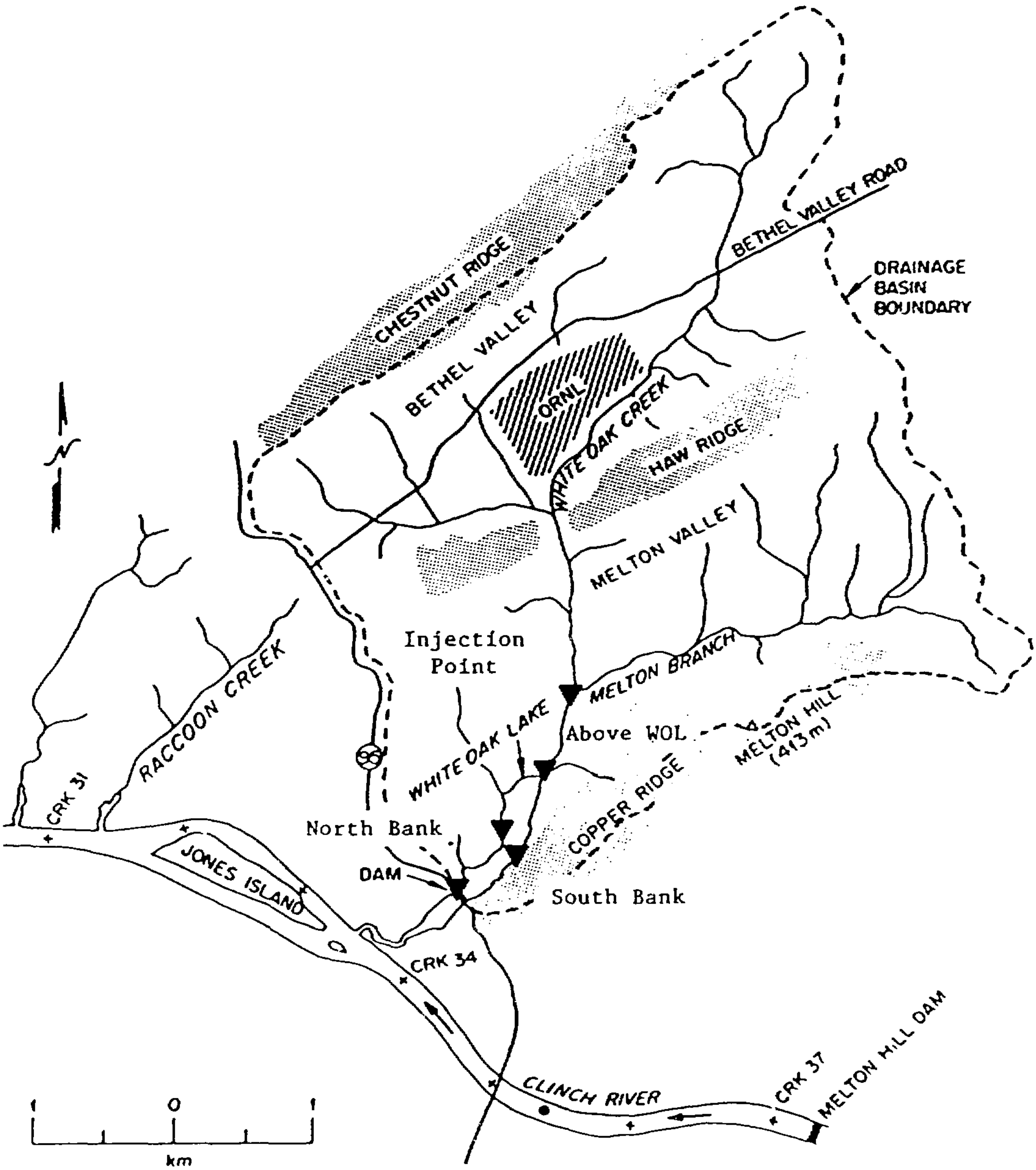


Figure 7. Location of automatic samplers during dye tracer study.

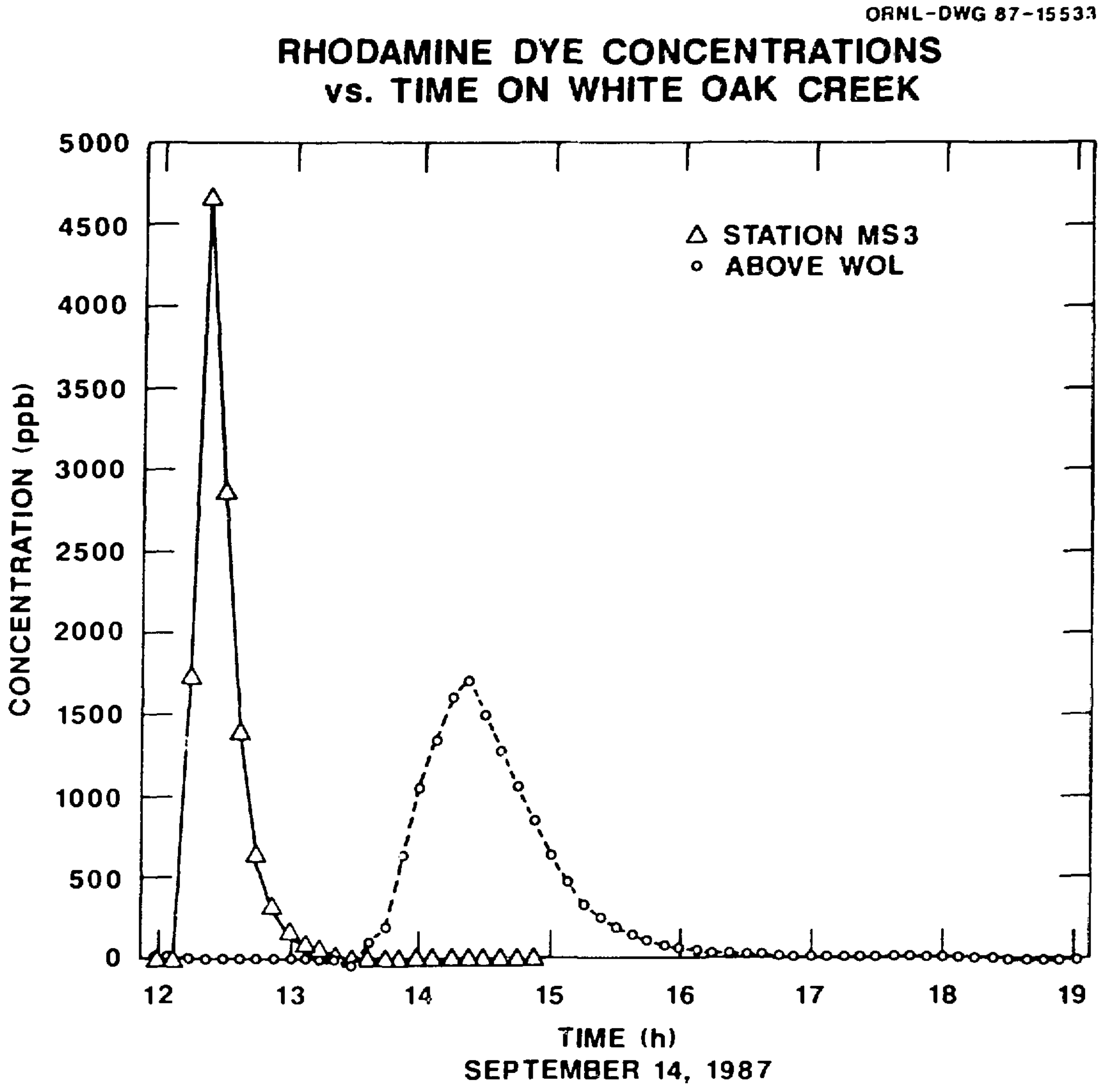


Fig. 8. Observed Rhodamine Concentrations in White Oak Creek.

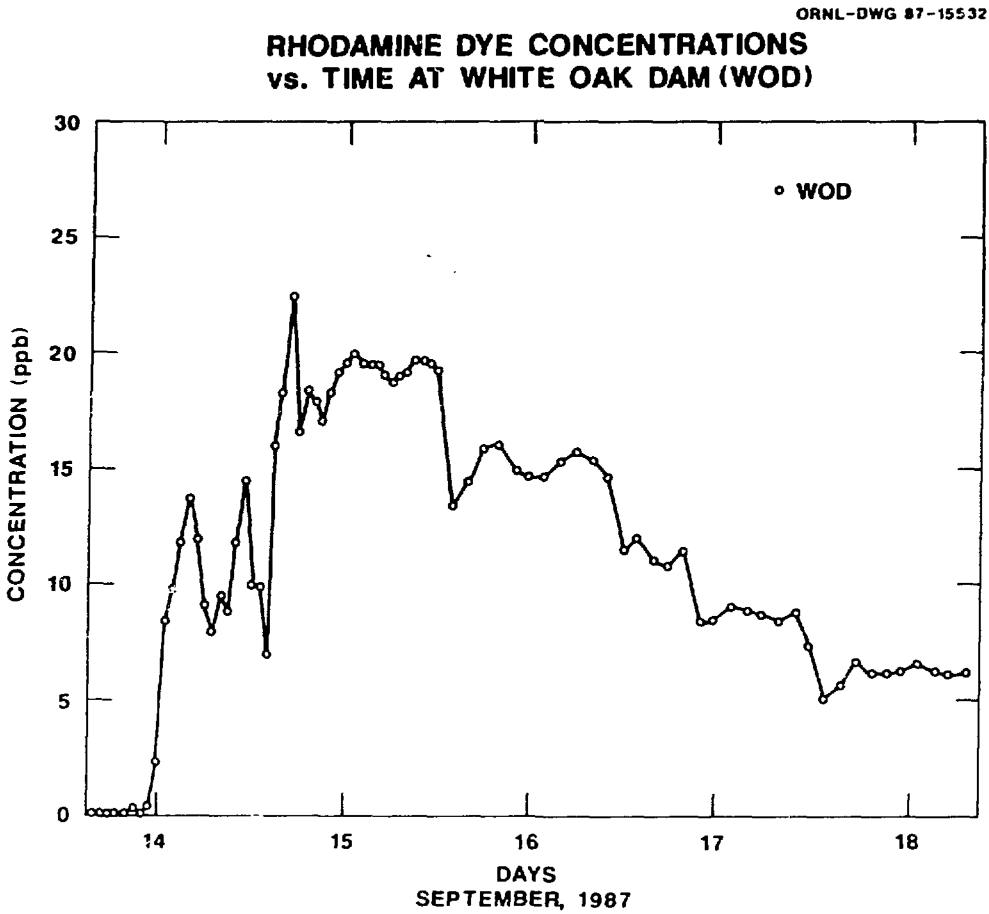


Fig. 9. Observed Rhodamine Concentrations at White Oak Dam.

ETHYLENE GLYCOL SPILL

Some useful information on the time of travel in WOC has been obtained from data collected during a spill of ethylene glycol which occurred on August 7, 1987 (Figure 10). Ethylene glycol, a coolant fluid, contains fluorescein dye to facilitate tracing in the event of a spill. Samplers were placed along the creek approximately 2 hours after the spill. However, the leading edge and peak of the spill had already passed the main plant area (spill site) and the 7500 Bridge water monitoring station in this interval. There were better results at MS3. Sample analyses at this location exhibit a well defined peak and recession of fluorescein dye concentrations. Additional data and information on the spill obtained by EMC staff should enable SSARR modelers to further characterize travel time and dispersion through the upper reaches of WOC for the conditions which existed during this event.

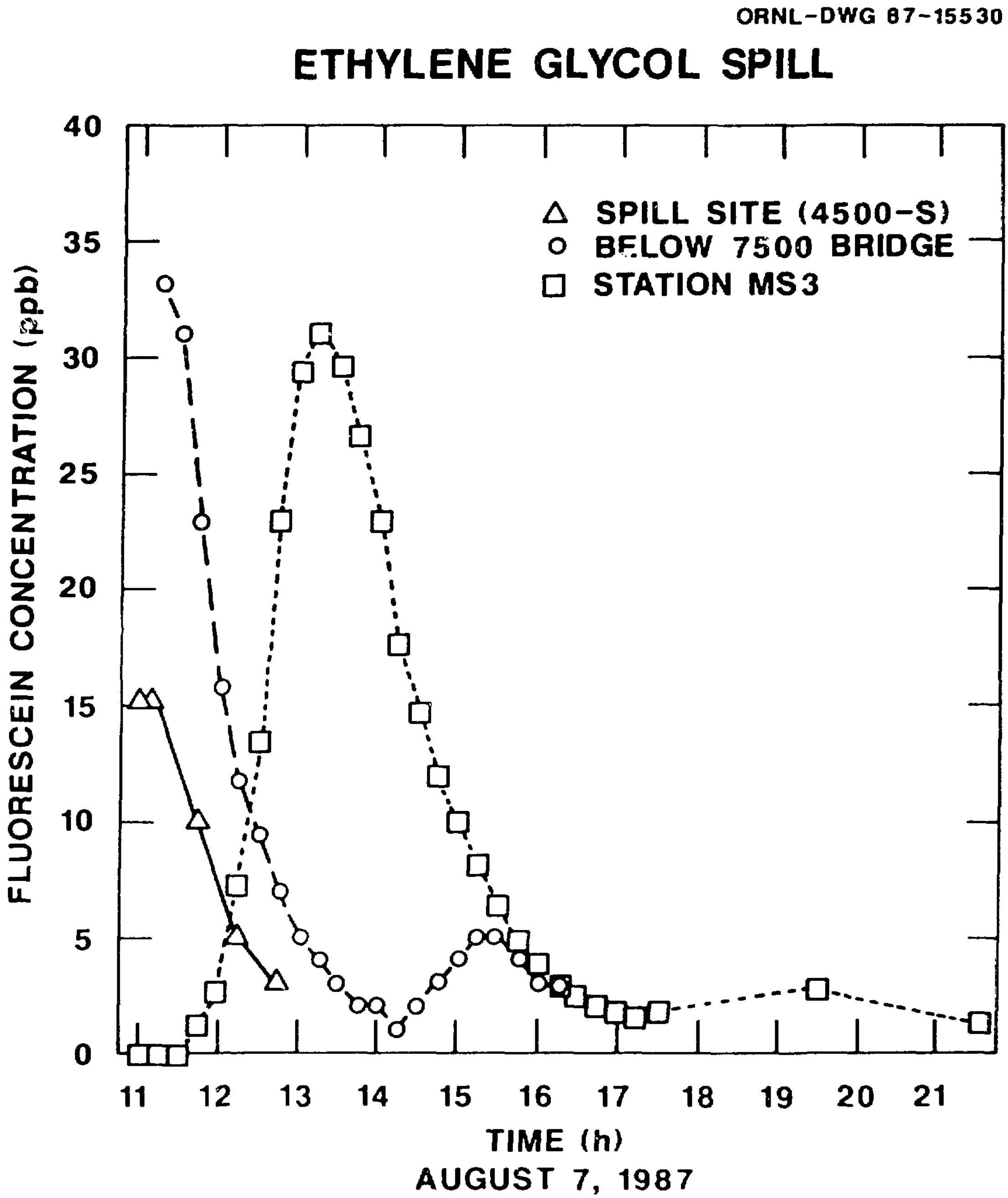


Fig. 10. Ethylene glycol spill data for August 7, 1987.

CONCLUSIONS

The most important and timely task for contaminant and discharge forecast modeling within the WOC watershed is the development and implementation of a method for representation of contaminant dispersion and travel through WOL as a function of WOC and MB flows (inflow to WOL) as well as the travel time from the main plant area to WOL through WOC. The first in a series of dye tracer studies has been performed to initiate this representation; however, experiments of this type must be performed under a variety of hydrologic conditions to properly calibrate the model for forecasting operations. In addition, procedures must be developed to characterize basin response to non-conservative contaminants and the effects of regulation on the fate of contaminants in the WOC system and downstream in the Clinch River.

The prospective future of the discharge forecast modeling project involves the establishment of a continuously operational model to achieve and maintain a high level of operational emergency response preparedness. Current goals include dynamic simulation of spills of conservative and non-conservative contaminants, the investigation of alternate operating rules for WOD, and the development of more refined data for improving model calibration. The model will also be utilized to generate response procedures for various types and magnitudes of emergency events. Using real-time flow data and a quantitative precipitation forecast, the SSARR model results can be combined with a dispersion model to predict expected contaminant concentrations at downstream locations.

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Chemical Transportation Emergency: A Case History

Presented by:

Patrick Touchard,

International Technology Corporation

CHEMICAL TRANSPORTATION EMERGENCY: A CASE HISTORY - Patrick Touchard, International Technology Corporation, Port Allen, Louisiana

International Technology (IT) Corporation, the nation's oldest and largest full service environmental management company, is under contract to numerous clients nationwide, who periodically require assistance when a given project exceeds that clients in house resources. One of the services supplied by IT, is that of emergency response, and recently a major transportation company requested our assistance.

Twenty-two cars of a regularly scheduled freight train derailed just after noon one Friday. Several cars of Carbon Black, Plastic Pellets, and Bulk Rubber were involved. Unfortunately, several bulk liquid tank cars spilled their contents, and three of them contained hazardous materials. Toluene Diisocyante - a DOT Poison B, Vinyl Acetate - a DOT flammable liquid, and 1,1,1 Trichloroethane - A DOT "Orm - A", were spilled. Twenty thousand gallons of TDI, eighteen thousand gallons of Vinyl Acetate, and eighteen thousand gallons of 1,1,1 Trichloroethane were estimated spilled. In addition, ten thousand gallons of Parrifin Wax , twenty thousand gallons of Rubber Extender, and quantaties of other non-hazardous liquids were spilled. Somewhere around ninety thousand gallons was the total of both regulated and non regulated liquids spilled.

Soil and water sampling commenced immediately upon arrival of IT personnel. A Civil Engineer, and a geologist from an IT field office were first to arrive, and they began a thorough site assessment. Air monitoring was begun, although limited to colormetric reagent crystal tubes, and flammable vapor detectors. However, by day three, a special IT air monitoring group was on scene. The sophisticated equipment used by this group has historically prevented client exposure to spurrious litigation by providing recorded analyses and effective documentation.

This group has the capability of continuous atmospheric monitoring with automatic recorded graphic results. Instrumentation of air sampling included: A flame Ionization organic vapor analyzer which is equipped with a gas chromatagraph mode for individual organic compounds; an infrared analyzer; and a photoelectric chemical tape data analyzer used in TDI detection. TDI was the primary health concern throughout the derailment.

The importance of the assessment phase of transportation emergency cannot be overstated. The "who, what, where, when, why, and how long" questions need to be answered, and continuously updated. Numbers are necessary to provide those answers, and data collection helps you obtain the numbers. Where to collect data is a function of the incident itself, and recording the location of data collection points is essential to accurately interpret data collected. Essential to the assessment is the generation accurate site maps, and this simple step is seldom credited with its true importance.

Arriving on site soon after the incident, the IT Engineer and geologist began their assessment of this incident by preparing a hand drawn sketch of the site. Obviously not to scale, relative locations still can be rather accurately recorded, and identification of specific topics of discussion can be graphically displayed. As time goes on, arial photographs, and detailed engineering maps can be obtained.

The numerous discussions which will ensue during an emergency, can be conducted in a logical fashion only if all the participant are able to visualize specific objects and locations relating to the incident. Accurate location of sampling points insures optimum contamination removal, minimizes expensive over excavation, and will prove invaluable for future reference. It is important to note that emergency remediation efforts will often remove or obliterate sample points, and much conflict can be avoided if previous data collection points can be precisely located in the future. In this incident, a thorough engineering study and risk assessment would be started some months after the departure of the last of the emergency response personnel. Detailed survey maps were therefore drawn up, using an engineering/survey team from IT.

For work to progress, a business orginization must be established. In many transportation incidents, the number of groups involved is staggering. The client, their contractors, the myraid of regulatory and governmental agencies, and the public must all be coordinated. At this emergency, the client chose to employ an oversight contractor who usually staffed the incident with one representative. It was their duty to coordinate the efforts of IT - the environmental contractor, the construction contractor (referred to by the client as the "emergency" or wrecking contractor), transportation contractor, and disposal contractors. In this case, IT subcontracted transportation for disposal of solids, and the client contracted the dispos.l itself directly. However, another contractor was responsible for liquids removal, and also sub-contracted for their disposal. If the oversight contractor method is chosen, it is crucial their duties be well defined. Not only must the work of several different companies be successfully choreographed, but cost accounting and compliance monitoring must also be accomplished.

Once an orginization is established, a flexible work plan can be set in motion. In transportation incidents, removal of the wreckage and removal of the contaminants may alternately preceed one another. In some cases they may proceed concurrently, and this was the case at this incident.

Debris from the accident was removed from the scene while liquids were constantly being pulled out. Environmental monitoring continued at a heightened pace, with an IT group of analytical specialists obtaining soil and water samples. Sampling protocol was determined by the specialists on consultation with the client and appropriate regulatory agencies. Samples were air freighted to an IT lab, and results telephoned to the site, with documentation following shortly. Expedient analytical results are extremely important for obvious reasons. Air monitoring was to continue on a twenty-four hour basis.

The removal of free liquids posed quite a problem. The derailment occurred over a natural ground depression which figured prominently in the local drainage pattern. The problems posed by the 90,000 gallons of spilled product was exacerbated by a four inch rainfall the night of the accident. An alert fire department chief recognized the potential harm that could have resulted from the spread of this material, and erected an earthen barrier which effectively contained all the material and run off, in an area to be designated as "East Pond". Although an environmentally sound decision, the trapped liquid would later greatly complicate excavation.

One of the more interesting aspects of this incident is the role played by the 10,000 gallons of spilled Parrafin. Usually transported as a heated liquid, this load of parrafin spread on top all other liquids present. When the parraffin cooled, it formed a crust as much as six inches thick, effectively preventing the evaporation of free standing liquids in east pond. A dichotemy resulted: on one hand, air emmissions were minimized creating a safer work environment. On the other hand, the large volume of water which was unable to evaporate would effectively increase the weight and volume of contaminated material to be disposed.

Excavation proved to be extremely complicated. Soil boring logs obtained from a nearby highway overpass construction project, indicated sandy soil to a 28 foot depth. It was feared that the spilled chemicals had already escaped into shallow aquifers, and further excavation could produce more paths for the contamination to enter. However, IT emergency response personel observed no decline of the liquid level in East Pond and decided to proceed with both liquid removal by vacuum truck, and excavation of soil for ulitmate disposal.

It proved exceedingly difficult for heavy equipment to move through the contamination in East Pond. Finally, a caterpiller 225 tracked excavator (whose operator had been instructed to carefully search for a clay layer) was found to be able to manuever through the soupy conditions. Within a few hours, a layer of firm clay was located at a depth of three feet. D-3 dozers were then able to assist by moving material toward the excavator, minimizing lost time repositioning the difficult to manuever excavator.

Contaminated soil was loaded into a series of dedicated twelve yard capacity dump trucks, and then driven to a preselected strech of roadway where it was placed on a sheet plastic liner. This derailment site happened to be adjacent to a four lane divided US Highway. The northbound traffic was routed on the southbound lanes by the police and highway departments early on in the incident, and remained so until departure of emergency response personnel, some five weeks later. This provided the construction contractor, and the entire operation, a most forunate stroke of good luck.

The hard roadway surface facilitated the movement of heavy equipment, and provided a unique volume reduction solution to the problem posed by the amount of liquids, mainly water, present in the excavated soil. The solution was suggested by the construction contractor, who throughout this incident was closely involved in all decisions, and who continuously provided excellent suggestions and cooperation. It was reasoned that construction equipment would have the easiest time on the hard surface, reducing turnaround and speeding up the entire process. A long stock pile of contaminated soil would be deposited on the roadway, increasing the surface area of the material and enhancing evaporation. Run off, if any, would flow back into an area already slated for excavation. IT proposed to lay the stockpile on a sheet plastic liner, and hydroblast the roadway after removal. Hopefully, these measures would prevent unacceptable levels of contamination on the road surface.

This proceedure worked exceptionally well. The continuous air monitoring verified emissions from the stockpile were at acceptable levels. The pile was covered at night in case of rain for the first few nights, but this was discontinued after a few nights to increase available evaporation time. Incidentally, only two periods of rainfall were experienced subsequent to the day of the incident. Less than an inch and one half total rain fell for nearly thirty-five days.

This dewatering process was very beneficial to the client, as the approved hazardous waste landfill would not accept any waste possessing free liquids. Had a solidifying agent been employed to absorb liquids, a significant increase in weight and volume, and therefore price, would have been experienced by the client.

Once the clay lens was discovered, it was determined that all visible contamination would be removed to the clay, and the excavation would be backfilled with a suitable material. Backfill was located very close to the sight, and a sandy clay was the material of choice. Clay was the material of choice as down migration of rainwater would be minimized, and run off would quickly drain to an unaffected area.

Examination of some of the transportation phase statistics helps reveal the magnitude of the project. Seven hundred-twelve trucks, averaging sixteen yards or twenty-two tons a load, were utilized. Over 11,000 cubic yards or 15,600 tons, of contaminated soil was disposed of. Each trip cost $447.60, and each ton cost $90 to dispose of, for a total of

$1,728,451.20 transportation/disposal cost for solids alone. The operation spanned thirty days, with work actually being performed on nineteen of those thirty days.

Thirty five days after the arrival of IT emergency response personnel, the last of them departed the scene. No matter what heroic efforts are expended during an emergency, seldom is contamination removed to non-existant levels. The engineering phase has been entered, and the "How Clean is Clean?" question will be debated. Only an exhaustive risk analysis can provide conclusions for future decisions. Soil borings and monitoring wells are now being drilled to determine how far, if at all, any contamination may be spreading. In the future, options ranging from doing nothing at all, or further excavation, or slurry wall and clay cap, or recovery wells, to a combination of several options, may be the course chosen. Right now of course, no one knows. What we all know is, these incidents are likely to occur again. Can we do more to lessen their impact when they do?

Integrated Risk/Decision Methodology for Hazardous Waste Management

Presented by:

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University of Texas at San Antonio

INTEGRATED RISK/DECISION METHODOLOGY FOR THE HAZARDOUS WASTE MANAGEMENT

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Arturo Riojas, P.E., Instructor
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ABSTRACT

Throughout the United States Hazardous Waste Management has become one of the most volatile issues in the United States. Risk assessment for Hazardous Waste Management is one of the most recent emerging tools in the engineering profession to respond to such public needs.

The objective of this paper is to present an integrated Risk/Decision methodology to systematically analyze the alternative courses of actions for the management of hazardous waste disposal sites. The probabilistic nature of all the potential events has been depicted in a sequence of event trees based on the detailed description of the logic and potential consequences. Following the description of the event trees, a comprehensive fault tree analysis is adopted to estimate potential risks objectively for all managerial actions. Based on the probability values assessed for each of the potential risks, a detailed analysis of its risk acceptability is made based on the review preference values derived from historical or existing risk data. Multi-attribute utility functions have been applied for final Decision Analysis. The classifications of each of the risks confronted by hazardous waste management has been anatomically analyzed. Real-world examples of actual hazardous waste site management have been developed as

illustrative cases for the application of this integrated risk/decision assessment methodology.

INTEGRATED RISK/DECISION METHODOLOGY FOR HAZARDOUS WASTE MANAGEMENT

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INTRODUCTION

Hazardous Waste Management has become one of the most volatile issues in the United States. Risk assessment is emerging as an invaluable tool in the engineering profession, incorporating public concern in the decision-making process for sound management of hazardous wastes. The integrated risk/decision methodology presented herein is a systematic approach for the analysis and evaluation of alternative courses of action in the management of hazardous waste.

Risk assessment consists of two major analytical steps: 1) risk estimation based on the systematic evaluation of probability values associated with events having negative consequences, and 2) risk acceptability analysis based on the quantitative revealed preference method (6).

Contamination of groundwater with hazardous materials has become a focal point for public concern. Thus, a comprehensive example involving the contamination of a aquifer which is the sole source of water supply for a major metropolis is used to illustrate the risk assessment procedure. To demonstrate the flexibility and versatility of the integrated risk/decision methodology, the Danny Farm problem is also developed.

PERSPECTIVES OF RISK ASSESSMENTS

Risk assessment is the determination of probability values associated with the negative consequences or adverse events in terms of the impacts to the public, while the performance or completion of specific activity is being attempted.

In recent years, the science of risk assessment has made significant advances. Many formal analytical methods have been proposed and developed for the quantification of risk assessment. The integrated method incorporates the strength of formal analysis in risk estimation, the perceptive clarity for risk acceptability analysis, and the flexible framework of multi-attribute decision analysis. In the risk estimation process, the event tree and the fault tree methods have been adapted to provide a systematic depiction and detailed computation for probability estimation of all failure events. In risk acceptability analysis, the revealed preference method proposed by Rowe (6) has been used in comparative analysis.

RISK ESTIMATION

The risk estimation process begins with a detailed description of the risk pathways. It should be noted that a risk can be modeled as a series of events. As indicated in Fig. 1, the events that occur in this path are hazard, outcome, exposure and consequence. In the meantime, one of the unique characteristics of all the events associated with the risks are "rare" events. This means that a data base of statistic occurrence frequency is limited or nonexistent and the probability of occurrence is on the order of 10^{-6} or smaller. Furthermore, risk estimation is complicated by the lack of data for either the exposure or the consequences associated with the pathways of risk formation.

Hazard -->	Outcome -->	Exposure -->	Consequence
Industrial Development inside recharge zone	Waste discharge	Pollution to aquifer	Injury to public

Figure 1. An example of events in a risk pathway.

To determine the probability for a specific adverse event, all the conditional probabilities along the specific risk pathway must be known. However, as indicated earlier, in many cases, there may be little or no historical data available which can be utilized to estimate these probability values. Considering the potential sensitivity of the risk estimation, the completeness of the information defining pathways for specific risks has also created added perceptive confusions for a complicated risk situation.

To address this problem, special efforts involving both technical experts and community-based citizen groups must be orchestrated, providing the needed consensus for some of the subjective judgments required for the quantification of all conditional events. It is apparent that a suitable analytical methodology for risk estimation must be:

a) A means of providing detailed estimates of risk probability or conditional probabilities for all the risk events,

b) A procedure to facilitate systematic thinking,

c) A process which allows the incorporation of inputs from multiple individuals and disciplines,

d) A framework for easy review and modification of special considerations for specific events.

Thus, the selected risk estimation method must be a quantitative tool which is both structured and flexible, while maintaining reasonably stringent standards of documentation.

A continuum of methods has been reviewed, ranging from totally informal and undocumented intuitive approaches to vigorous statistic modeling. The coupling of event tree analysis with fault tree analysis can provide powerful, yet flexible procedures for detailed risk estimation.(1,8,9).

EVENT TREE ANALYSIS

Event trees are used to provide a systematic logic tracing of sequential events that are normally involved in a specific risk formation.(9) Stemming from an initial event, all failures or malfunctions of system components related to hazardous waste management are documented clearly and thoroughly. In this paper, groundwater protection is used as an illustrative example for both risk estimation and risk acceptability analysis. The specification of type and amount of urban development permitted (i.e., land use policy) inside the recharge zone is a critical event in groundwater protection, and is portrayed as the initiating event in the example that follows. A systematic event tree is then constructed to depict a set of possible events associated with the subsequent contamination of an aquifer and potable water supply.

Fig. 2 shows the general structure of an event tree. Each circled letter or node represents an event. An event may appear in single branch, or it may be common to two or more branches. When it is common to several branches, the details and consequences of the event depend on previous events in that branch. Each event has two possible outcomes: one with favorable or desired consequences (designated by a letter followed by a zero), and the other (designated by a letter followed by a one) with negative or generally unwanted connotations. However, the exact consequence of the negative branch may depend on the circumstances responsible for the negative outcome at the node. To illustrate this fact consider the following event: a boy attempts to cross the street. The successful or desired consequence is that the boy reaches the other side of the street unharmed. The unwanted possibilities which will keep the boy from reaching the other side of the street include but are not limited to: 1) the boy falls down, scrapes his knee, 2) the boy is abducted by a man in a passing car, and 3) the boy is struck by a car. The consequences of the boy not crossing the street successfully in this example could be 1) the boy returns home crying, 2) the parents receive a ransom letter, and 3) the boy is rushed to the hospital, respectively. Thus while Fig. 2 shows only two possible paths emanating from each node (e.g. A0 and A1), the negative path could be subdivided into several paths (e.g., A1a, A1b, and A1c), depending on what caused the failure or negative consequence.

Fig. 3 depicts a single branch of an event tree relating the likelihood of the contamination of an aquifer and a potable water supply to a series of events. In this example, positive results of an event are those results that are least likely to cause or completely preclude the possibility of groundwater contamination, and negative results are those which have significant likelihood of contributing to the pollution of the aquifer. Thus, while flaws in a design might ordinarily relate to the operating efficiency or reliability of a piece of equipment, in the context

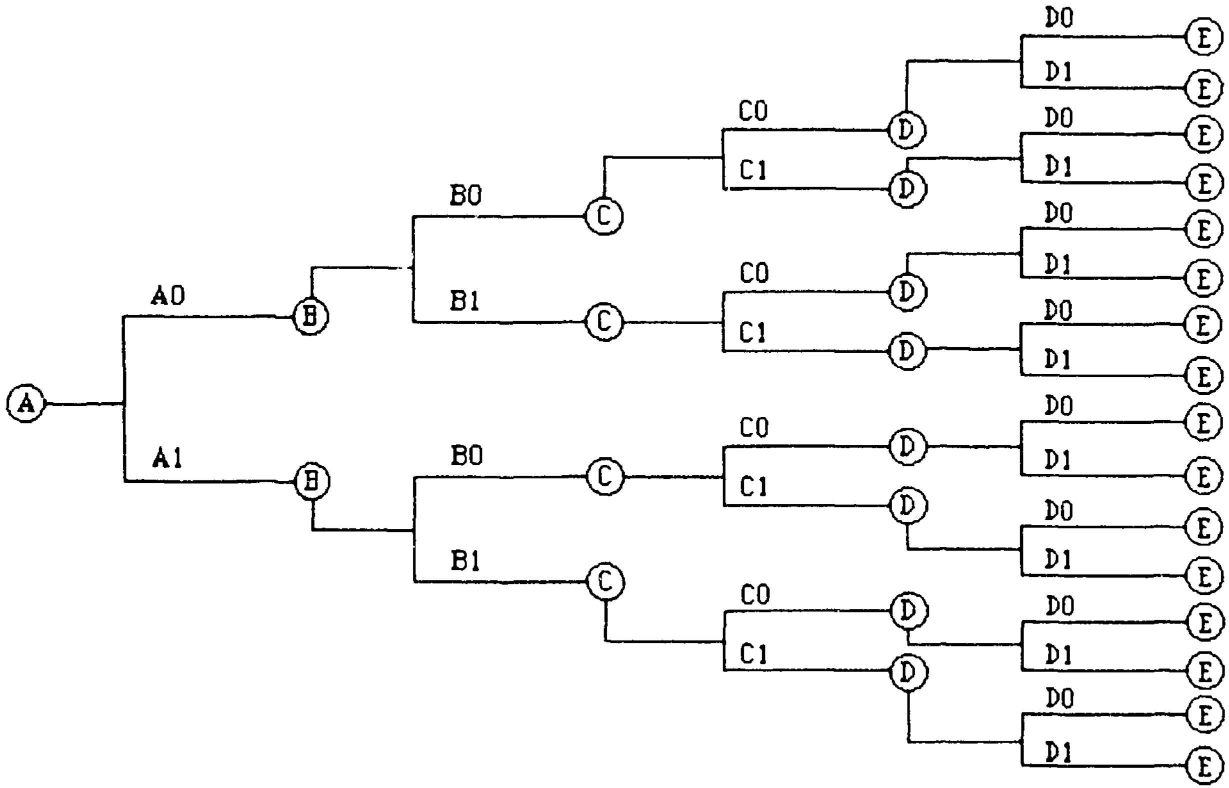


Figure 2 Generalized Event Tree (Events A Through E)

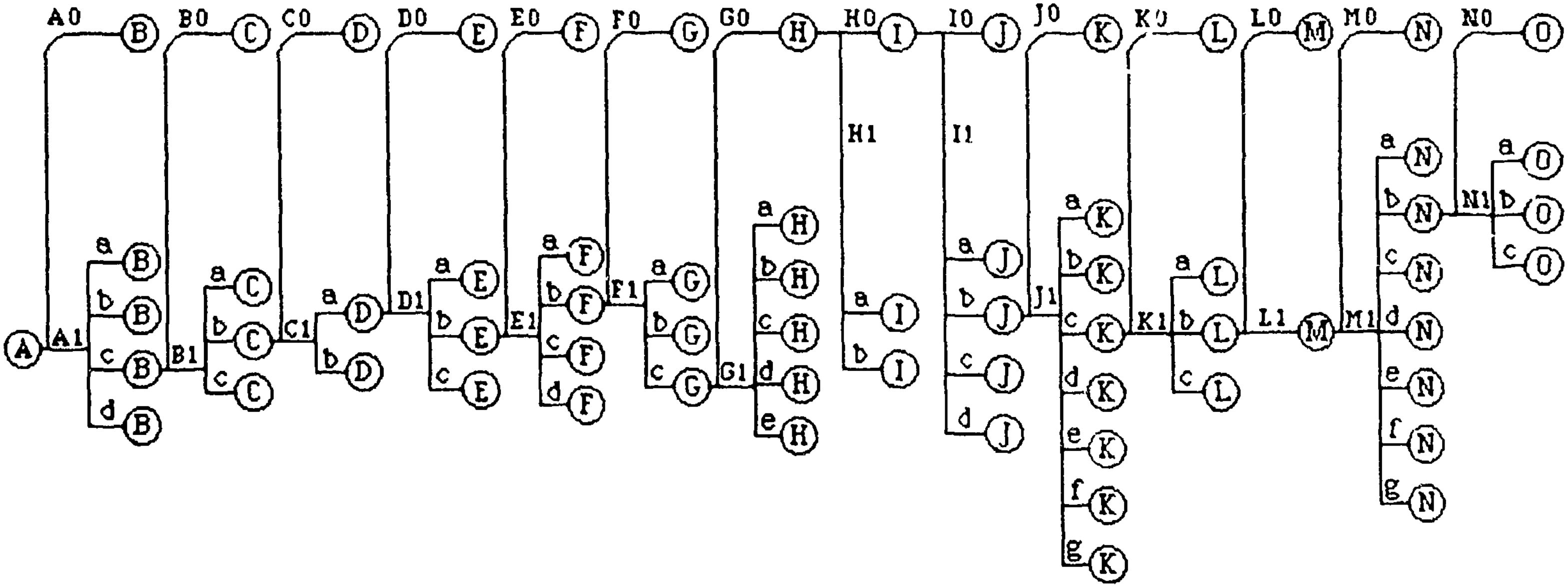


Figure 3 Single branch of an event tree for groundwater contamination example.

of this analysis, a design flaw refers to its potential for causing groundwater pollution. Events that may appear very different are given the same designation (e.g., the design of a house, following path A1 compared to the design of a refinery, following path A4), but they are similar in nature and differ only in detail and objective (i.e., both involve design). Table 1 contains a list of events and represents an event tree developed to help assess the risk of groundwater and water supply contamination due to hazardous materials. The events that were selected and used in the example have an asterisk next to them.

The first event (A) that will be considered is the making of policy. A multitude of alternative results can evolve from this process, but only the following five will be considered:

A0 -- allow no development (essentially making the recharge zone a protected watershed).

A1 -- allow only construction of homes and minor roads to access them. Septic systems would be allowed.

A2 -- same as A1 plus limited amenities (e.g. larger roads, shopping malls and supermarkets, but no gasoline stations, dry cleaners, or other facilities that would deal with significant quantities of hazardous materials).

A3 -- same as A2, but including more amenities (e.g., gasoline stations, dry cleaners).

A4 -- no restrictions (this would allow the construction of major highways, chemical plants, transport of hazardous materials by truck, rail, or pipeline, etc.).

Acts of man will influence the likelihood of groundwater contamination in each of the development schemes prescribed in A1a - A1d. In each development scheme, the design of facilities (event B), the fabrication and installation of facilities (event C), the training and educating of operating and maintenance personnel (event D), the maintenance of facilities (event E), and the operation of facilities (event F) will follow. Some of these events may occur simultaneously, but for different facilities. For example, the design and construction places may be complete and the operation and maintenance phases in progress for a home, before the design phase for a shopping mall is complete. Fig. 2 does not include this possibility and treats all facilities as being in the same phase for the same period of time. As the number of the various facilities prescribed in A increases, so do the complexity of the development and the degree of interaction between facilities. Those interactions will not be considered in this analysis.

The possibility of success and failure exists at each step in the development process (events B - F). Only the path consisting of all successful steps or events will result in development over the aquifer recharge zone without the spill of hazardous materials or precursors. There are generally many ways that a step can fail. For instance, a faulty design can evolve due to any of the following reasons, just to name a few: incorrect specifications (B1a), inexperienced engineers and inadequate review (B1b), computational error (B1c). Fig. 2 includes only a

Table 1

LIST OF EVENTS

	A	Policy decision is made (e.g., zoning)
	A0	Decision to allow no development
	A1	Decision in favor of development
	A1a	Domestic
	A1b	Domestic plus limited amenities
*	A1c	Domestic plus extensive amenities
	A1d	No restrictions
	B	Facilities are designed
	B0	Successful design
	B1	Flawed design
	B1a	Incorrect specifications
*	B1b	Inexperienced engineers and inadequate review
	B1c	Computational error
	C	Facilities are fabricated and installed
	C0	Successful fabrication and installation
	C1	Faulty fabrication/installation
*	C1a	Use of improper materials or materials of incorrect size (e.g., thickness)
	C1b	Improper assembly, improper hook-up, or inadequate cleanup
	D	Personnel are trained and educated
	D0	Training and education are adequate
	D1	Training and education are inadequate
	D1a	Inadequate training about the product and its properties
*	D1b	Inadequate emergency procedure and safety training
	D1c	Inadequate "hands-on" experience
	E	Maintenance of facilities proceeds
	E0	Maintenance is adequate
	E1	Maintenance is inadequate
	E1a	Poor supervision
*	E1b	Insufficient personnel
	E1c	Inadequate tools
	E1d	Inadequate cleanup
	F	Operation of facilities proceeds
	F0	Operation proceeds as designed
	F1	Operation does not meet design expectations
	F1a	Poor supervision
	F1b	Insufficient personnel
*	F1c	Inadequate technical support, supplies and equipment
	G	Acts of God occur
*	G0	Good weather
	G1	Bad weather
	G1a	Floods
	G1b	Earthquakes/tidal waves
	G1c	Thunderstorms/windstorms/tornados/hurricanes
	G1d	Cold fronts/ice storms/blizzards
	G1e	Droughts/brush fires
	H	Malicious destruction attempted
*	H0	Attempt fails (effective security)
	H1	Destructive event occurs
	H1a	Arson
	H1b	Sabatoge

I Hazardous material(s) or precursor(s) are spilled
I0 Immediate and complete containment of spilled material
I1 Incomplete containment of spilled material
I1a Slow, observable leak
* I1b Slow, non-observable leak (e.g., LUST)
I1c Sudden, relatively small spill
I1d Sudden, massive spill
J Spilled material is cleaned up
J0 Complete cleanup
J1 Incomplete removal
J1a Leave surface contaminants
J1b Leave soluble contaminants
* J1c Leave adsorbed contaminants
J1d Leave surface and soluble contaminants
J1e Leave surface and adsorbed contaminants
J1f Leave soluble and adsorbed contaminants
J1g Leave some of all contaminants
K Pollutant interacts with aquifer material
K0 Complete removal of pollutants in aquifer
K1 Incomplete or no removal of pollutants in aquifer
K1a Retardation
* K1b Transformation
K1c Dispersion
L Contaminated water travels in aquifer
L0 Contaminant plume bypasses well
* L1 Contaminant plume reaches well
M Water is treated for removal of contaminants
M0 All contaminants are removed by treatment
M1 Not all contaminants are removed by treatment
M1a Volatile (light) organics remain
* M1b Heavy organics remain
M1c Heavy metals remain
M1d Volatile and heavy organics remain
M1e Volatile organics and heavy metals remain
M1f Heavy organics and heavy metals remain
M1g Volatile and heavy organics and heavy metals remain
N Water is prepared for use in potable water system
N0 All contaminants are removed by final treatment
N1 Some contaminants remain in water after final treatment
N1a Water receives no additional treatment
* N1b Water is chlorinated as final treatment
N1c Water is ozonated as final treatment
O Water is pumped into potable water system
O0 Potable water system is not contaminated
O1 Potable water system is contaminated

* Indicates branch of event tree taken in groundwater contamination example.

few of the many possibilities for failure at each step. Although maintenance and operation are given as events E and F, respectively, periodic maintenance during the operation phase or between distinct operation phases is normally required, and it is not at single event which precedes the operation phase as indicated in Fig. 2.

Other events known as "acts of God" or "acts of Nature" (event G), or malicious acts of men (event H) can happen at any time during the development over the aquifer recharge zone or after its completion, but they are generally of consequence only after the operation phase has been reached.

There is a multitude of paths leading to the spill of a hazardous material (event I), and a vast variety of types of hazardous materials that could be spilled. The spilled material may be completely contained (path I0), or completely cleaned up (path J0), resulting in no groundwater contamination. On the other hand, slow but continuous leakage of hazardous material could go undetected, for example, from a leaking underground storage tank (LUST) at a gasoline station or a leaking underground pipeline which crosses the recharge zone (path I1b), resulting in little or no cleanup of the material (path J1c) until after the hazardous material is detected at the well head where water is being pumped from the ground. Another example of a situation where little or no cleanup may be possible is that of a spill over a sensitive area of the recharge zone of a limestone aquifer. In this case, there is rapid communication between the surface and the groundwater due to solution channels in the limestone, and there would not be sufficient time to attempt a cleanup before the hazardous material had reached the groundwater in the aquifer. In the example presented, only three types of contaminants (or precursors) will be considered: volatile organics, heavy organics, and heavy metals. Some hazardous materials, for example, leaded gasoline, may contain all three. Furthermore, only point sources of contamination are included in the example. Thus, neither nitrate contamination of the aquifer, which might cause methemoglobinemia (blue babies), nor pesticide contamination of the aquifer, is included in this analysis since those pollutants would neither emanate from point sources nor would they be included in the list of contaminants being considered. Both contaminants might be expected in an area having heavy agricultural activity. This aspect of potential groundwater contamination will be addressed in a separate research effort.

Once a hazardous material has reached the aquifer or the soils of the recharge zone, the impact of the hazardous material on the groundwater may be mitigated by natural processes which would remove, transform, or disperse the hazardous material, or retard its transport in the groundwater. These interactions between the aquifer and the hazardous material (event K) depends on the specific nature of the hazardous material, the type and condition of the aquifer, as well as conditions which may vary with the time of the year during which the spill occurs (e.g. temperature, water level in the aquifer). An aquifer is, thus, considered to have some water purification capabilities, but one or more of the natural processes described below is always responsible for the apparent purification.

Removal of contaminants from water can be accomplished by one or more of the following mechanisms. Volatilization involves mass transfer from the liquid phase to the gas phase, and would, therefore, be likely to occur in the soils of the recharge zone or in the unsaturated portion of the aquifer. In this case, the water pollution problem is transformed into an air pollution problem, where the pollutant(s) emerge from the soil and enter the atmosphere. Removal of contaminants can proceed through mineralization (complete biodegradation, yielding products such as carbon dioxide and water). The products of the contaminant mineralization volatilize and are released to the atmosphere, dissolve into the water, are adsorbed by the aquifer material, or are assimilated by living organisms in the aquifer and soils of the recharge zone. Adsorption of contaminants onto the aquifer material often facilitates biodegradation by concentrating and immobilizing the contaminants for bacterial utilization.

Some soil and aquifer bacteria are capable of minieralizing contaminants. However, prevailing conditions may not favor the complete biodegradation of a contaminant, resulting in the transformation of one pollutant into another (e.g., degradation that is obtained depends upon many factors including the type of bacteria present in the aquifer and soils, type and oxidation state of the hazardous contaminants, type of aquifer material, pH of the groundwater, presence of other dissolved materials, and oxidation potential of the system. In the case of groundwater contamination by highly chlorinated (and, therefore, highly oxidized) solvents, for example, reducing conditions would favor a more rapid degradation than would oxidizing conditions, and even under the best of conditions, it is likely that intermediate degradation products (i.e., other solvent molecules having fewer chlorine atoms per molecule) will be introduced into the water. These by-products may be more volatile than were the original contaminants, increasing the likelihood of volatilization. On the other hand, the by-products could be more toxic than the original contaminants.

Retardation of contaminant transport can result from a variety of combinations of physical, chemical and biological processes. The most likely combination is adsorption and desorption, where a contaminant adsorbs onto a surface only to desorb a short while later when equilibrium conditions favor its release into the surrounding water. For some contaminants, such as heavy metals, precipitation and dissolution can cause a similar phenomenon, as can biological assimilation followed by death and decay. In each the first process in the pair immobilizes the contaminant, but the possibility of its release is present as conditions change or with the passing of time.

Dispersion and convection of contaminants in an aquifer are not only likely, but almost unavoidable. The convective transport of contaminants means that groundwater users can be affected by a hazardous material spill many miles away because of the flow path of the groundwater. The dispersion of the contaminants means that although the pollutant concentration may decrease as the water proceeds downstream, the affected area increases as the contaminant plume fans out.

The travel of a contaminant plume (event L) depends greatly on aquifer type. Flow in an aquifer is general horizontal. For a conservative contaminant (one which does not adsorb onto the aquifer material and is not susceptible to biological degradation or chemical reaction) emanating from a point source, its transport in the aquifer is governed by the subterranean water flow. It is subject to dispersion as it flows in the porous medium, making its concentration vary with both time and location. In an aquifer having uniform porosity, the flow of the pollutant can be envisioned as an expanding pie wedge with the highest pollutant concentration the source (the point of the wedge). The concentration decreases as you move toward the leading edge of the traveling wedge. There is also variation along the circumference of the circle of which the wedge is a part, with the concentration decreasing as you move away from the center of the traveling front of the plume. A well may show no sign of contamination by hazardous materials in a highly polluted aquifer if it remains outside the pie wedge, or slight contamination if it is near one of the outside edges of the wedge. However, seasonal changes are usually accompanied by changes in water inventory, flow rates, and flow paths within the aquifer, and increases in pumping rates draw contaminant plumes toward active wells. This means, for example, that a contamination problem from a LUST that is detected at the well and identified as a minor contamination problem during the rainy season when pumping rates are low may cause great concern in the dry season when both the pollutant concentration and pumping rates are higher. In any case, contamination of the aquifer will be a problem for users who pump from the aquifer downstream from the point of introduction of the pollutant and within the expanding wedge of polluted aquifer. The situation is much more complex in an aquifer which is not made of a uniformly porous material, with plume definition and spreading being ill-defined.

If an aquifer is contaminated (event M), and the contaminants cannot readily be removed or contained, treatment of the water will be required before use in a potable water system. The kinds of unit operations that would be needed to purify the water depend on factors such as pollutant concentration in the feed water, required effluent concentration, type of pollutant, temperature, waste disposal capabilities. A sequence of water treatment processes may be needed in order to meet water quality requirements. Treatment processes such as flocculation/coagulation followed by sedimentation, air stripping, activated carbon adsorption, and reverse osmosis could be used to remove different contaminants. Of course, the cost of the design, construction, maintenance, and operation of these facilities would be added to the costs associated with supplying water to the potable water system prior to the contamination. These prior costs are probably related to the running of a pump and injection of a little chlorine for most potable systems supplied by groundwater.

A hazardous material may be found in a potable water system, even if there has been no spill of that material nearby. Incomplete removal of contaminants (event N) from groundwater prior to the final treatment (usually chlorination) can result in the generation of hazardous materials. For example, seepage from a septic system could lead to the introduction of some innocuous organics (hazardous material precursors) into the groundwater. The subsequent chlorination of that groudnwater would produce trace levels of chlorinated organics such as chloroform, methylene chloride, and others, many of which are carcinogenic. This would be a situation where groundwater contamination goes undetected (and, therefore, untreated). Another example would be when the treatment processes that are installed to treat a contaminated groundwater source are not performing as designed (e.g. an activated carbon bed is exhausted and begins to allow organics to pass through).

FAULT TREE ANALYSIS

Fault tree analysis is a technique used to determine the failure sequences and the probabilities associated with a complex problem (7). It may be used by itself or in conjunction with a causal network. However, it is simpler when used in conjunction with event tree analysis. In constructing a fault tree, the following basic rules have evolved:

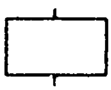
1) Write the statements that are entered in event boxes as faults by stating the nature of the fault and when it would precisely occur,

2) If the functions of a component are to propagate a fault sequence, then the component is a transitional event,

3) All inputs to a particular gate should be completely defined before further analysis of any one of the inputs is undertaken, and

4) Gate inputs should be properly defined. The fault events and the gates should not be directly connected to other gates.

Accordingly, for the fault tree in the groundwater protection example, the contamination of the aquifer is designated as the "top event". Tracing backwards, all failures documenting the event trees are sub-events. The symbols for fault trees are unique but fairly common to engineers. As shown in Fig. 4 to basic symbols utilized in the fault tree are described in detail. All the symbols can be readily classified into three groups,

SYMBOL	DESCRIPTION
	And gate: logic operation that requires the existance of all the input events to produce an output event.
	Priority and gate: logic operation that requires the occurance of all of the input events in a specific sequence to produce an output event.
	Or gate: logic operation that requires the existence of only one input events to produce an output event.
	Exclusive or gate: logical operation that requires the existance of exactly one input event to produce an output event.
	Event that requires no additional development.
	Event resulting from a combination of events through the input of a logic gate. A rectangle is also used as a label when placed next to or below a group of events.
	An event that could be developed further, but it is not deemed necessary to do so.
	Transfer in: branch is developed at the corresponding transfer out.
	Transfer out: branch development to be attached at the corresponding transfer in.

Bottom numbers in event symbols indicate paths from event tree.

Figure 4. Legend for fault tree.

1) event symbols--indicate the existence of an event and its status,

2) gate symbols--indicate the logic relationship between input and output events, and

3) transfer symbols--mechanisms uniting multiple sections or pages.

Using these building blocks, the fault tree for groundwater contamination is presented in Figs. 5-7. The actual construction of a fault tree is a straight forward and simple procedure. With the aid the event tree as shown in Fig. 2, the fault tree is readily developed. There isno requirement of a one-to-one correspondence between events in the event tree and entries in the fault tree. However, the logic statements accompanying the fault tree entries should provide for all events to be considered.

In Fig. 2, development over the recharge zone is treated as a single product of policy decision, and the events that are considered are treated as sequential events. The fault tree presented in Figs. 5,6, and 7, evolved from the selected events in Fig. 2, and includes logic to demonstrate that simultaneous conditions or individual members of a group of similar conditions must sometimes be met in order for events to lead to the undesirable end. Fig. 4 contains a legend which defines the symbols used in the fault tree and explains the mathematical operations associated with the different logic gates. The fault tree is developed by working backwards from the event selected in the event tree, with the undesirable end in the event tree being the top event in the fault tree. Fig. 5 shows that in order to contaminate a potable water system which receives water from an aquifer, three conditions must be met simultaneously: 1) a contaminant plume must reach the well, 2) the efforts (if any) to remove the pollutant from the water before introducing the water into the potable water system must be unsuccessful, and 3) the treatment that was being used as a final treatment before the aquifer was contaminated must fail to remove all the contaminants that slip past the equipment specifically installed to remove them in condition 2 above. Events and paths from the event tree can be used readily to show the development of conditions 2 and 3. Additional development of these branches (e.g. what caused the pollutant-removal equipment to fail) is possible, but it is not necessary for the evolution of the main branch of the tree leading back to the original event, the recharge zone development policy decision. Branch 1 does lead back to the original event and is shown in Figs. 6 and 7. In order for the contaminant plume to reach the well, first, there has to be a source of contamination, and second, interactions between the pollutant and the aquifer must not result in removal of the pollutant. The contaminant and the aquifer can interact in many ways, involving one or more classes of processes, as illustrated in the top part of Fig. 6. The bottom portion shows that the source of

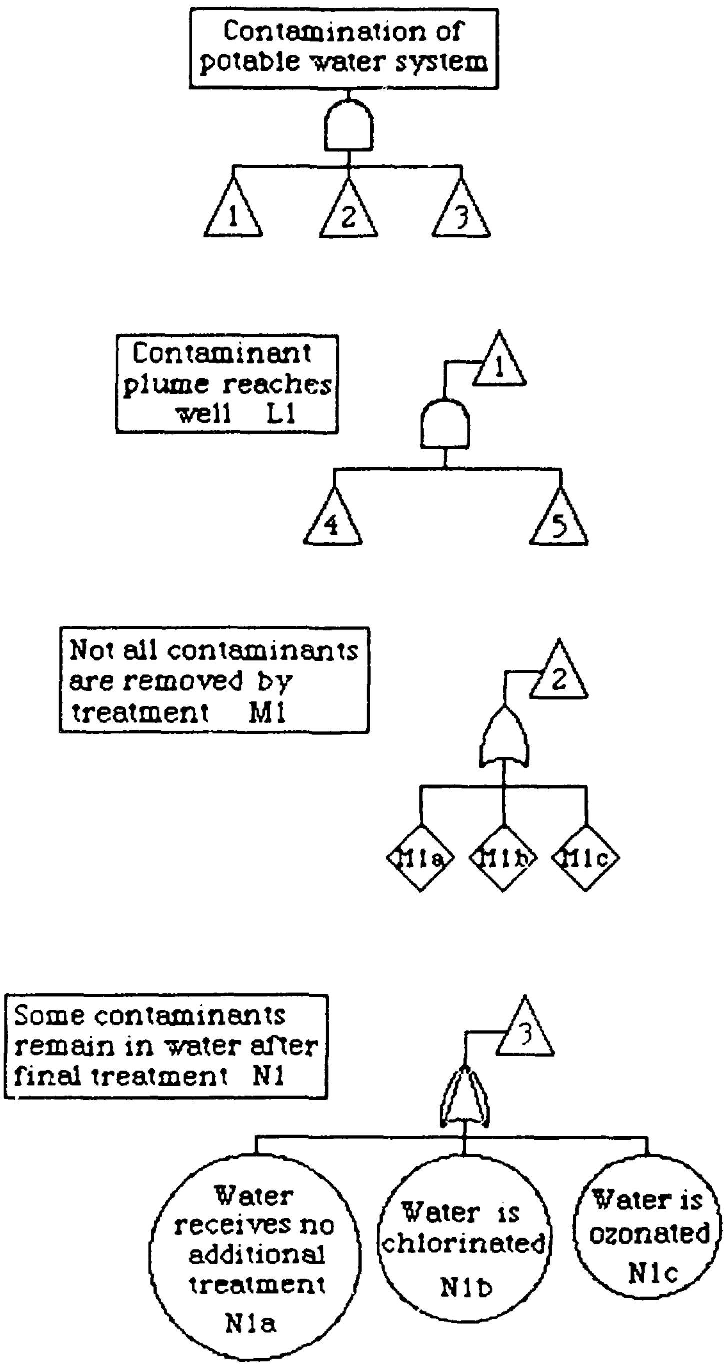


Figure 5. Fault tree for groundwater contamination example, part I.

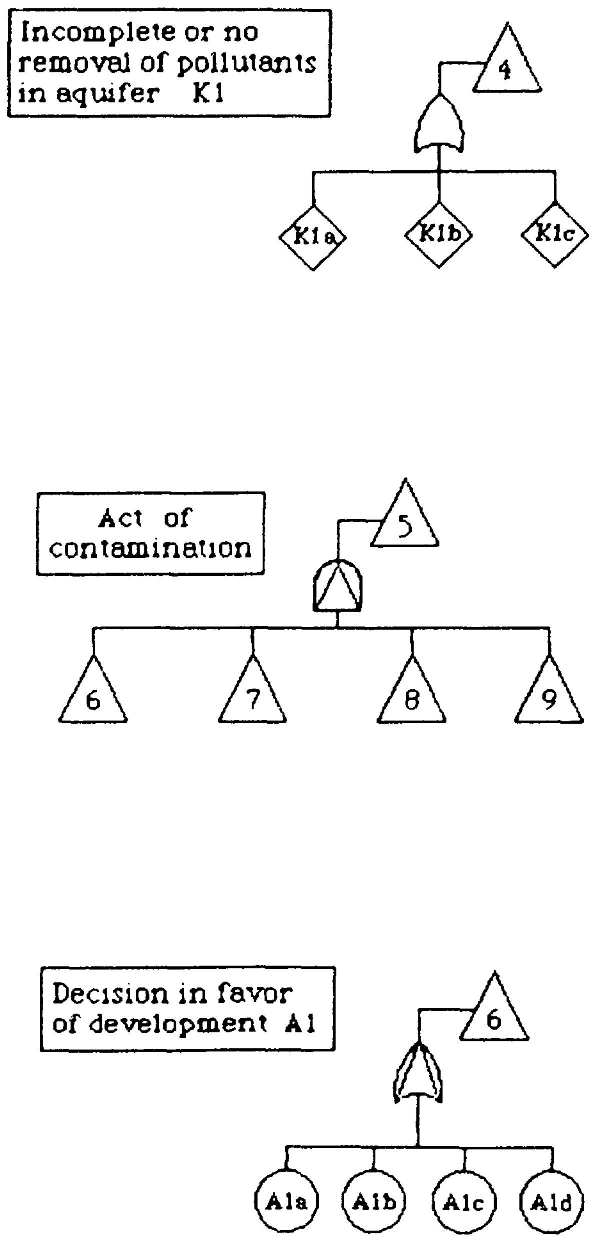


Figure 6 Fault tree for groundwater contamination example. part II.

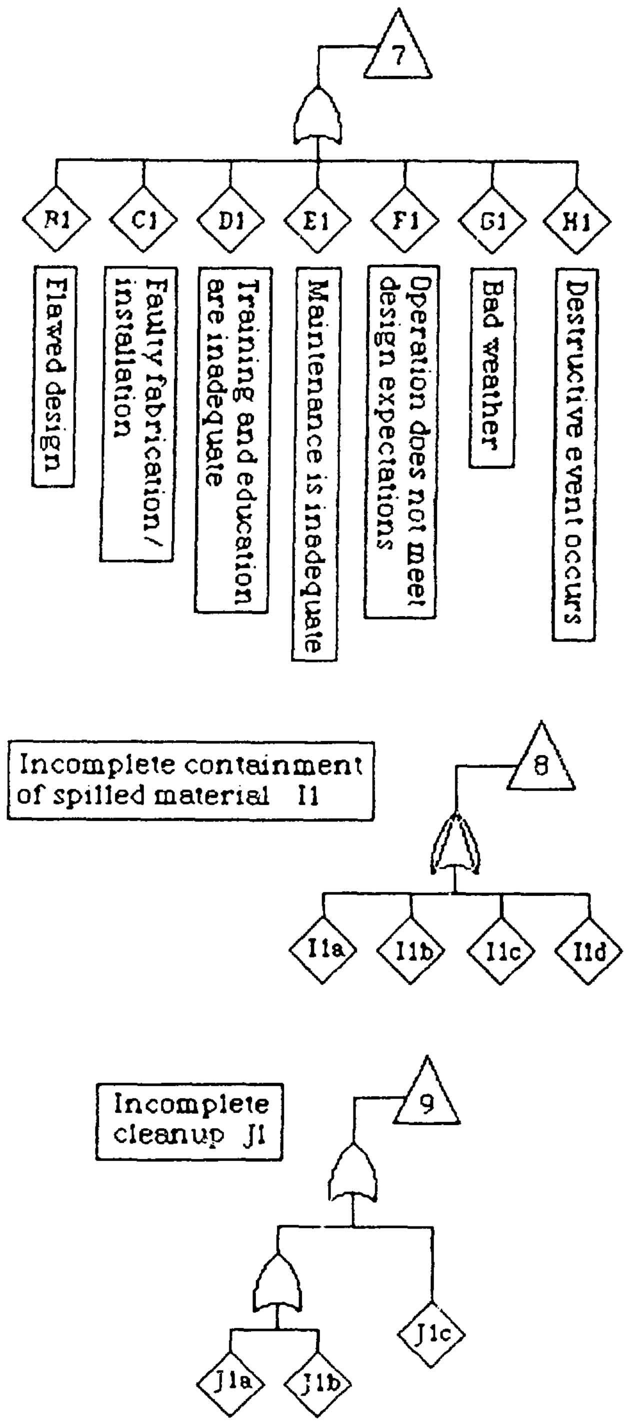


Figure 7. Fault tree for groundwater contamination example, part III.

contamination exists only if: 1) there is a decision to permit development over the recharge zone, 2) one or more events occurs (not all of which are necessarily in man's control) with the development causing a spill, 3) the spill is not completely contained, allowing hazardous material (or a precursor) to reach the soils of the recharge zone, and 4) cleanup efforts are not completely successful.

The equations describing the probability of a failure and corresponding to the fault tree are listed in Table 2. Because the probability of a failure occuring as a result of several independent, simultaneous events is usually quite low. Probabilities of three-event failures are taken as zero in most cases in order to simplify the mathematics. A list of the probabilities used in the four policy-decision cases are given in Table A1 in the appendix. A linear weighting function is assumed. Risk can be assessed after values (or losses) are assigned.

ACCEPTABLE LEVELS OF RISKS

Risk acceptability analysis determines what level of risk is acceptable or allowed by society for specific risk situations. The problem can be summarized with the following two questions: 1) How safe is safe enough?, and, 2) Who are the parties determining the acceptability?

There are no organized techniques to handle these two problems. It is, of course, impossible to answer the first question without first answering the second. However, often the answer to the second question is implicit, if it exists at all. For the purpose of this paper, the authors assume the parties who determines the acceptability are the individuals who are suffering the consequences of specific events. Normally, the general public or the political leaders determine the acceptable levels of the risks. Unfortunately, there have been no studies conducted, nor historical data collected which can be utilized explicitly for determining risk associated with groundwater contamination. Furthermore, there has been no publication of data on the acceptability of risk related to various consequences associated with groundwater contamination.

The historical revealed preference developed by Rowe(6) provides an intial quantitative basis for the psychological tendencies of risk acceptability. The authors utilize the revealed preference values as current cumulative risk acceptability levels and applies appropriate attenuating factors to develop acceptable risk level for groundwater contamination under specified socioecomonic conditions.

In assessing the acceptability of a particular risk situation, it is difficult to precipitate the confusion created by various individual perceptions.(9) People do not perceive reality in the same way. The risk problems addressed in this paper are neither well established nor documented. These problems are

Table 2

PROBABILITY EQUATIONS CORRESPONDING TO FAULT TREE DIAGRAM IN GROUNDWATER CONTAMINATION EXAMPLE

1. $P = P(1)\,P(2)\,P(3)$

2. $P(1) = P(4)\,P(5)$

3. $$\begin{aligned} P(2) &= P(M1a + M1b + M1c) \\ &= P(M1a) + P(M1b) + P(M1c) \\ &\quad - [\,P(M1a\,M1b) + P(M1b\,M1c) + P(M1c\,M1a)] \\ &\quad + P(M1a\,M1b\,M1c) \end{aligned}$$

4. $$\begin{aligned} P(3) &= P(N1a + N1b + N1c)^{*} \\ &= P(N1a) + P(N1b) + P(N1c) \\ &\quad - 2\,[\,P(N1a\,N1b) + P(N1b\,N1c) + P(N1c\,N1a)] \\ &\quad + 3\,P(N1a\,N1b\,N1c) \end{aligned}$$

5. $$\begin{aligned} P(4) &= P(K1a + K1b + K1c) \\ &= P(K1a) + P(K1b) + P(K1c) \\ &\quad - [\,P(K1a\,K1b) + P(K1b\,K1c) + P(K1c\,K1a)] \\ &\quad + P(K1a\,K1b\,K1c) \end{aligned}$$

6. $P(5) = P(6)\,P(7)\,P(8)\,P(9)$

7. $$\begin{aligned} P(6) &= P(A1a + A1b + A1c + A1d)^{*} \\ &= 1.0 \end{aligned}$$

8. $$\begin{aligned} P(7) &= P(B1 + C1 + D1 + E1 + F1 + G1 + H1) \\ &= P(B1) + P(C1) + P(D1) + P(E1) + P(F1) + P(G1) + P(H1) \\ &\quad - [P(B1\,C1) + P(B1\,D1) + P(B1\,E1) + P(B1\,F1) + P(B1\,G1) + P(B1\,H1) \\ &\qquad + P(C1\,D1) + P(C1\,E1) + P(C1\,F1) + P(C1\,G1) + P(C1\,H1) \\ &\qquad + P(D1\,E1) + P(D1\,F1) + P(D1\,G1) + P(D1\,H1) \\ &\qquad + P(E1\,F1) + P(E1\,G1) + P(E1\,H1) \\ &\qquad + P(F1\,G1) + P(F1\,H1) \\ &\qquad + P(G1\,H1)] \\ &\quad + [\text{ all possible combinations of 3 events}] \\ &\quad - [\text{ all possible combinations of 4 events}] \\ &\quad + [\text{ all possible combinations of 5 events}] \\ &\quad - [\text{ all possible combinations of 6 events}] \\ &\quad + P(B1\,C1\,D1\,E1\,F1\,G1\,H1) \end{aligned}$$

9. $$\begin{aligned} P(8) &= P(I1a + I1b + I1c + I1d)^{*} \\ &= P(I1a) + P(I1b) + P(I1c) + P(I1d) \\ &\quad - 2\,[\,P(I1a\,I1b) + P(I1b\,I1c) + P(I1c\,I1d) + P(I1d\,I1a) \\ &\qquad + P(I1a\,I1c) + P(I1b\,I1d)] \\ &\quad + 3\,[\,P(I1a\,I1b\,I1c) + P(I1a\,I1c\,I1d) + P(I1a\,I1d\,I1b) \\ &\qquad + P(I1b\,I1c\,I1d)] \\ &\quad - 4\,P(I1a\,I1b\,I1c\,I1d) \\ &= P(I1a) + P(I1b) + P(I1c) + P(I1d) \end{aligned}$$

10. $$\begin{aligned} P(9) &= P(9a + J1c) \\ &= P(9a) + P(J1c) - P(9a\,J1c) \\ &\text{where } P(9a) = P(J1a) + P(J1b) - P(J1a\,J1b) \\ &\quad \text{and } P(9a\,J1c) = P(J1a\,J1c) + P(J1b\,J1c) - P(J1a\,J1b\,J1c) \end{aligned}$$

surrounded by a high degree of uncertainty due to factors such as diversity of opinion, limited knowledge, and restricted measurement capabilities. Compounding all of these difficulties, the complexity of groundwater contamination due to hazardous wastes is further augmented by the multiplicity of risk pathways as well as the multiple dimensions of consideration involving tangible and intangible factors dominating the decision-making process.

The intuitive and cognitive ability of a normal individual is hampered by the complexity just described, forcing him to rely on simplified rules of thumb. Unfortunately simplified information-synthesis and decision-making rules often lead to erroneous judgments. In many cases the unjustified biases may become the dominant reasoning for the estimation of specific probability values. Furthermore, as the constituents of "public" are vague and large in numbers, the assessment of risk acceptability by the "public" often becomes an almost impossible task.

The anatomy of human perception and its impact on decision making has evolved into a prospect theory based on experimental evidence (10). Under this theory, the use of expected value (i.e. probability-averaged consequence) has been challenged. A significant difference was observed due to the perception associated with the problem framing (i.e. the observer's perception of the problem, consequences, and its contingencies). As a result, instead of the familiar and accepted value formulation, risk is defined by the function presented in Equation 1:

$$R = W(P) \times V(C) \qquad (1)$$

where W(P) = the decision weight associated with the probability of occurrence, P, V(C) = value associated with the consequences, and R = Risk.

Hypothetical value and decision weight functions are depicted in Figs. 8 and 9, respectively. If the function of W and V were linear throughout, a individuals preference would be independent of the problem's framing. However, due to the characteristic nonlinearities, different frames can lead to different choices, although the expected values remain the same.

Besides the theoretical and experimental studies on prospect theory, a great deal has been developed for the determination of inferred or intuitive factors in the development of perception. One of the most complete analyses for the area of risk assessment has been initiated by Rowe(6). Rowe proposed a transformation system for the subjective perception from objective reality based on the factors as summarized and classified in Table 3.

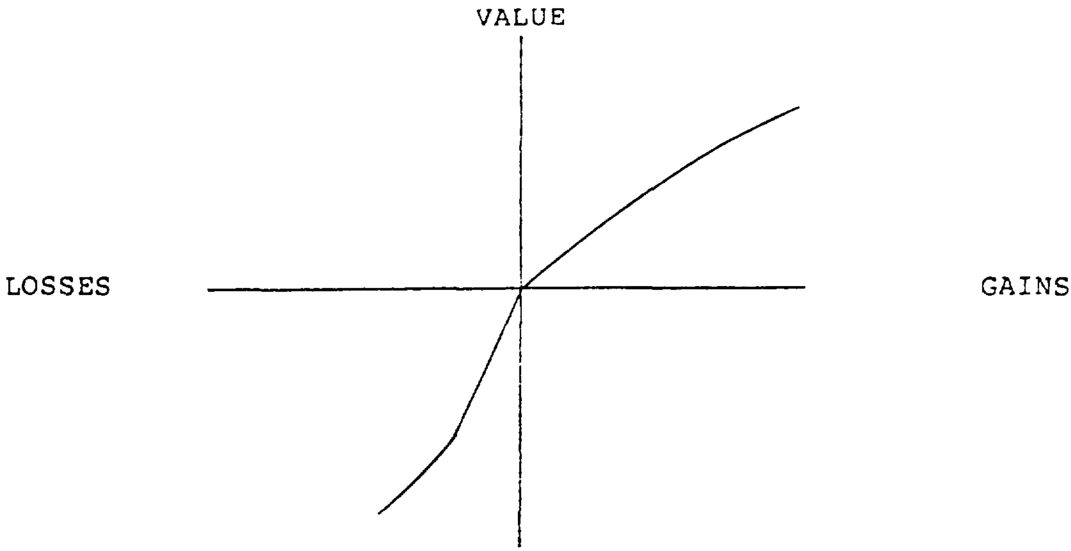


FIG. 8 HYPOTHETICAL VALUE FUNCTION

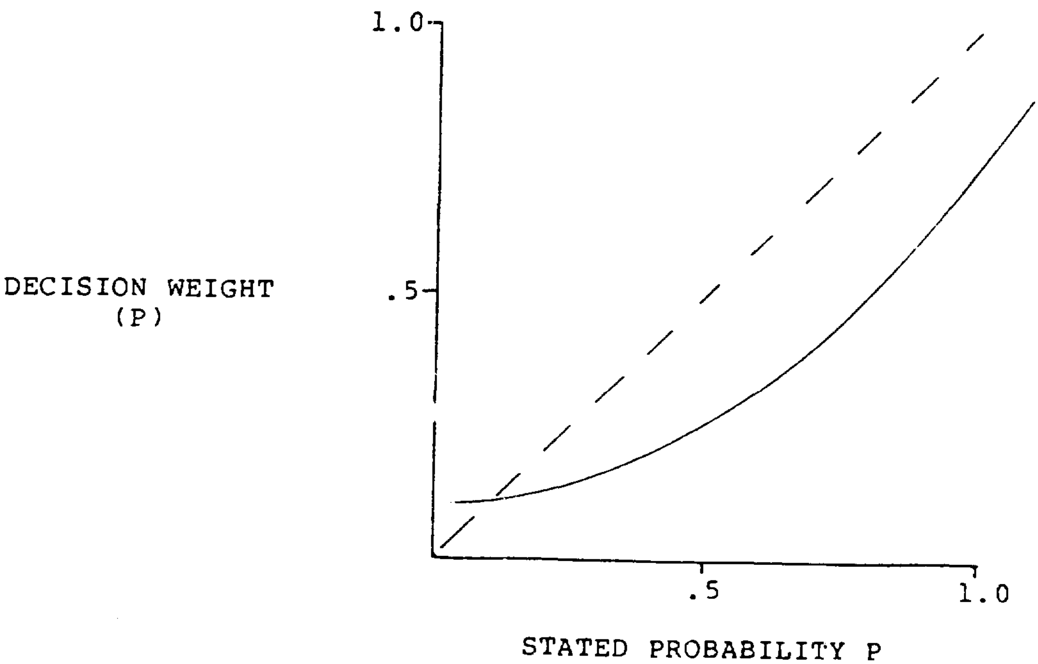


FIG. 9 HYPOTHETICAL PROBABILITY FUNCTION

Table 3

Transformation Factors From Objective Observations to Subjective Judgment

INVOLVING TYPE OF CONSEQUENCE	INVOLVING NATURE OF CONSEQUENCE
-Voluntary or involuntary	-Position in hierarchy
-Discounting of time	-Ordinary or catastrophic
-Identifiable or statistical risk taker	-Natural or man originated
-controllability	

OTHER FACTORS
-Magnitude of probability of occurrence
-Propensity for risk taking

A brief description of some of the factors includes in Table 3 is as follows:

1) Voluntary vs. involuntary: Perception appears to be markedly affected by whether the risk is incurred by choice or not. For instance, one normally expects a worker on the top of a high-rise pouring concrete to be much more tolerant of risk than the passer-by on the street.

2) Controllability: People appear to accept much higher risk when they feel that the situation is totally well controlled by themselves, such as when they are driving their cars versus traveling in a commercial airplane.

3) Ordinary versus catastrophic: Large numbers of fatalities, etc., in a single accident have a much more pronounced impact than the same number of fatalities spread over a number of accidents.

4) Natural versus man-originated: Risk imposed by natural causes tend to be much more easily tolerated than that by man-made causes.

RISK ACCEPTABILITY ANALYSIS

A number of techniques addressing the question, "How safe is safe enough?", have been proposed. Based on in depth comparison of all quantitative techniques using five key characteristics--decision making criteria, focus of wisdom, principal assumptions, decision attributes and data requirements--the quantitative revealed preference based on accumulated historical acceptable levels is the most appropriate measurement for risk acceptability. The computational procedures are as follows:

1) Devise an appropriate risk classification scheme,

2) Determine an absolute risk reference for each class in the scheme,

3) Using risk references as a base, calculate risk referents that act as the acceptability limits for specific situations,

4) Compare the estimated risk from fault tree analysis with appropriate risk referent.

Table 4

Summary of Risk References for All Classes

Risk Classification	Class of Consequence			
	Fatalities per year	Immobility cases/year	MM Dollars per year	LER* (years)
Naturally occurring				
Catastrophic	$1x10^{-6}$	$5x10^{-6}$	0.02	$3x10^{-2}$
Ordinary	$7x10^{-5}$	$4x10^{-4}$	3	0.2
Man originated				
Catastrophic				
Involuntary	$1x10^{-7}$	$5x10^{-7}$	$2x10^{-2}$	$3x10^{-4}$
Voluntary	$2x10^{-6}$	$2x10^{-6}$	0.4	$6x10^{-3}$
Regulated voluntary	$3x10^{-5}$	$3x10^{-6}$	0.4	$6x10^{-2}$
Ordinary				
Involuntary	$5x10^{-6}$	$3x10^{-5}$	1	$1x10^{-2}$
Voluntary	$6x10^{-4}$	$3x10^{-1}$	200	1
Regulated voluntary	$1x10^{-4}$	$6x10^{-2}$	30	0.1
Man triggered				
Catastrophic				
Involuntary	$2x10^{-7}$	$1x10^{-6}$	$4x10^{-2}$	$6x10^{-4}$
Voluntary	$4x10^{-6}$	$4x10^{-6}$	0.8	$6x10^{-3}$
Ordinary				
Involuntary	$1x10^{-5}$			$3x10^{-2}$
Voluntary	$1x10^{-3}$			2
Regulated voluntary	$2x10^{-4}$			0.2

*LER = Life Expectancy Reduction

If the estimated risk is within an order of magnitude of the referent, then it can be considered acceptable. The first two steps are intended to be generally applicable to all situations involving risk. The third step is repeated for each new activity and allows for the modification of the referent value to fit the situation. As summarized in Table 4, the risk reference is based on the transformation factors listed, as well as the effects of the magnitude of the probability of occurrence in historical data.

As eluded in the previous section, the only way to facilitate the utilization of risk reference values is not to treat risk as an aggregate quantity. Components involved in the risk must be broken into individual sub-elements. The basic classification scheme relating to risk advocated by Rowe, is summarized in Table 5.

The ultimate consequences normally encountered by the public due to groundwater contamination by hazardous wastes are: 1) fatalities, 2) injuries and immobilities, 3) water supply costs increase.

Table 5

Classification of Absolute Risk

Immediate statistical	Voluntary	Regulated	Involuntary
1. Natural			
a. Catastrophic			X
b. Ordinary			X
2. Man triggered			
a. Catastrophic	X		X
b. Ordinary	X	X	X
3. Man originated			
a. Catastrophic	X		X
b. Ordinary	X	X	X

Immediate identifiable(1) Delayed identifiable (1)
Delayed statistical (1)

(1) Same as immediate statistical

Following the classification of the risk, an absolute risk reference value may be established for each of the risk classes, as shown in Table 4. It must be pointed out all that the risk references are developed based on the analogous set of risk classes for each specific situation, as referred by event designations. In all cases the direct data for specific risk class do not exist for groundwater contamination.

Based on the risk reference values stipulated in Table 5, appropriate risk referent values are developed for the specific risks associated with the groundwater contamination using the following four steps:

1) Determine the appropriate risk proportionality factors, i.e. the fraction of existing societal risk that would be considered acceptable in a situation where there is a very favorable indirect benefit/cost balance for both the voluntary and in voluntary risks (F1).

2) Determine the derating factor which modifies the risk proportionality factor based on the indirect benefit/cost

balance (F2).

3) Determine the discounting factor associated with the degree of risk controllability (F3).

4) Calculate the risk referent based on the Equation 2:

Risk referent = risk reference x F1 x F2 x F3. (2)

The first two factors, F1 and F2, address the inherent propensity of specific individuals or groups to take risks and incorporate the additional decision dimension of indirect benefit/cost ratio. This acknowledges the tendency for people to accept a higher level of risk if the benefit to them more than offsets the imposed risks, or to be increasingly risk-aversive if it does not. As shown in Table 6 the risk proportionality and derating factors have a highly dependence upon the degree of voluntarism, as well as the balance between the cost and the benefits. For instance, the derating factor for the involuntary risk under the unfavorable benefit/cost situation is 10^{-4} whereas the regulated voluntary with favorable benefit/cost condition is 1.0.

Table 6
Risk Proportionality and Risk Derating Factors

Factor	Involuntary Risk	Regulated Voluntary
Proportionality factor (F1)	0.01	1.0
Derating factor (F2)		
Balance		
Favorable	1.0	1.0
Marginal favorable	0.1	0.2
Indecisive	0.01	0.1
Marginal unfavorable	0.001	0.02
Unfavorable	0.0001	0.01

The third factor, F3, is the aggregate discounting factor reflecting four considerations associated with the controllability. At this time the simplest relationship based on simple multiplication is employed. The four sub-factors are: a) Control approach (C1): the type of risk control management being used, b) Degree of control (C2): the effectiveness of risk control management, c) state of implementation for the specific method (C3), and d) Basis for control effectiveness (C4): whether or not the control approach will provide absolute firmness or not. As shown in Table 7, the controllability factor is simply defined by some fractional numbers indicating the relative values for each of the four considerations on a cardinal ratings.

For a typical case of groundwater protection against hazardous wastes, using the fault tree presented in Figs. 5 through 7, it is estimated that the probability values for contamination of the aquifer in cases A1 and A4 are 4.12×10^{-8} and 1.12×10^{-4}, respectively, based on probability values provided in Table A1 of the appendix.

Table 7
Controllability Factor

Control Approach C1	Degree of Control C2	State of Implementation C3	Basis for Control Effectiveness C
Systematic Control 1.0	Positive 1.0	Demonstrated 1.0	Absolute 1.0
Risk Mgt. System 0.8			
Special design 0.5		Proposed 0.5	Relative 0.5
Inspec. & regulation 0.3	Level 0.3		
No scheme 0.1	Uncontrolled 0.1	No action 0.1	None 0.1

The calculated risk referent values for cases A1 and A4 are 2.4×10^{-6} and 1.5×10^{-12}, respectively, using the risk reference values shown in Table 4 and appropriate values of F1, F2, and F3 shown in Table A2 in the appendix. For case A1, the risk referent value is greater than the estimated probability, and, therefore, the policy allowing residential development is acceptable. Conversely, the risk referent value corresponding to case A4 is less than the estimated probability, making uncontrolled development over the recharge zone an unacceptable option.

MULTIATTRIBUTE DECISION-MAKING EMBEDDED WITH RISK ASSESSMENT

Hazardous waste management, as it involves risks to human health and safety, is becoming technologically uncertain but a politically volatile problem. It calls for a systematic technique which would allow decision makers to adequately address the complex issues involved and develop viable solutions based on both objective analysis and subjective adjustments.

Decision analysis that incorporates a multiattribute utility function is an apparent, effective tool for this type of problem since it is highly flexible, incorporates methods to handle uncertainty, and multiple objectives and is also a well-developed technique. However, it is not without faults. The most glaring, as pointed out by Rowe (6), is its inability to properly treat the subjective nature of risk. Thus, an integrated method incorporating multiattribute decision analysis with a quantitative risk assessment technique is needed to handle such problems as sludge and compost utilization. The basic steps entailed in such a unified approach include:

- Construct a decision tree for the specific situation

- Complete a detailed risk analysis
  * Determine the objective risk of each decision branch
  * Determine the appropriate risk referents
  * Use an objective risk versus risk referent comparison to determine if a decision branch requires modification or should be eliminated from consideration

- Conduct a sensitivity analysis of the risk comparison in order to determine which branches are only "marginally" acceptable

- Conduct a sensitivity analysis of the "solution"

DECISION TREE CONSTRUCTION

The organization and construciton of a decision tree is essentially the first task in the decision-making process. In general, the following steps should be utilized to construct a tree:

- Generate an objective hierarchy which terminates in the attributes (which includes risks) and attribute measurements

- Determine the viable courses of action available

- Determine the possible chance events (i.e. failure events, outcomes, etc.) resulting from a decision

- Arrange the decision options and resulting chance events in chronological order (a generalized structure for problems which largely involve risk is shown in Fig. 10)

- Evaluate the specific probabilities for each chance event

- Evaluate the magnitude of each attribute

A number of key areas in this process require a more detailed explanation. First, it is necessary to take a closer look at the meaning of "viable courses of action". the term implies that some pre-decision tree criteria are used to eliminate "nonviable"

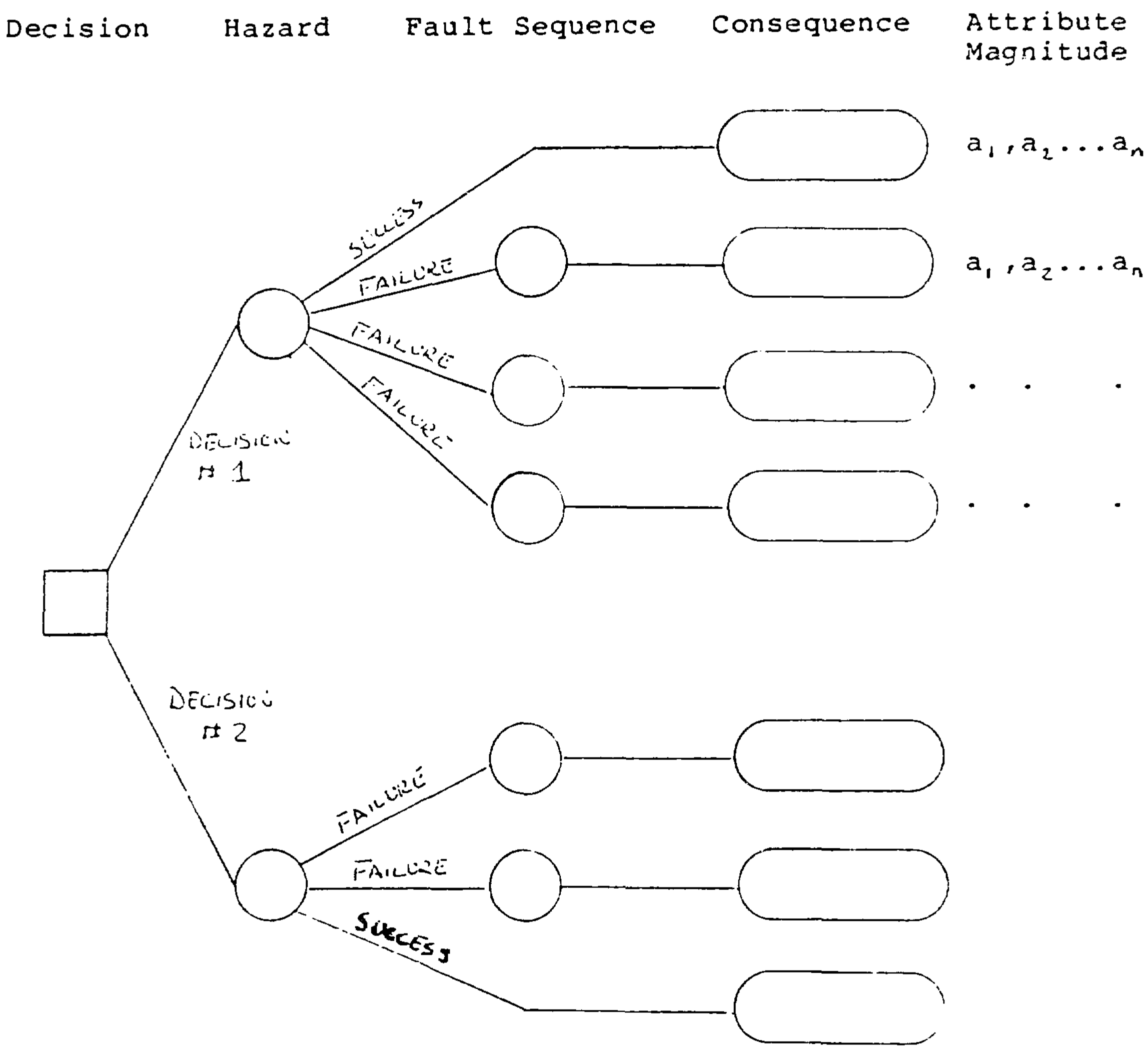


FIG. 10 GENERALIZED DECISION TREE STRUCTURE

alternatives from entering into the decision making process. In the hazardous waste area, the principal criterion to serve this purpose is implementation time. The discovery of an uncontrolled dump site for highly toxic substances would in all political reality require initial positive action which took a minimum time to implement. The number of viable options would probably be small. In the case of planning a new controlled disposal/storage site, this constraint would probably be greatly reduced, allowing a much wider scope of options to be considered.

MULTIATTRIBUTE DECISION ANALYSIS

This process can be broken into three principal parts:

- the determination of utility functions for each attribute
- the development of a multiattribute utility function
- the calculation of expected utilities

The first two are by far the most complicated. The determination of an attribute's utility function is a well-developed analyst-decision maker interrogation procedure. It normally includes questioning both the qualitative and quantitative characteristics of the decision makers preferences. The result is a function which transforms attribute magnitudes into a cardinal measurement, utility, structured so that the best course of action is always the alternative with the highest expected utility.

The development of a multiattribute utility function involves the assessment of attribute independence, followed by the development of an appropriate mathematical formulation. This formulation allows the analyst to combine each attribute's utility function into a single utility function. It should be noted that the concept of preferential independence involves attributes under the condition of certainty while utility independence is specifically concerned with uncertainty. This process is developed according to the decision maker's perception of the attributes' relationships not according to some established standard rules. Some general observations about the perceptions held by most decision makers in hazardous waste management seems in order. First, the risk attributes normally will be both preferential and utility independent of the other attributes. Second, each risk attribute would normally be both preferential and utility independent of each other.

The third part of the procedure, the calculation of expected utlities, is basically just a mechanical process of "averaging out" and "folding back". Averaging out involves the computation of expected utility at each chance mode. Folding back entails the elimination of the less desirable paths at a decision node.

APPLICATION

In order to illustrate the use of the integrated methodology, the case study of Denny Farm (1) will be utilized. In this case an uncontrolled chemical dump site containing TCDD along with other substances was discovered in Missouri. The problem posed is how best to eliminate the health risk at and around this site. Four viable alternatives were suggested: (1) leave the site as is, (2) install and maintain a groundwater monitoring system, (3) excavate the dump and restore in a controlled manner on iste, and (4) excavate the site and transport liquids and residues via truck to Syntex, an approved hazardous waste storage site. Since joint probabilities for each chance path have been delineated in the study, the simplified decision tree shown in Figure 11 is used. Due to lack of information provided by the study, only four attributes can be used: two classes of human risk, fatalities and immobility, cost and lead time. The division of human impacts between fatalities and immobility is made possible by assuming that 1.0% of all possible harmful human exposures determined in the study will result in fatalities. In reality, this assumption would have to be verified and revised as necessary.

The next step is to proceed with a risk analysis. The risk data provided by the study are summarized in Table 8. In order to use these data, it is necessary to express them in terms commensurate with the risk referents that will be calculated. This requires that a time duration in years for long term risk be established and that estimates of the total population exposed be determined. For the purposes of this paper, the long term risk duration is assumed to be evenly distributed over a span of 30 years.

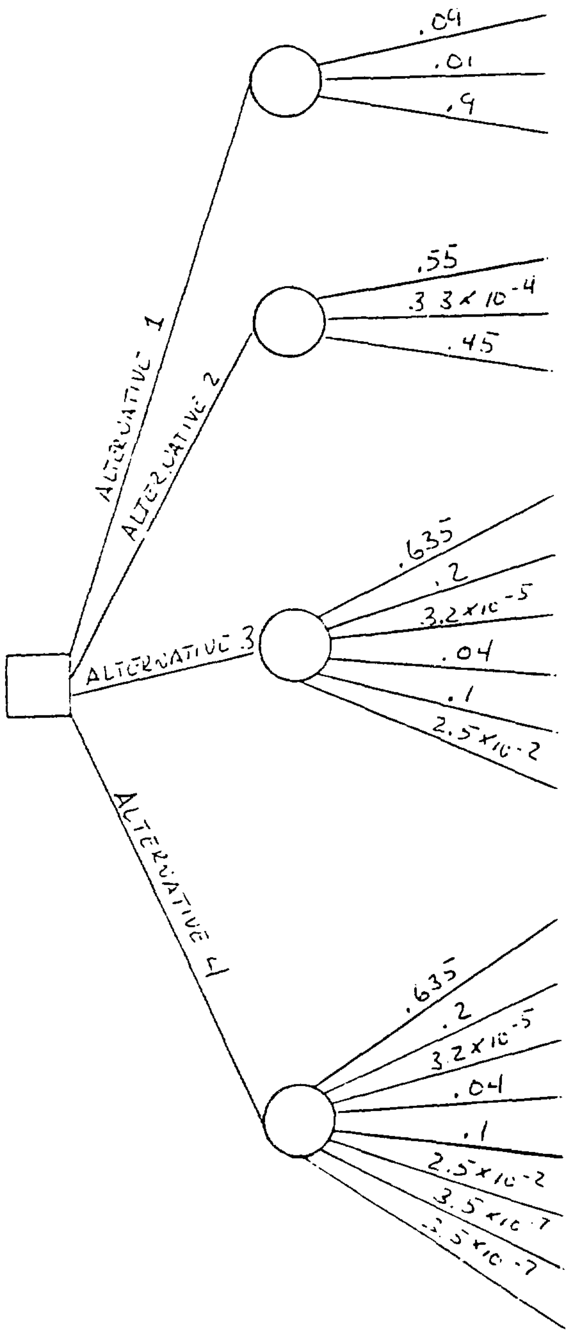
Estimates of the total exposed population were calculated using data provided in the study. In some, but not all cases, this could be reasonably assumed to be equal to the maximum exposed numbers derived in the study. The objective risk was then calculated using the equation provided in the "Risk Estimation" section of this paper. These risk estimates are summarized in Table 10.

With objective risk determined, the next step was to calculate risk referents. This was accomplished using the procedure outlined by Rowe (6). In order to do this, some reasonable assumptions about the public's and worker's perception of the indirect gain-loss balance and the controllability of each alternative had to be made. These assumptions are shown in Table 9. A summary of the factor used in the risk referent calculation is also provided. A comparison of objective risk and risk referents is provided in Table 10. A quick glance at this comparison indicates that none of the proposed alternatives is "acceptable" to the public and that alternatives 3 and 4 are only marginally "acceptable" to the workers in terms of fatalities.

At this point it is fairly clear that alternatives 1 and 2 will

Table 8 DENNY FARM RISK DATA SUMMARY

Alternative	Joint Probability (Term)	Involuntary Fatal.	Involuntary Morb.	Reg. Vol. Fatal.	Reg. Vol. Morb.
1. Leave buried	.01 (long)	145	1301	-	-
	.9 (long)	12	107	-	-
2. Install & maintain a groundwater monitoring system	3.3×10^{-4} (long)	38	341	-	-
	.45 (long)	12	107	-	-
3. Excavate & store material on site	.2 (short)	-	-	-	3
	3.2×10^{-5} (short)	5	45	-	-
	.04 (long)	7	60	-	-
	.1 (short)	-	-	4	36
	2.5×10^{-2} (short)	12	108	-	-
4. Excavate & transport liquids and residues via truck to Syntex	same as 3 plus:				
	3.5×10^{-7} (short)	-	-	-	2
	3.5×10^{-7} (short)	1	9	-	-



Human Risk Fatal	Human Risk Morbid.	Cost (10 $)	Lead Time (mo)
0	0	0	0
145	1301	0	0
12	107	0	0
0	0	.75	3
38	341	.75	3
12	107	.75	3
0	0	3.0	8
0	3	3.0	8
5	45	3.0	8
7	60	3.0	8
4	36	3.0	8
12	108	3.0	8
0	0	3.5	10.5
0	3	3.5	10.5
5	45	3.5	10.5
7	60	3.5	10.5
4	36	3.5	10.5
12	108	3.5	10.5
0	2	3.5	10.5
1	9	3.5	10.5

FIG.11 INITIAL DECISION TREE

not, under foreseeable circumstances, approach an acceptable level of risk so they should be eliminated. It appears potentially feasible and worth-while to modify alternatives 3 and 4 by eliminating the risk to the public of significant release of residual TCDD after excavation, by either eliminating most of this residual during the cleanup or by some form of encapsulation. This modification will of course cause both the cost and lead time of each alternative to be increased. No other risk modifications seem realistic with the information given. As indicated in Table 10, with the suggested modification alternatives 3 and 4 would become acceptable. This suggests that it is time to seriously consider the modified approach or assemble some other alternatives. Possible other approaches would need to include means to either mitigate or eliminate the public exposure due to tornados and contaminated workers. Since no in-depth information is provided, assumptions that alternatives No. 3 and 4, as modified above, are the best that can be developed for further analysis. In real life this is possibly an outcome that could materialize, in which case the public must be informed in detail.

With the risk assessment completed as above, a revised decision tree including only alternatives 3 and 4 (modified) is needed for further analysis. Such a tree is illustrated in Fig. 12. However, completion of the formal analysis required utility functions for each individual attribute and a multiattribute utility function. The utility functions used for each attribute are diagrammed in Figs. 13 to 16. Fig. 13 and 14, fatalities and immobility, provide an example of risk neutral functions while Fig. 15, costs, is slightly risk prone and Fig. 16, lead time, is risk averse. These functions would be a direct result of the perceptions of the decision maker for the problem. The original cost and lead time for the modified version of alternatives 3 and 4 are being used. Due to the similarity of the two options and the likelihood that the changes would be relatively minimal, this should not create any deviations for the resolution of data. In order to combine the four separate utility values for different attributes into a single utility value, a multiattribute utility function is required. As in the case of the individual utility functions, this multiattribute utility function is directly related to the perceptions of the decision maker in question. For the purposes of this paper the use of an additive function seems reasonable due to the general observations mentioned previously and the small relative difference between the two alternatives being considered.

Finally, expected utility for each path is calculated using the mechanics of decision analysis to arrive at a "solution". The decision tree with all calculated values is diagrammed in Fig. 17. Alternative 3 (modified) is obviously preferable to 4 (modified) in this particular case. Since both alternatives are so similar it is unlikely that sensitivity analysis would indicate any significant different choice within any reasonable limits.

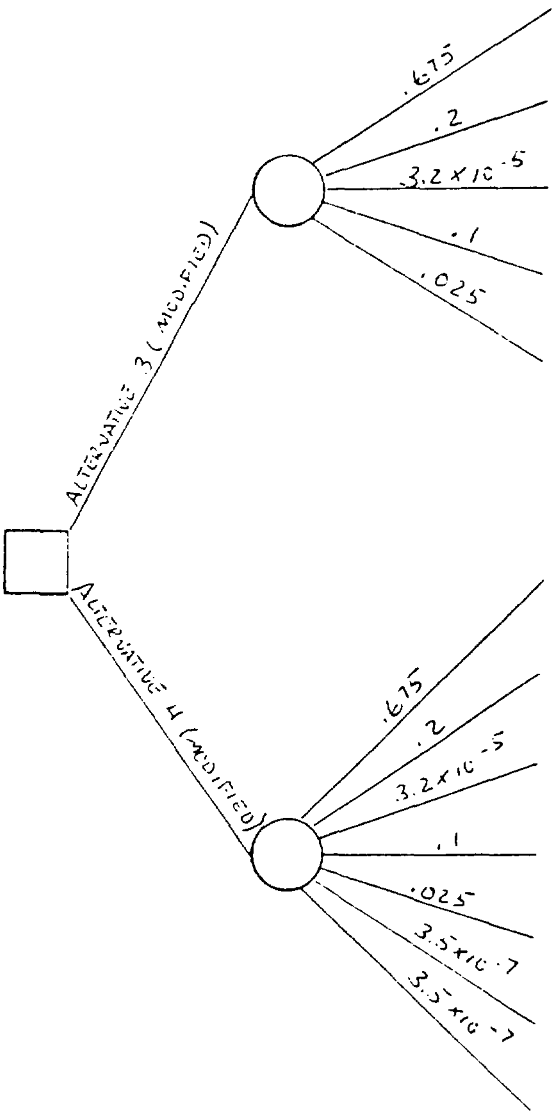
Table 9 RISK REFERENT CALCULATION FACTORS

Risk Classification	Risk Ref	Risk Prop Fac.	Proportion. Derating Factor	Control. Factor
Involuntary, catastrophic, fatal	1×10^{-7}	.1	Alt 1 .001 2 .01	Alt 1 .01 Alt 2 .015
Involuntary, ordinary, fatal	5×10^{-6}	.1	Alt 1 .001 2 .01 3/4 .1	Alt 1 .01 2 .015 3/4 1.0
Involuntary, catastrophic, health effect	5×10^{-7}	.1	Alt 1 .001 2 .01	Alt 1 .01 2 .015
Involuntary, ordinary, health effect	3×10^{-5}	.1	Alt 1 .001 2 .01 3/4 .1	Alt 1 .01 2 .015 3/4 1.0
Regulated voluntary, ordinary, fatal	1×10^{-4}	1.0	1.0	1.0
Regulated voluntary, ordinary, health effect	6×10^{-2}	1.0	1.0	1.0

Note: All risks are treated as immediate

Table 10 RISK COMPARISON

Alt	Risk Classification	Objective Risk	Risk Referent
1	Involuntary, catastrophic, fatal	3.3×10^{-5}	1.0×10^{-13}
	Involuntary, ordinary, fatal	3.0×10^{-3}	5.0×10^{-12}
	Involuntary, catastrophic, health	3.0×10^{-4}	5.0×10^{-12}
	Involuntary, ordinary, health	2.7×10^{-2}	3.0×10^{-11}
2	Involuntary, catastrophic, fatal	1.1×10^{-6}	1.5×10^{-12}
	Involuntary, ordinary, fatal	1.5×10^{-3}	7.5×10^{-11}
	Involuntary, catastrophic, health	9.9×10^{-6}	7.5×10^{-12}
	Involuntary, ordinary, health	1.3×10^{-2}	4.5×10^{-10}
3/4	Involuntary, ordinary, fatal	1.7×10^{-4}	5.0×10^{-8}
	Involuntary, ordinary, health	1.5×10^{-3}	3.0×10^{-7}
	Reg. voluntary, ordinary, fatal	3.2×10^{-3}	1.0×10^{-4}
	Reg voluntary, ordinary, health	3.3×10^{-2}	6.0×10^{-2}
3/4 Mod	Involuntary, ordinary, fatal	4.1×10^{-5}	5.0×10^{-8}
	Involuntary, ordinary, health	3.7×10^{-4}	3.0×10^{-7}
	Reg. voluntary, ordinary, fatal	3.2×10^{-3}	1.0×10^{-4}
	Reg. voluntary, ordinary, health	3.3×10^{-2}	6.0×10^{-2}



Human Risk Fatal	Morbid.	Cost (10 $)	Lead Time (mo)
0	0	3.0	8
0	3	3.0	8
5	45	3.0	8
4	36	3.0	8
12	108	3.0	8
0	0	3.5	10.5
0	3	3.5	10.5
5	45	3.5	10.5
4	36	3.5	10.5
12	108	3.5	10.5
0	2	3.5	10.5
1	9	3.5	10.5

FIG. 12 REVISED DECISION TREE

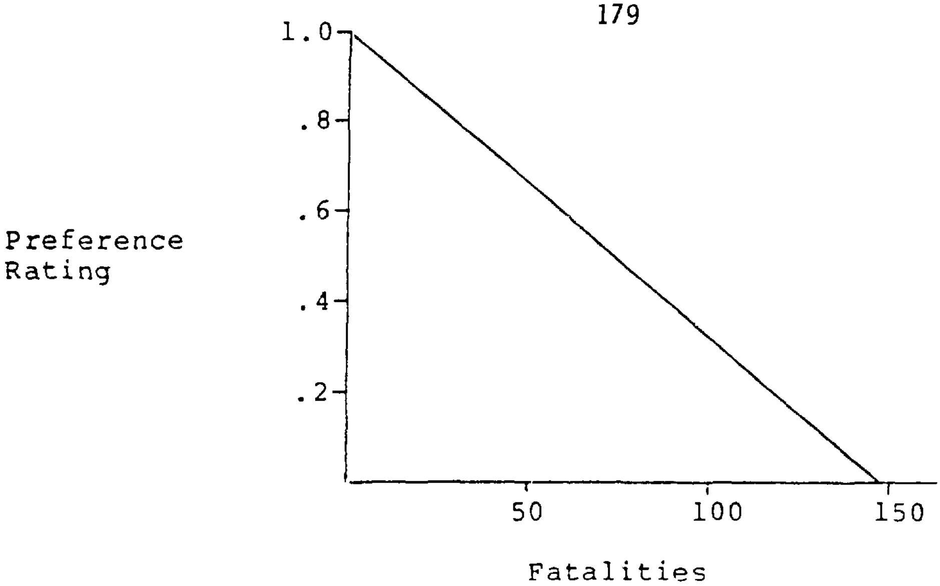


FIG. 13 FATALITIES UTILITY FUNCTION

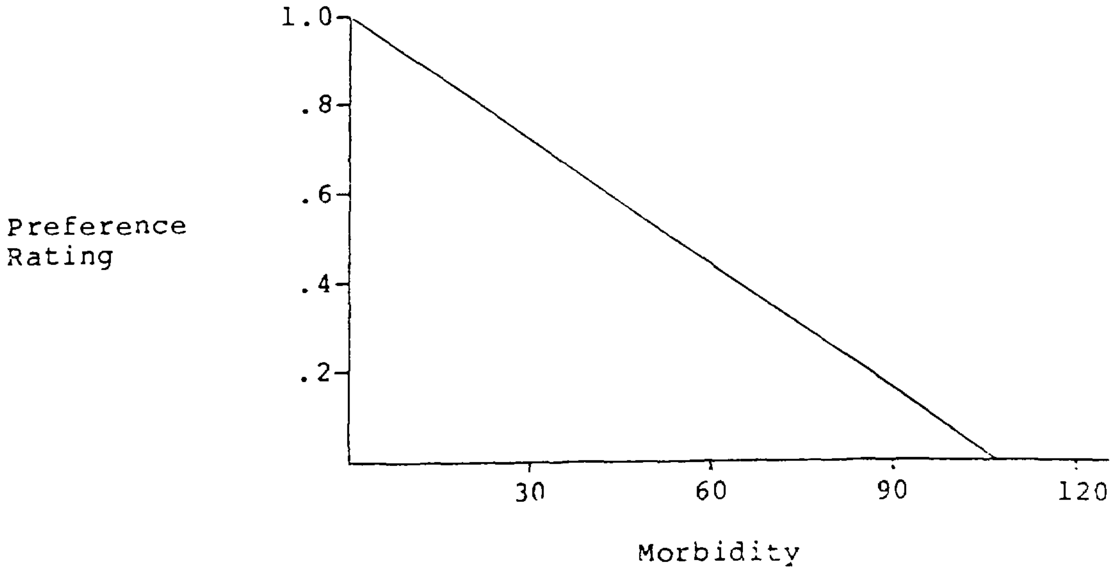


FIG.14 MORBIDITY UTILITY FUNCTION

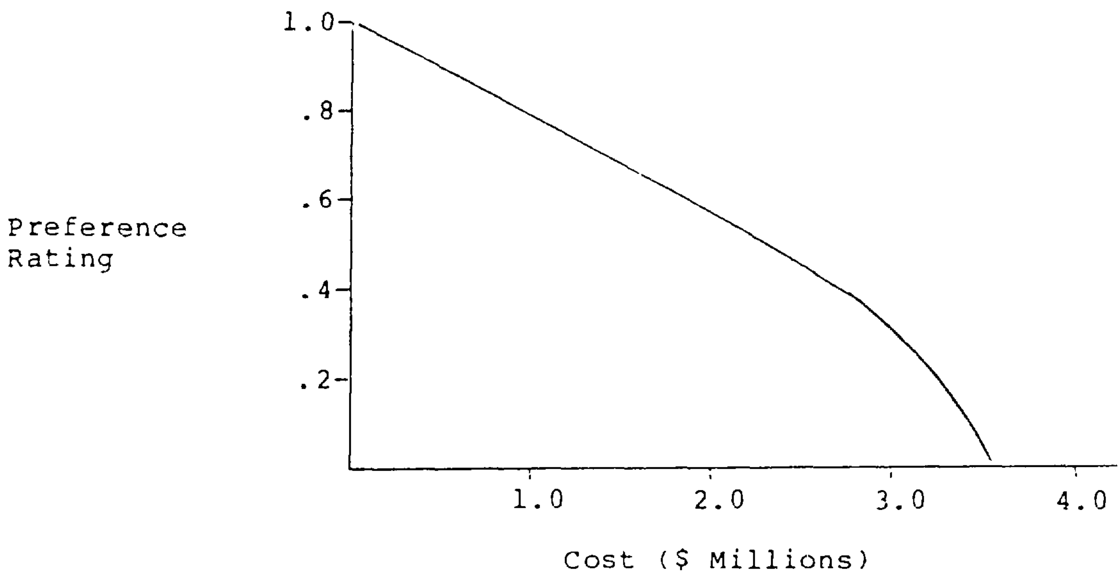


FIG.15 COST UTILITY FUNCTION

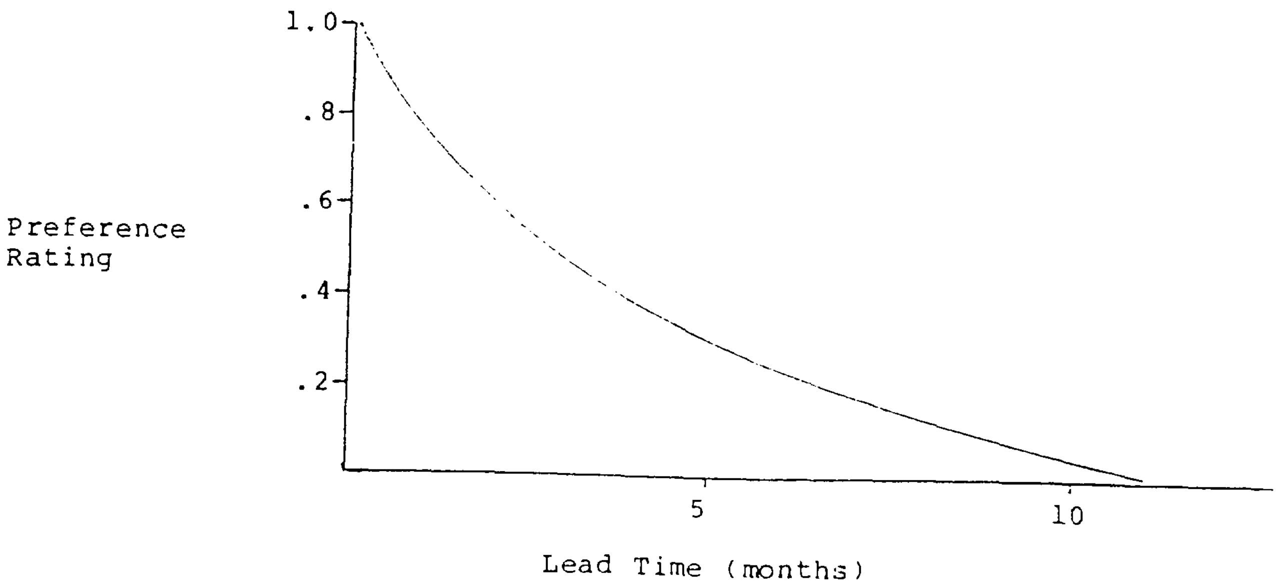
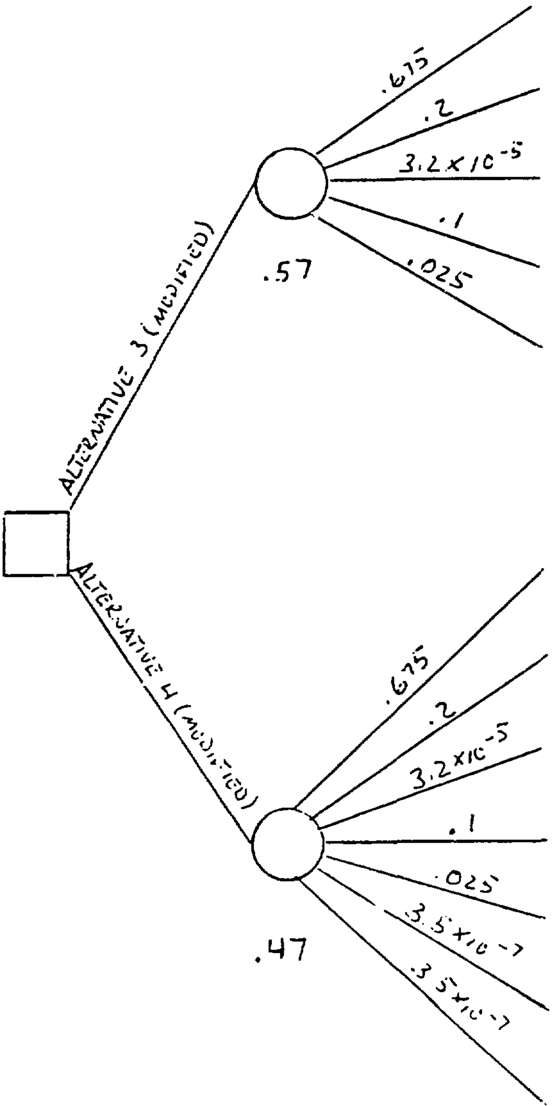


FIG. 16 LEAD TIME UTILITY FUNCTION



	Human Risk Fatal	Morbid.	Cost (10 $)	Lead Time (mo)	Total
Relative Weights	.38	.12	.25	.25	1.0
	1	1	.3	.1	.6
	1	.97	.3	.1	.6
	.58	.58	.3	.1	.39
	.67	.67	.3	.1	.44
	0	0	.3	.1	.10
	1	1	0	0	.5
	1	.97	0	0	.5
	.58	.58	0	0	.29
	.67	.67	0	0	.34
	0	0	0	0	0
	1	.98	0	0	.50
	.92	.92	0	0	.46

FIG.17 PROBLEM SOLUTION

CONCLUSIONS

The proposed method provides a quantitative tool that is systematic, yet flexible. It is capable of handling uncertainty, multiple conflicting objectives and the subjective judgements of decisionmakers, and addresses the highly subjective nature of public risk perception. With the prudent use of a "viable option" criteria and risk assessment, the number of options that must be fully considered can be effectively limited. On the other hand, this approach will help pinpoint requirements for considering a wider scope of alternatives when necessary.

The process is obviously powerful, and is appropriate for use with multiattribute problems. Given the potential complexities and controversies inherent in the use of land over the recharge zone of an aquifer for urban development, the application of this technique appears justified. This method of problem solving does not try to eliminate subjective judgements. Instead, it provides those making decisions the opportunity to scrutinize the alternatives with more objectivity than might otherwise be possible. It is the authors' attempt to bring together a set of powerful tools and apply them to the site management of uncontrolled hazardous wastes. More refinement and improvement are still required to permit the application of this method to larger scale problems.

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Table A1

PROBABILITY VALUES USED IN FAULT TREE ANALYSIS OF GROUNDWATER CONTAMINATION EXAMPLE

EVENT/SEQUENCE IDENTIFICATION	CASE NUMBER 1	2
	PROBABILITY VALUE	
A1a	1.0	0.0
A1b	0.0	0.0
A1c	0.0	0.0
A1d	0.0	1.0
B1	0.025	0.2
C1	0.025	0.2
D1	0.025	0.2
E1	0.125	0.2
F1	0.025	0.2
G1	0.00001	0.01
H1	0.00001	0.01
B1 C1	0.001	0.04
B1 D1	0.001	0.04
B1 E1	0.002	0.05
B1 F1	0.001	0.05
B1 G1	0.000001	0.0001
B1 H1	0.000001	0.0001
C1 D1	0.001	0.04
C1 E1	0.002	0.05
C1 F1	0.001	0.05
C1 G1	0.000001	0.001
C1 H1	0.000001	0.001
D1 E1	0.002	0.045
D1 F1	0.001	0.045
D1 G1	0.000001	0.001
D1 H1	0.000001	0.001
E1 F1	0.002	0.10
E1 G1	0.000002	0.002
E1 H1	0.000002	0.002
F1 G1	0.000002	0.002
F1 H1	0.000002	0.002
G1 H1	10^{-14}	10^{-8}

Table A1 (Continued)

EVENT/SEQUENCE IDENTIFICATION	1	2
	PROBABILITY VALUE	
I1a	0.00001	0.01
I1b	0.1	0.6
I1c	0.001	0.06
I1d	0.0	0.01
I1a I1b	0.0	0.0
I1a I1c	0.0	0.0
I1a I1d	0.0	0.0
I1b I1c	0.0	0.0
I1b I1d	0.0	0.0
I1c I1d	0.0	0.0
I1a I1b I1c	0.0	0.0
I1a I1b I1d	0.0	0.0
I1a I1c I1d	0.0	0.0
I1b I1c I1d	0.0	0.0
J1a	0.01	0.05
J1b	0.00	0.00
J1c	0.03	0.20
J1a J1b	0.0	0.0
J1a J1c	0.005	0.10
J1b J1c	0.006	0.10
J1a J1b J1c	0.003	0.01
K1a	0.04	0.02
K1b	0.005	0.001
K1c	0.05	0.10
K1a K1b	0.01	0.002
K1a K1c	0.07	0.10
K1b K1c	0.055	0.05
K1a K1b K1c	0.10	0.08
L1	0.1	0.1
M1a	0.0001	0.080
M1b	0.001	0.025
M1c	0.060	0.180
M1a M1b	0.00001	0.005
M1a M1c	0.004	0.100
M1b M1c	0.030	0.040
M1a M1b M1c	0.005	0.030
N1a	0.10011	0.46
N1b	0.05	0.20
N1c	0.05	0.09
N1a N1b	0.00	0.00
N1a N1c	0.00	0.00
N1b N1c	0.00	0.00
N1a N1b N1c	0.00	0.00

Table A2 Summary of Data for Risk Referent Development (Groundwater Contamination Example)

Policy Decisions	Apparent Risk	Risk Classification	Risk Reference	Proportionality Factor	Derating Factor	Controllability Factor
Low-Density Residential Development (A1)	Health affects on small group of population	Man-originated ordinary regulated voluntary	3×10^{-5}	1.0	0.1	0.8
Unrestricted Urban/Indust. Devlpmnt (A4)	Health affects on large mass of population	Man-originated catastrophic involuntary	5×10^{-7}	0.01	0.001	0.3

187 | 1%

Grouping and Analysis of Risk Impacts from Multiple Consequence Waste Site Remediation Operations

Presented by:

Arthur McBride,

Science Applications International Corporation

ABSTRACT

Grouping and Analysis of Risk Impacts from Multiple Consequence Waste Site Remediation Operations

Speaker: Arthur McBride, Manager
Systems Engineering Division
Science Applications International Corporation

The use of risk analysis as an input to waste site remediation operation decision making is relatively new. Risk analysis has been useful in presenting decision makers with a more complete assessment of the comparative overall risks associated with waste site remediation options. Yet the analysis results also raise significant questions. These include the relative importance of diverse risk measures (e.g., fatalities vs. exposure to hazardous materials) and the populations affected (on-site workers vs. off-site general populations).

Based on recent SAIC screening analyses of waste sites at a DOE facility's waste sites, the risk analysis methods used to develop and consolidate risk measures resulting from waste removal and waste isolation operations will be discussed briefly. Given the risk results of site analyses, a discussion of how these results may be interpreted and used will be presented - specifically addressing the problems associated with their interpretation and use. The interpretation and use questions will be presented principally from a physical standpoint but will consider some legal and social implications.

Grouping and Analysis of Risk Impacts from Multiple Consequence Waste Site Remediation Operations

Speaker: Arthur McBride, Manager
Systems Engineering Division
Science Applications International Corporation

- Risk Assessment and Results
- Risk Analysis Results for DOE Waste Site Remedial Actions
- Benefits and Difficulties of Using Risk Analysis Results

Definitions

Risk:	The expected magnitude of a consequence over a period of time (a time averaged consequence)
Risk Calculation:	The product of an event's consequence magnitude and its frequency: Event A results in 10 injuries and occurs once in 10 years. Therefore, the Risk A is: (10 injuries/event) (1 event in 10 years) = 1 injury/year
Utility of Risk:	A total risk of an operation can be computed as the sum of its constituent risks of like consequences. The total risks of competing operations can be compared on a simple, consistent basis.

Risk Assessment Process

1. Decide on the reason for performing a risk assessment of an operation
2. Identify the hazards of the operation
3. Identify the type of consequences of interest for each hazard
4. Identify the processes by which each hazard can result in its consequences
5. Calculate the frequency (probability) of each process and the magnitude of the associated consequences
6. Compute the expected consequence (risk) of each process as the product of process frequency and consequence magnitude
7. Sum all risks of like consequence

DOE Defense Waste Sites' Remediation Operations Analysis

1. Objective: Develop risk based comparisons among the alternative waste site remediation operations:

   a. Limited access
   b. Waste isolation
   c. Waste removal

2. Hazards:

   a. Buried radioactive wastes
   b. Dissolved/suspended radioactive wastes
   c. Buried toxic wastes
   d. Dissolved/suspended toxic wastes
   e. Construction/excavation hazards
   f. Heavy construction/excavation vehicles

3. Consequences:

   a. Radiation doses to onsite & offsite populations
   b. Toxic chemical effects on onsite & offsite population
   c. Construction/excavation injuries/fatilities to onsite populations

Process Definition Summary

HAZARD	PROCESS	CONSEQUENCE
Radioactive waste	Excavation/high wind	Onsite & offsite population dose
	Earthquake/surface water	Onsite & offsite population dose
	Excavation/fire/atm. trans.	Onsite & offsite population dose
	Excavation/direct exposure	Onsite dose
	Groudwater*	Offsite dose
	Biosphere*	"Onsite" dose
	Erosion-population access*	"Onsite" dose
Toxic waste	Similar to Radiation Waste	Similar to Radioactive Waste
Excavation/equipment	Excavation, transportation	Onsite injuries/ fatilities

*Very long term process

Summary of Risks Over 1000 Years

	No Action	Waste Isolation	Waste Removal
Near Term Risk (20 years)			
• Total Health Effects	4×10^{-7}	2×10^{-8}	4×10^{-5} (7×10^{-3})
• Offsite Health Effects	3×10^{-7}	2×10^{-8}	3×10^{-5} (4×10^{-3})
• Occupational Injuries	7×10^{-3}	23	99
• Occupational Fatalities	5×10^{-7}	2×10^{-3}	0.2
Long Term Risk (1000 years)			
• Total Health Effects	8	8	1
• Offsite Health Effects	1	0.9	0.9
• Total Toxic Burden/Pers/Yr $R_T = \sum \frac{\text{Burden}}{\text{No Effect Limit}}$	0.3	0.05	0.04

Summary of Risks Over 1000 Years (Continued)

	No Action	Waste Isolation	Waste Removal
Totals (1000 years)			
• Total Health Effects	8	8	1
• Modified Toxic Burden			
1 of 1000, FAT. at 0.001 R_T	0.5	0.5	0.5
1 of 100, FAT. at 0.01 R_T	5	5	5
1 of 10, FAT. at 0.1 R_T	50	0	0
• Total Health Effects 1000 Yr. Inst. Control	1	0.9	1
• Background Radiation Health Effects			
Offsite Pop. (50,000)	1000	1000	1000
Onsite Pop. (10)	0.2	0.2	0.2
• Cost (Million 1985 $)	50	200	10,000

Risk Analysis Issues

- Weight given to very long term projections
- Weight given to occupational injuries/fatalities vs numerically small future benefits
- Weights given to differing risk types (e.g., a fractional fatality vs many injuries)
- Weight given to cost-benefit or resource allocation considerations
- State of knowledge concerning population health effect responses (e.g., no effect limits, effects of multiple toxic chemicals, population sensitivities)
- Impact of "Not In My Backyard"

Benefits of Risk Analysis

1. Risk analysis is a powerful tool for simplifying complex problems to manageable proportions

2. Specifically addressing a broader range of issues may complicate near term decision making

3. However, the capability to address these issues directly should result in better decisions

Groundwater Transport Risk Analysis and Cumulative Impact Assessment of Waste Site Closure Options

Don J. Wilkes,
Science Applications International Corporation

ABSTRACT

GROUNDWATER TRANSPORT RISK ANALYSIS AND CUMULATIVE IMPACT ASSESSMENT OF WASTE SITE CLOSURE OPTIONS

In conjunction with reviewing waste management activities for groundwater protection at a defense activity site, environmental impacts of alternative closure and remedial actions are being assessed. Part of this assessment includes evaluation of the cumulative environmental consequences associated with closure and remedial activities at more than 80 waste sites. These waste sites are characterized as pits and basins containing solid and liquid low-level radioactive, hazardous non-radioactive, and mixed wastes. For data collection and assessment purposes, waste sites have been aggregated into 26 functional groupings according to the kinds of wastes they have received. The objectives of this study are: (1) to select a preferred alternative based upon the results of the disciplinary and option-specific assessments; and (2) aggregate impacts across functional groupings of waste sites for each of the closure alternatives and express these in a form useful for cumulative impact assessment on a site-wide basis.

GROUNDWATER TRANSPORT RISK ANALYSIS AND CUMULATIVE IMPACT ASSESSMENT OF WASTE SITE CLOSURE OPTIONS - Don J. Wilkes, Science Applications International Corporation, Oak Ridge, Tennessee

1.0 INTRODUCTION AND CONTEXT

1.1 BACKGROUND

In conjunction with reviewing waste management activities for groundwater protection at a defense activity site, environmental impacts of alternative closure and remedial actions are being assessed at more than 80 waste sites. These waste sites are characterized as pits and basins containing solid and liquid low-level radioactive, hazardous non-radioactive, and mixed wastes. For data collection and assessment purposes, waste sites have been aggregated into 26 functional groupings according to the kinds of wastes they have received.

Disciplinary assessments and modeling are being performed for each of the 26 waste site functional groupings. The principal focus of this study is to consider the disciplinary results available for each specific waste site grouping in the context of a cumulative or aggregate assessment of potential impacts across all 26 functional groupings of waste sites.

1.2 GENERIC DESCRIPTION OF WASTE SITE CLOSURE OPTIONS

The alternatives for waste site closure vary from site to site depending on the specific characteristics and requirements of each site. They can, however, be grouped into three generic categories of closure options as follows: (1) Closure with Waste Removal; (2) Closure without Waste Removal; and (3) No Action. The alternatives for closure and remedial action that are considered in the cumulative assessment relate in general to the site-specific options noted above, except that they would be applied across all sites. A fourth alternative is included in the assessment that would allow a combination of the other three alternatives (i.e., the application of closure alternatives on a site-specific basis, as appropriate to the special considerations and requirements for each site).

1.2.1 No Action

Under the No Action closure option, sites would be left largely in their present condition. Groundwater monitoring would be continued where appropriate, as would site maintenance (e.g., fencing, vegetation mowing, and erosion control). Sites containing impounded liquids would be allowed to dry by natural processes. Many would become temporary ponds, with volume depending on the rainfall regime.

1.2.2 Closure without Waste Removal

Closure under this option would involve many of the same types of procedures undertaken in the Closure with Waste Removal option, except that no waste would be exhumed. For those sites requiring placement of a nonpermeable cap over the sites, surface structures would have to be removed. Any sites that are currently inactive and have already been backfilled would require some excavation of backfill before capping. In other cases, retention tank discharge lines to the seepage basin and contaminated soil in the immediate vicinity of the discharge line would be excavated and moved to a suitable disposal facility. As was the case for the Closure with Waste Removal option, any impounded surface water would be drained before capping and/or grading and seeding. Before capping those sites containing high moisture content soils, the soil would be stabilized with a mixture of bentonite granules or crushed stone.

For those sites with containerized waste, the drums would be exhumed; the liquids in the drums stabilized with cement, bentonite, or another appropriate substance; and the drums reburied.

1.2.3 Closure with Waste Removal

This closure option involves excavating the waste, backfilling with clean soil, compacting to prevent settling, grading and seeding the site, transporting and disposing the excavated waste in an approved disposal site, and maintaining the site after closure activities have ended. Most sites will be capped with an infiltration barrier (usually consisting of an artificial membrane, compacted clay, sand, and gravel), which will be covered with clean soil, and subsequently graded and seeded.

Several basins contain impounded (bermed) water, which is to be removed under all closure options, either by infiltration and evaporation, or as in the case of several sites, by removal to a treatment plant. After the waste is exhumed, the berms would be used to backfill the basins.

Some sites may require groundwater remediation, involving placement of a hydraulic barrier (a soil-bentonite slurry wall) to retain the contaminated groundwater within a specified area, and/or pumping and treatment of the contaminated groundwater.

Depending on the hazards of the contaminants and character of the excavated soil, the exhumed waste may or may not be packaged and transported to a disposal and/or processing site. In some cases, the contaminated soil would be stabilized with bentonite before excavation, while at other sites the soil would be stabilized with cement or other stabilizers before disposal. The particular receiving facility to which the exhumed material would be transported depends on the character of the waste at the site.

Some sites have surface structures, such as concrete pads, pipelines, buildings, and parking lots, that would have to be removed before waste exhumation could begin. Similarly, some inactive sites have existing clay caps or backfill that would have to be removed to gain access to the contaminated waste.

Maintenance activities would include regular mowing and periodic inspection for unacceptable erosion. Groundwater would be monitored at most sites, quarterly or annually, for a period up to 30 years. New monitoring wells will be drilled at some sites. If groundwater monitoring indicates that contaminant levels are not decreasing, additional remedial action will be considered.

1.2.4 Combination-Closure of All Sites with Waste Removal at Selected Sites

Under this option, hazardous, low-level radioactive, and mixed wastes (including contaminated soils) would be removed to the extent practicable from selected existing waste sites based on cost-effectiveness and environmental/human health risks. After a maximum 100-year institutional control period, the areas from which waste material and contaminated soil had been removed could be used for purposes other than waste management. Sites from which waste material and contaminated soil had not been removed would be dedicated for waste management purposes if they could not be returned to public use after the 100-year control period.

2.0 OBJECTIVES OF THE ASSESSMENT

The principal objective of this cumulative impacts assessment is to aggregate impacts across all functional groupings of waste sites for each of four closure options and express these in a form useful to decision makers choosing the most suitable closure options.

These four closure options are:

- No action at all sites
- Closure without waste removal at all sites
- Closure with waste removal at all sites
- Combination-closure of all sites with waste removal at selected sites

3.0 METHODS AND SCOPE

3.1 OVERVIEW

The methods used for this assessment are shown in Figure 1. The assessment proceeds in two main stages. In Stage 1, the combination alternative is defined. To do this, the closure options at each functional grouping of waste sites are compared, and a preferred alternative is identified by considering

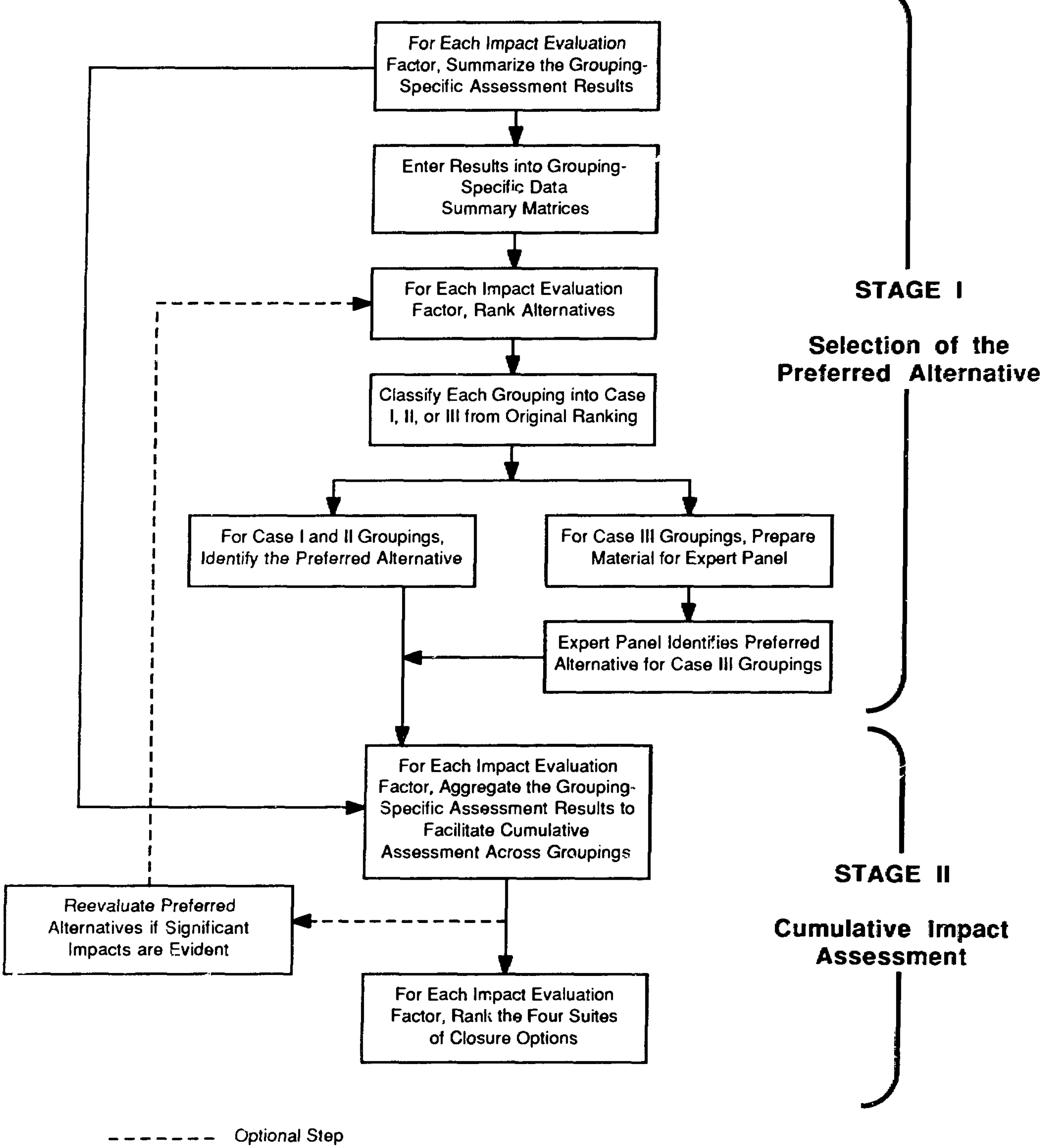

Figure 1. Summary Schematic of Methodology for Cumulative Impact Assessment

only impacts specific to each respective functional grouping. After the suite of 26 functional grouping-specific preferred alternatives has been identified (i.e., the combination alternative), the cumulative impacts are evaluated (in Stage II) for each of four closure options applied across all 80 waste sites.

The assessment used as base data the results of the functional grouping- and closure-option-specific analyses presented for the following impact evaluation factors:

- Human health effects
- Ecological effects
- Water resources and hydrological relationships
- Accident risks
- Archaeological resources
- Cost estimates

The results of the functional grouping- and closure-option-specific assessments for each evaluation factor are presented in summary matrices expressed in the appropriate physical or monetary units or qualitative terms. The approach permits evaluation of closure options by showing how they differ for each impact evaluation category.

For each of the closure options and impact categories, the results summarized in the initial sets of matrices are aggregated across functional groupings in a manner appropriate to the limitations of the data. This aggregation provides a comparative cumulative effects index for assessing the four closure options for the waste site groupings. An overall summary matrix across impact evaluation categories was not considered practicable. Such a matrix would be an overly simplified aggregation which could lead to subjective and potentially misleading comparisons.

3.2 PHASE I - IDENTIFICATION OF THE COMBINATION ALTERNATIVE

The grouping-specific evaluations will result in a ranking of the closure options for each impact evaluation factor. The next step is to identify the preferred alternative for each grouping from the various rankings.

As shown in Table 1, there are basically three cases that will have to be considered in selecting the preferred alternative for each grouping. The first case yields a single preferred alternative. In this case, alternative A is clearly preferred by at least one impact evaluation factor and is indifferent for the remaining evaluation factors. In the second case, alternatives A and B are clearly preferred to C, but there is indifference between A and B across the various factors. For this case, the preferred alternative at the site will be selected on the basis of minimum cost. For the third case, there is a clear conflict between two or more of the evaluation factor

TABLE 1. Three Cases of Preference Orderings

Case I - Preference Indicated

A > B > C
A = B > C
A = C > B

Case II - Indifference Indicated

A = B > C

Case III - Conflict Indicated

A > B > C
B > A = C

NOTE: A, B, and C refer to the three closure options. The examples are shown for the minimum number of preference orderings that make the case true. For Cases I and II it is assumed that the preference orderings in the remaining 3 and 5 impact evaluation areas, respectively, do not contradict those shown. The symbols include the following:

> strictly preferred
= indifferent

rankings. In this case, an expert panel will be used to select the preferred alternative.

The expert panel will be convened in a group format with a professional facilitator used as the group moderator. Two members of the project team will be observers but will not participate in the discussions. The purpose of the group's deliberations will be to identify the preferred alternative at groupings of sites where there is a clear conflict in the rankings between two or more impact evaluation factors. In effect, the expert panel will assess the relative importance of the evaluation factor after being provided estimates of the magnitudes of the impacts.

The expert panel will be provided with the following information about each grouping of waste sites: (1) a brief description of the current status of the site; (2) a matrix that summarizes the impacts for each closure option; and (3) the rankings of the closure options for each impact evaluation factor. With this information, the panel will identify the preferred closure alternative for each grouping.

In the group discussion, the panel will progress from grouping to grouping until the evaluations for all groupings are complete. Then the facilitator will ask the panel to reevaluate the groupings as a package to avoid any trending in the panel's initial selections.

Members of the panel will be drawn from the various disciplinary areas involved in assessing the cumulative impacts. Panel members would include members from the following areas:

- o Aquatic toxicologist
- o Geohydrologist
- o Environmental health specialist
- o Environmental engineer
- o Ecologist

3.3 PHASE II - CUMULATIVE ASSESSMENT

3.3.1 Health Effects

Health risks for each functional grouping of waste sites are expressed differently for the three types of contaminants considered:

1. Radionuclides
2. Non-radiological carcinogens
3. Toxic chemicals

In the health effects assessment, eight pathways of the hazardous materials to receiving populations have been addressed: three via "groundwater," three via "land," and two via "air."

Groundwater

- o Groundwater to river
- o Groundwater to 1-meter well
- o Groundwater to 100-meter well

Land

- o Reclaimed farmland
- o External gamma exposure
- o Erosion

Air

- o Respiratory intake and ingestion of food affected by deposition from air transport
- o External gamma exposure

The external gamma exposure pathway is relevant only to radiological contaminants. All other pathways are relevant to all contaminants.

Finally, the receptor populations were defined as follows:

1. Population drinking river water
2. Population eating biota from river
3. "Onsite" population after year 100
4. Occupational workforce during period of institutional control
5. Surrounding population exposed to contaminants via air pathways

The results of the human health effects assessment at each functional grouping of waste sites were summarized in simple data matrices (Table 2) to facilitate comparisons of the closure options. All relevant pathways for three categories of contaminants are considered for individual and population risk. Atmospheric pathways are analyzed separately from the surface and subsurface pathways because of differences in the original modeling methods and base assumptions. Also, occupational risks are kept separate because of the limited duration (i.e., essentially at time of closure) of workforce exposure.

TABLE 2. Summary Matrix of Maximum Health Risks

Pathway	Radionuclides: Individual (HE/yr)	Radionuclides: Population (HE)	Non-Radiological Carcinogens: Individual (HE/lifetime)	Non-Radiological Carcinogens: Population (HE)	Toxic Chemicals: Individual (EPA Hazard Index)
Public					
Groundwater to River	Maximum exposed individual risk (health effects/year) in peak year	Total risk (health effects) from exposure in year of maximum exposure	Maximum exposed individual risk (health effects/lifetime) from lifetime beginning in year of maximum exposure	Total risk (health effects) from exposure in year of maximum exposure	Maximum exposed individual risk (sum of ADI fractions) in year of maximum exposure
Groundwater to 1m Well	Maximum exposed individual risk (health effects/year) in peak year	Total risk (health effects) from exposure in year of maximum exposure	Maximum exposed individual risk (health effects/lifetime) from lifetime beginning in year of maximum exposure	Total risk (health effects) from exposure in year of maximum exposure	Maximum exposed individual risk (sum of ADI fractions) in year of maximum exposure

TABLE 2. Summary Matrix of Maximum Health Risks (Continued)

Pathway	Radionuclides		Non-Radiological Carcinogens		Toxic Chemicals
	Individual (HE/yr)	Population (HE)	Individual (HE/lifetime)	Population (HE)	Individual (EPA Hazard Index)
Groundwater to 100m Well	Maximum exposed individual risk (health effects/year) in peak year	Total risk (health effects) from exposure in year of maximum exposure	Maximum exposed individual risk (health effects/lifetime) from lifetime beginning in year of maximum exposure	Total risk (health effects) from exposure in year of maximum exposure	Maximum exposed individual risk (sum of ADI fractions) in year of maximum exposure
Reclaimed Farm	Maximum exposed individual risk (health effects/year) in peak year	Total risk (health effects) from exposure in year of maximum exposure	Maximum exposed individual risk (health effects/lifetime) from lifetime beginning in year of maximum exposure	Total risk (health effects) from exposure in year of maximum exposure	Maximum exposed individual risk (sum of ADI fractions) in year of maximum exposure
Direct Gamma	Maximum exposed individual risk (health effects/year) in peak year	Total risk (health effects) from exposure in year of maximum exposure	Maximum exposed individual risk (health effects/lifetime) from lifetime beginning in year of maximum exposure	Total risk (health effects) from exposure in year of maximum exposure	Maximum exposed individual risk (sum of ADI fractions) in year of maximum exposure

TABLE 2. Summary Matrix of Maximum Health Risks (Continued)

Pathway	Radionuclides: Individual (HE/yr)	Radionuclides: Population (HE)	Non-Radiological Carcinogens: Individual (HE/lifetime)	Non-Radiological Carcinogens: Population (HE)	Toxic Chemicals: Individual (EPA Hazard Index)
Erosion	Maximum exposed individual risk (health effects/year) in peak year	Total risk (health effects) from exposure in year of maximum exposure	Maximum exposed individual risk (health effects/lifetime) from lifetime beginning in year of maximum exposure	Total risk (health effects) from exposure in year of maximum exposureMaximum exposed individual risk (sum of ADI fractions) in year of maximum exposure	Maximum exposed individual risk (sum of ADI fractions) in year of maximum exposure
Atmospheric	(Maximum) individual risk (health effects/year) from exposure in year of maximum exposure	Total risk (health effects) from exposure in year of maximum exposure	(Maximum) individual risk (health effects/lifetime) from lifetime of exposure beginning in year of maximum exposure	Total risk (health effects) from lifetime exposure beginning in year of maximum exposure	(Maximum) individual risk (sum of ADI fractions) in year of maximum exposure

TABLE 2. Summary for Matrix of Maximum Health Risks (Continued)

Pathway	Radionuclides: Individual (HE/yr)	Radionuclides: Population (HE)	Non-Radiological Carcinogens: Individual (HE/lifetime)	Non-Radiological Carcinogens: Population (HE)	Toxic Chemicals: Individual (EPA Hazard Index)
Occupational					
All	(Maximum) individual risk (health effects/year) from exposure during specified closure option	Total risk (health effects) for specified closure option	(Maximum) individual risk (health effects/lifetime) from exposure during specified closure option	Total risk (health effects) for specified closure option	(Maximum) individual risk (sum of ADI fractions) from exposure during specified closure option

The original health effects data for each population group, contaminant category, and time period for each option at each site grouping are summed across all groupings of waste sites for each of the four suites of closure options to provide relative indices for comparative assessment of cumulative impacts. On the basis of these summations, data are arrayed in the resulting matrices to show: (1) cumulative health risks by time period; and (2) maximum (cumulative) health risks by pathway with peak year indicated.
Human health risks were calculated to the population level. Results indicate that, when all closure options and sites are considered, no pathways can be eliminated as being quantitatively unimportant under all options at all sites. Therefore, risks are summed across surface and subsurface pathways (atmospheric release pathways and occupational risks are assessed separately) to get a total onsite population risk for each type of contaminant, for each of the time periods modeled. The year of highest risk is selected to represent population risk for the cumulative assessment process. As an additional index of cumulative impact, risks are summed across all surface and subsurface pathways for the entire 1000 time period modeled for each closure option. For the occupational workforce total risk is calculated for each closure option.

3.3.2 Ecological Effects

The approach to cumulating ecological effects involves: (1) segregating groupings of waste sites on the basis of the surface water bodies (streams or wetland system) into which they drain: (2) calculating their aggregate contribution to surface water quality; and (3) comparing these aggregated concentrations to benchmarks, using the quotient method. The grouping-specific assessments consider only the "worst" time period, which is not consistently the same across site groupings or options. Therefore, additional time-period-specific calculations of surface water quality are performed to implement this methodology. For all groupings drained by a common stream or wetland system, data are developed for the worst overall time period (i.e., that time period when the combined impacts from all relevant sites is greatest). Over the 48 geographically distinct locations of waste sites, there are six surface water/wetland systems for which such cumulations are performed. In the quotient method, calculated doses (environmental concentrations or body burdens) are compared to benchmarks representing ecologically meaningful endpoints. This results in the ranking of various contaminants by relative risk (i.e., the higher the quotient the higher the risk). The QM does not estimate uncertainties associated with the risk estimate, nor does it provide the capability to predict effects. It is appropriately used to compare closure options at a site or in this case, across groupings of sites, but not to estimate risks, per se.

The main advantage of the quotient method are: (1) it can be applied rapidly once exposures are estimated, thereby permitting its application to numerous site specific closure option scenarios; (2) it can be applied to both terrestrial and aquatic ecosystems; and (3) it can be applied to both radiological and non-radiological contaminants if benchmarks can be identified or developed in the cumulative assessment. The same benchmarks will be used as were used in the grouping/specific assessments.

Final results are related to endangered species and critical habitats whenever possible.

3.3.3 Water Resources and Hydrological Relationships

Grouping-specific evaluations were completed and the potential for contamination of shallow offsite aquifers and the deep "Tuscaloosa" aquifer are evaluated qualitatively from the perspective of all the relevant waste sites combined.

3.3.4 Accident Risks

The basic methodology involved in developing group-specific or option specific risk parameters from the frequency[1] and consequence data (SAIC 86/1106) is straightforward. From the data, numerical risk parameters (expectations[2] of a consequence expressed as the product of frequency and consequence) can be developed for each site, option, and accident. These risks (expectations) can then be added as appropriate to calculate the overall risks per option values.

From the accidents analyzed, six types of consequences were identified: population dose, maximum individual dose, toxic chemical concentrations, local contamination, occupational injuries and occupational fatalities. Maximum individual dose is not a consequence but the potential for consequence (dose) if a person remained at a location of maximum boundary concentrations. The actual dose contribution is included in the population dose values.

Risks for toxic chemical releases were considered negligible. Peak calculated concentrations in the 0-1 mile distance range were, in order of descending magnitude, 40% of the limiting concentration (RA), 5.5%, 3%, and the remainder of the 167 calculated RA. Values (excluding variants) were approximately 1% and less.

Based on the above, the following risk types were considered.

1. Expected radiological dose to the onsite population (person-rem/closure option)

2. Expected radiological dose to the offsite population (person-rem/closure option)

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1 Frequencies (SAIC 86/1106) expressed as events/year x years/option or events/manhour x manhours/option. These may also be called the expected number of events.

2 The product of the consequence per event and the expected number of events yielding the expected consequence.

3. Expected total dose (sum of expected onsite and offsite closures, i.e., person-rem/closure option)

4. Expected number of local contamination incidents per closure option

5. Expected number of injuries per closure option

6. Expected number of fatalities per closure option

The risks of like consequences were summed over all accidents for each site and option yielding the six risk measures listed above. No attempt was made to develop health effect measures which combined the risk types listed. It is recognized that the expected health effects from local contaminations are negligible. This risk type was retained for completeness. The risk values were then summed over the sites to yield the risks per option, per functional site grouping, and the risks per option.

3.3.5 Archaeological and Cultural Resources

The nature of archaeological and cultural resources dictate an approach to impact assessment that is somewhat different from that used for other resources. Cumulative assessment must be performed on a site-specific basis for the area of concern because there is no interaction between these resources from site to site. The quality of any archaeologically or historically significant sites are determined from existing survey data where such sites exist in conjunction with existing waste sites. For such sites, the potential magnitude for unmitigated effects imposed by the various closure options are compared. To cumulate the effects by option for an assessment across waste sites, qualitative expressions of impacts and total numbers of impacted sites are used.

3.3.6 Cost Estimates

The relative costs of implementing each of the proposed closure options have been estimated in conjunction with preparing Venture Guidance Appraisals (VGA) for each of the waste site functional groups. Three VGA estimate categories were identified (i.e., preparation and waste treatment; waste disposal; maintenance and monitoring) and totaled by alternative for each of the 26 groups. For some sites, sub-alternatives (e.g., closure with cap without waste removal; closure without cap without waste removal) were identified in the VGAs with costs estimated. Cumulative costs of each option will be determined by summing costs, by option, across groupings of waste sites. A range of costs will be used in the summation process to account for sub-options.

4.0 SUMMARY OF RESULTS

4.1 IDENTIFICATION OF THE COMBINATION ALTERNATIVE

The process for identification of grouping specific preferred alternatives proved to be rather straightforward. Waste removal was indicated at only two site groupings. The no action alternative, which included site maintenance and monitoring, was selected for five site groupings. Closure actions without waste removal was the alternative of choice selected for the remaining site groupings. This mix of alternatives comprised the combination alternative used in the cumulative assessment.

4.2 CUMULATIVE ASSESSMENT

4.2.1 Human Health

At existing waste sites, there would be no significant increase in health effects under the combination alternative. For new waste sites, the essentially zero or ALARA release design would prevent significant radionuclide and hazardous chemical health effects.

4.2.2 Ecology

The combination strategy at existing waste sites would significantly reduce impacts to aquatic biota, particularly long-term effects. Terrestrial wildlife would also benefit from restricted access to open waste sites and improved groundwater quality. The use of borrow pits for backfill in closure actions would create minor short-term impacts. For new waste sites, no contaminant-related impacts are expected because of the zero release or ALARA design features. However, impacts will result at new waste facilities from the clearing of land, and the dedication of areas for storage and disposal.

4.2.3 Hydrology

At existing sites, the combination of closure and remedial actions with the removal of hazardous and radioactive wastes from selected sites would reduce contaminant concentrations in groundwater to acceptable water quality criteria standards. Groundwater drawdown effects would be localized. New facilities would be designed for essentially zero or ALARA releases of contaminants to the groundwater. Surface water quality is expected to improve as a result of actions at existing sites and new facilities.

4.2.4 Accidents/Occupational Risks

The removal and transport of waste from existing sites to storage and disposal locations by vehicles will involve risks of fires, spills, leaks, and exposure of onsite workers. At new facilities, high-integrity containers, spill recovery measures, and other safety procedures will reduce impacts from accidents. Once existing sites are closed and new waste management procedures are implemented, future accident rates for waste disposal and recovery operations should be reduced.

4.2.5 Archaeological Resources

An archaeological survey and evaluation concluded there will be no effect on the archaeological resources from the closure of existing sites or the development of new waste management facilities.

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Risk Assessment of Mixed Waste Sites

Presented by:

David F. Montague, JBF Associates, Inc.

RISK ASSESSMENT OF MIXED WASTE SITES

Waste sites at U.S. Department of Energy facilities often contain both radioactive and nonradioactive contaminants. Remedial actions for these sites are being determined, in part, by the risk the contamination poses to cleanup workers and the public. Special assessment problems and considerations arise when both radioactive and hazardous nonradioactive contaminants are present at the same site. This paper presents an overview of the methodology used to solve these assessment problems, the same methodology used to estimate public and worker risk from atmospherically released contaminants at 83 Savannah River Plant waste sites. Also, risk assessment results are presented for 3 different remedial actions being considered for each of the 83 sites.

RISK ASSESSMENT OF MIXED WASTE SITES - David F. Montague and Gregory A. Holton, JBF Associates, Inc., Knoxville, TN 37932-3341

INTRODUCTION

As part of its ongoing efforts to ensure environmental regulation compliance at DOE facilities, DOE published on April 26, 1985, a notice of intent to write an Environmental Impact Statement on Waste Management Activities for Groundwater Protection (Groundwater EIS) at the Savannah River Plant (SRP). In order for the EIS to be prepared, it was necessary for E. I. du Pont de Nemours & Co. (DuPont) to conduct a cost/benefit human health risk assessment of the several SRP waste sites being considered for closure. To perform a human health risk assessment of each waste site for each closure action considered, DuPont organized a project team led by personnel from the Savannah River Laboratory (SRL) and supported by outside contractors specializing in risk assessment work. As part of that team, JBF Associates, Inc. (JBFA) performed an atmospheric containment transport analysis and human health risk assessment of nonradioactive contaminants from SRP waste sites.

Eighty waste sites, categorized into 26 waste site functional groupings (Table 1) were being considered for closure. For each waste site, three closure actions were examined: (1) excavate the site, backfill it, and cap it followed by regular groundwater monitoring (Option 1); (2) backfill and cap the site followed by regular groundwater monitoring (Option 2); and (3) no remedial action, regular groundwater monitoring, and some site maintenance work (Option 3). The human health risk assessment performed by JBFA estimated the public and worker risks from contaminants released to the atmosphere from each waste site for each closure option.

This paper first presents the methodology JBFA used to estimate the public and worker risks attributable to the inhalation and ingestion of airborne, nonradioactive contaminants. Following the description of our analysis methodology, we present the risk results for the waste sites that were due to atmospherically released nonradioactive contaminants. Both worker risks and public risks are presented. (Public and occupational risks from airborne, radioactive releases were estimated by others and are not presented herein.) Finally, we present the results and conclusions derived from our analysis of the risk from airborne, nonradioactive contaminants.

METHODOLOGY

The waste sites at the Savannah River Plant contained a variety of wastes that posed some risk to the public and to workers who would be involved in cleanup activities at the sites. To determine the public and worker risks attributable to nonradioactive contaminants that could be atmospherically released from the sites in a functional grouping, we

Table I The 26 Waste Site Functional Groupings Defined for Analysis

Functional Grouping Name	DPST No.[a]	Number of Sites Considered for Closure
SRL Seepage Basins	688	3
Metallurgical Laboratory Basin	689	1
Burning/Rubble Pits	690	15
Metals Burning Pit/Misc Chemical Basin	691	2
Old F-Area Seepage Basin	692	1
Separations Area Retention Basins	693	2
Radioactive Waste Burial Grounds	694	2
Bingham Pump Outage Pits	695	7
Hydrofluoric Acid Spill Area	696	1
SRL Oil Test Site	697	1
New TNX Seepage Basin	698	1
Road A Chemical Basin	699	1
L-Area Oil and Chemical Basin	700	1
Waste Oil Basins	701	2
Silverton Road Waste Site	702	1
M-Area Settling Basin & Vicinity	703	3
F-Area Seepage Basins	704	3
Acid/Caustic Basins	705	6
H-Area Seepage Basins	706	4
Reactor Seepage Basins	707	7
Ford Building Waste Site	708	1
Ford Building Seepage Basin	709	1
Old TNX Seepage Basin	710	2
TNX Burying Ground	711	4
CMP Pits	712	7
Gun Site 720 Rubble Pit	713	1
		80 TOTAL

[a]This number is a Savannah River Laboratory document number and is used in this paper to designate functional groupings.

used the following five-step procedure: (1) estimating the contaminant source terms for the sites, (2) modeling the atmospheric transport of contaminants from the sites, (3) estimating the public exposure to airborne contaminants, (4) estimating the public risk associated with exposure to these contaminants, and (5) estimating the worker risk associated with exposure to airborne contaminants generated during site cleanups. (Similar methodology was used to estimate risks from atmospherically released radioactive contaminants.)

We accomplished the five steps of the procedure with the aid of computer programs contained within the automated CHEMTREX Exposure Analysis Methodology. The programs modeled various physical processes that were associated with each step. For example, the XOQDOQ program[1] was used to estimate contaminant atmospheric dispersion and deposition (Step 2). Figure 1 shows the program(s) used for each step of the analysis, the interface between programs, and the inputs and outputs for each program.

The source term estimation step initially involved selecting the contaminants of concern for each site based on site waste disposal history, groundwater monitoring results, and core drilling analysis results provided by SRL and SRL-developed screening criteria.[2] After the contaminants of concern had been selected, we estimated initial site contaminant concentration profiles using either (1) core sample results for the site (if this information was available) or (2) historical inventory data and contaminant transport modeling techniques (SESOIL[3] and HISTORY*). After the initial concentration profiles had been determined, we used the SESOIL computer program and regression models (REGRES†) to determine a time-dependent concentration profile and volatilization for each site. These profile and volatilization results, in conjunction with a saltation model and excavation-dust generation models (MARIAH), were used to estimate the contaminant loading to the atmosphere for each site.

The second step of the analysis, modeling the atmospheric transport of contaminants from the waste sites to potential receptor sites, was accomplished with the use of the XOQDOQ computer program. XOQDOQ uses a modified Gaussian plume model to estimate atmospheric contaminant concentrations as a function of distance and direction from a waste site. Inputs to the program included the time-dependent contaminant source strength (our source term estimate) and site meteorological conditions (taken from SRL data).

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*HISTORY is a simple LOTUS® 1-2-3® program that uses historical SESOIL results from several years to determine the contaminant inventory at a given time.

†REGRES is a simple linear regression model that estimates regression parameter values.

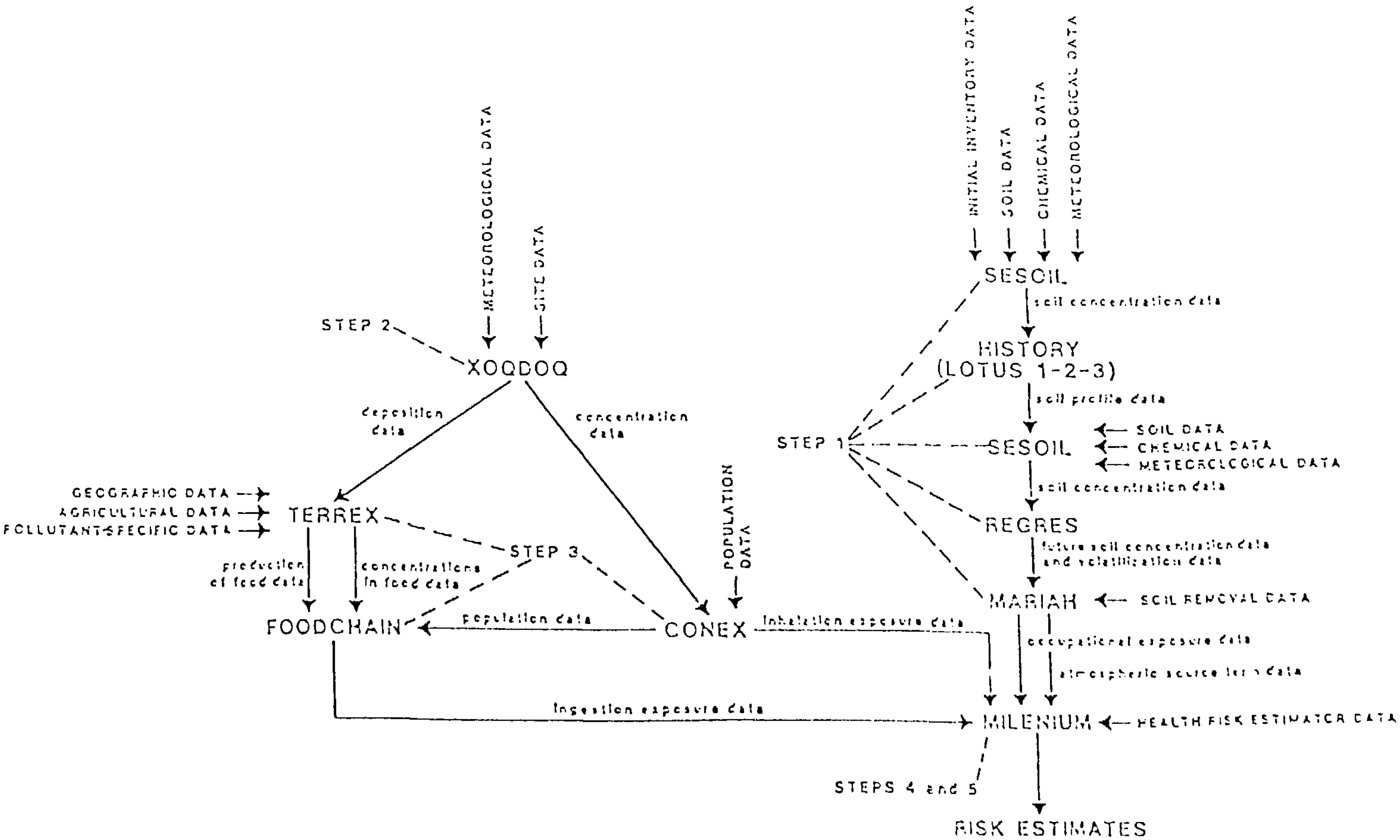

Figure 1 The Computer Programs (with Input and Output Files) Used To Estimate Risks

After determining contaminant concentrations at potential receptor sites, we translated these results into population exposures (Step 3 of the analysis). We considered population exposures to airborne contaminants via two pathways: (1) the inhalation of polluted air and (2) the ingestion of contaminated foodstuffs. We used the CONEX computer program[4] to (1) combine the XOQDOQ atmospheric concentration results with the local population demographics and (2) estimate time-dependent population inhalation exposures to polluted air. To estimate exposures to contaminated foodstuffs, we first used the TERREX computer program[4] to combine the XOQDOQ[1] deposition results with local crop production data. We then used the FOODCHAIN program[4] to combine TERREX results with local population demographics and estimate population ingestion exposures to contaminated foodstuffs.

The risk posed to the public by the waste sites for each of the three cleanup options was estimated in Step 4 using the MILENIUM program. For carcinogenic contaminants, MILENIUM translated time-dependent exposure results into a population dose and into a maximally exposed individual dose. It then used these dose results and appropriate unit carcinogenic risk factors (UCRs) to estimate the population risk and maximally exposed individual risk that were due to exposure to carcinogens. Moving-average, 50-year (lifetime) inhalation and ingestion doses were multiplied by inhalation and ingestion UCRs to estimate carcinogenic risk. The total carcinogenic risk posed to the public by a functional grouping, for a given year, was estimated by summing the carcinogenic risk results for all contaminants at a waste site, for all waste sites in the functional grouping.

For noncarcinogenic contaminants, MILENIUM translated time-dependent exposure results into a maximally exposed individual dose only. Using these dose results and the appropriate acceptable daily intakes (ADIs), MILENIUM then estimated the maximally exposed individual risk. Individual year daily inhalation and ingestion doses were divided by inhalation and ingestion ADIs to estimate noncarcinogenic risk. As with the carcinogenic contaminants, the total noncarcinogenic risk posed to the public by a functional grouping, for a given year, was estimated by summing the noncarcinogenic risk results for all contaminants at a waste site, for all waste sites in the functional grouping.

In the last step of the analysis, the risk posed to workers who would be involved in excavating the sites was estimated using the MARIAH results from Step 1 and the MILENIUM program. MARIAH had estimated the amount of contaminated dust that would be generated during the excavation of the sites and the time that would be required for excavating the sites. MILENIUM then used these results and appropriate UCRs and ADIs to estimate worker risk. Risk estimates were computed for two cases: (1) workers wearing no special, protective clothing and (2) workers wearing a full facepiece, air purifying negative pressure respirator.

RISK ASSESSMENT RESULTS

The human health risk assessment calculated the following for each of the waste sites:

1. population exposures and health risks, by site and closure option, attributable to releases of contaminants for a 1000-year assessment period. (These exposures and risks were determined for the public within 50 mi of the SRP waste sites)

2. worker exposures and risks attributable to releases of contaminants during site excavations

The results presented in this section are the human health risks by waste site and closure option attributable to atmospherically released nonradioactive contaminants. In particular, the results contained in this section are (1) tables that summarize, for the public risks, the total carcinogenic and noncarcinogenic risks for each functional grouping for three selected years--1986, 2085, and 2985;* (2) summaries of the functional groupings that dominate the risk for each closure option analyzed; (3) summaries of the contaminants that are the major contributors to these risks for each functional grouping; and (4) a table that summarizes worker risks attributable to atmospheric releases of nonradioactive contaminants during site excavations.

While it was desirable to portray the health risks for each waste site/closure option as a single value, research performed by the analysis team determined that there was no rigorously defendable method for combining the health impacts associated with chemical carcinogens, noncarcinogens, and radioactive contaminants and reporting these impacts as a single risk value. Thus, the results presented herein are in terms of chemical carcinogenic risk and noncarcinogenic risk for the functional groupings.

Also, this analysis was one designed to obtain data upon which risk comparisons for each of three closure options could be made. Caution should be exercised in interpreting the results of our analysis. Mitigating actions, such as population diurnal movement, indoor

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*The three years for which the risk results are reported represent the following: 1986 - the assumed year in which remedial actions would occur and the waste site be closed; 2085 - 100 years after closure of the waste site, at which time the SRP reservation is assumed open for public habitation; 2985 - 1000 years after closure of the waste site and the end of our assessment period.

sheltering, and dust control were not considered in the assessment of human exposures. Also, the "rule-of-reason" was applied at all sites when contaminant input data were quantified (i.e., we usually selected average or most-likely input parameter values and conditions for our analyses versus worst-case values). When contaminant input data had not been previously quantified, conservative assumptions regarding the contaminant's chemical form, transport, and fate were made. Consequently, the assessment results reported herein are appropriate for making relative risk comparisons but not appropriate for drawing conclusions about the absolute risk posed by any cleanup option considered for any SRL waste site. In addition, because of inherent uncertainties associated with the data input to this analysis (and hence the risk estimates) caution should also be exercised when making relative risk comparisons.

PUBLIC EXPOSURE AND RISK FROM CARCINOGENS

Two measures of public risk were calculated for exposures to carcinogens: (1) the risk to a maximally exposed individual and (2) the risk to the population as a whole. These measures represent (1) the maximum insult to any one individual and (2) the averaged, total insult to the population as a whole.

For the Years 1986, 2085, and 2985 in the assessment period, Tables 2 through 4 contain summaries of the calculated carcinogenic risks, by site closure option, for both the maximally exposed individual and the population, for each functional grouping. The risk to the maximally exposed individual is the "health effects per lifetime," or the probability that the maximally exposed individual will suffer a health effect due to exposure to a specified carcinogen (if the individual were to receive the calculated dose over his lifetime). The risk to the population is the "health effects" the population would experience in the 50-year period beginning in the year represented, because of exposure to site releases of carcinogens (if the population were to receive the calculated average dose over the 50-year period).

Option 3 involves the least amount of remedial action for the three closure options analyzed. Risk results for Option 3 (allowing the waste sites to remain undisturbed) also show the highest calculated risk to the public for all functional groupings (except for 694, the Radioactive Waste Burial Grounds). The five functional groupings with the highest calculated risk for Option 3 are, by year:

Year 1986

Functional Grouping	Population	Max. Exposed Indiv.
703	1.38E-03	2.17E-08
688	1.34E-03	2.31E-08
700	5.88E-04	8.59E-09
706	2.26E-04	3.30E-09
710	1.33E-04	1.92E-09

Table 2 Summary of Public Risks Attributable to Atmospherically Released Carcinogens, by Option, for the Year 1986[a]

Functional Grouping	Waste Removal and Closure		No Waste Removal and Closure		No Action	
	Population	Max. Exposed Indiv.	Population	Max. Exposed Indiv.	Population	Max. Exposed Indiv.
688	6.31E-07[b]	1.12E-11	0.00E-01	0.00E-01	1.34E-03	2.31E-08
689	1.23E-09	1.86E-14	0.00E-01	0.00E-01	9.01E-06	1.33E-10
690	1.12E-06	1.89E-11	3.31E-05	4.87E-10	3.31E-05	4.87E-10
691	2.74E-11	3.65E-16	0.00E-01	0.00E-01	3.54E-11	5.07E-16
692	4.72E-10	8.39E-15	0.00E-01	0.00E-01	7.21E-07	1.22E-11
693[c]	-	-	-	-	-	-
694	8.22E-08	1.46E-12	0.00E-01	0.00E-01	0.00E-01	0.00E-01
695[c]	-	-	-	-	-	-
696[c]	-	-	-	-	-	-
697[d]	-	-	-	-	-	-
698	1.59E-09	2.82E-14	0.00E-01	0.00E-01	1.37E-05	1.92E-10
699[c]	-	-	-	-	-	-
700	1.03E-07	1.83E-12	0.00E-01	0.00E-01	5.88E-04	8.59E-09
701	1.42E-15	2.53E-20	1.20E-14	2.13E-19	1.20E-14	2.13E-19
702	8.32E-16	1.48E-20	0.00E-01	0.00E-01	4.41E-11	6.98E-16
703	9.06E-04	1.52E-08	9.06E-04	1.52E-08	1.38E-03	2.17E-08
704	9.77E-09	1.74E-13	0.00E-01	0.00E-01	1.97E-05	2.90E-10
705	2.06E-09	3.67E-14	8.54E-13	1.52E-17	6.32E-06	1.04E-10
706	1.18E-07	2.10E-12	0.00E-01	0.00E-01	2.26E-04	3.30E-09
707[c]	-	-	-	-	-	-
708[d]	-	-	-	-	-	-
709	1.36E-09	2.42E-14	0.00E-01	0.00E-01	7.75E-06	1.14E-10
710	7.06E-08	1.26E-12	0.00E-01	0.00E-01	1.33E-04	1.92E-09
711[c]	-	-	-	-	-	-
712	1.29E-07	2.31E-12	0.00E-01	0.00E-01	1.22E-05	2.17E-10
713[d]	-	-	-	-	-	-

[a]Risks to the population are the health effects; risks to the maximally exposed individual are the health effects per lifetime. The risks for a functional grouping are the total risks posed by all sites in the functional grouping.

[b]The value 6.31E-07 is read 6.31×10^{-7}; this same notation applies to all values in this table.

[c]There were no carcinogens (among the nonradioactive contaminants) selected for analysis for this functional grouping.

[d]This functional grouping was not analyzed.

Table 3 Summary of Public Risks Attributable to Atmospherically Released Carcinogens, by Option, for the Year 2085[a]

Functional Grouping	Waste Removal and Closure		No Waste Removal and Closure		No Action	
	Population	Max. Exposed Indiv.	Population	Max. Exposed Indiv.	Population	Max. Exposed Indiv.
688	5.01E-12[b]	1.24E-15	5.01E-12	1.24E-15	6.50E-05	1.61E-08
689	1.16E-09	2.88E-13	1.17E-09	2.89E-13	1.98E-06	4.92E-10
690	7.28E-08	1.80E-11	7.54E-06	1.87E-09	7.54E-06	1.87E-09
691	8.74E-12	2.17E-15	8.74E-12	2.17E-15	8.74E-12	2.17E-15
692	4.60E-13	1.14E-16	4.62E-13	1.15E-16	4.69E-08	1.16E-11
693[c]	-	-	-	-	-	-
694	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
695[c]	-	-	-	-	-	-
696[c]	-	-	-	-	-	-
697[d]	-	-	-	-	-	-
698	4.20E-17	1.04E-20	4.20E-17	1.04E-20	7.13E-06	1.77E-09
699[c]	-	-	-	-	-	-
700	2.36E-22	5.85E-26	2.35E-22	5.85E-26	1.49E-04	3.70E-08
701	3.88E-27	9.63E-31	3.88E-27	9.63E-31	3.88E-27	9.63E-31
702	2.52E-12	6.25E-16	2.52E-12	6.25E-16	2.52E-12	6.25E-16
703	1.74E-06	4.30E-10	1.74E-06	4.30E-10	3.72E-04	9.22E-08
704	0.00E-01	0.00E-01	0.00E-01	0.00E-01	4.56E-06	1.13E-09
705	1.84E-18	4.56E-22	1.84E-18	4.56E-22	6.05E-07	1.50E-10
706	0.00E-01	0.00E-01	0.00E-01	0.00E-01	5.52E-05	1.37E-08
707[c]	-	-	-	-	-	-
708[d]	-	-	-	-	-	-
709	0.00E-01	0.00E-01	0.00E-01	0.00E-01	1.85E-06	4.58E-10
710	1.01E-13	2.51E-17	1.01E-13	2.51E-17	4.44E-05	1.01E-08
711[c]	-	-	-	-	-	-
712	7.94E-17	1.97E-20	1.37E-11	3.40E-15	1.37E-11	3.40E-15
713[d]	-	-	-	-	-	-

[a]Risks to the population are the health effects; risks to the maximally exposed individual are the health effects per lifetime. The risks for a functional grouping are the total risks posed by all sites in the functional grouping.

[b]The value 5.01E-12 is read 5.01×10^{-12}; this same notation applies to all values in this table.

[c]There were no carcinogens (among the nonradioactive contaminants) selected for analysis for this functional grouping.

[d]This functional grouping was not analyzed.

Table 4 Summary of Public Risks Attributable to Atmospherically Released Carcinogens, by Option, for the Year 2985[a]

Functional Grouping	Waste Removal and Closure		No Waste Removal and Closure		No Action	
	Population	Max. Exposed Indiv.	Population	Max. Exposed Indiv.	Population	Max. Exposed Indiv.
688	2.07E-26[b]	5.14E-30	2.07E-26	5.14E-30	1.14E-09	2.82E-13
689	5.02E-10	1.24E-13	5.03E-10	1.25E-13	5.04E-10	1.25E-13
690	9.40E-18	2.33E-21	9.74E-16	2.42E-19	9.74E-16	2.42E-19
691	7.32E-22	1.82E-25	7.32E-22	1.82E-25	7.32E-22	1.82E-25
692	1.24E-34	2.90E-38	1.25E-34	2.92E-38	5.39E-18	1.34E-21
693[c]	-	-	-	-	-	-
694	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
695[b]	-	-	-	-	-	-
696[c]	-	-	-	-	-	-
697[d]	-	-	-	-	-	-
698	0.00E-01	0.00E-01	0.00E-01	0.00E-01	3.93E-10	9.74E-14
699[c]	-	-	-	-	-	-
700	0.00E-01	0.00E-01	0.00E-01	0.00E-01	1.70E-09	4.21E-13
701	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
702	5.19E-28	1.29E-31	5.19E-28	1.29E-31	5.19E-28	1.29E-31
703	2.36E-10	5.87E-14	1.94E-09	4.80E-13	4.13E-08	1.03E-11
704	0.00E-01	0.00E-01	0.00E-01	0.00E-01	8.61E-16	2.14E-19
705	0.00E-01	0.00E-01	0.00E-01	0.00E-01	6.84E-17	1.70E-20
706	0.00E-01	0.00E-01	0.00E-01	0.00E-01	1.47E-14	3.65E-18
707[c]	-	-	-	-	-	-
708[d]	-	-	-	-	-	-
709	0.00E-01	0.00E-01	0.00E-01	0.00E-01	3.74E-16	9.28E-20
710	0.00E-01	0.00E-01	0.00E-01	0.00E-01	2.16E-09	5.37E-13
711[c]	-	-	-	-	-	-
712	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
713[d]	-	-	-	-	-	-

[a] Risks to the population are the health effects; risks to the maximally exposed individual are the health effects per lifetime. The risks for a functional grouping are the total risks posed by all sites in the functional grouping.
[b] The value 2.07E-26 is read 2.07×10^{-26}; this same notation applies to all values in this table.
[c] There were no carcinogens (among the nonradioactive contaminants) selected for analysis for this functional grouping.
[d] This functional grouping was not analyzed.

Year 2085

Functional Grouping	Population	Max. Exposed Indiv.
703	3.64E-04	9.22E-08
700	1.49E-04	3.70E-08
688	6.50E-05	1.61E-08
706	5.52E-05	1.37E-08
710	4.44E-05	1.01E-08

Year 2985

Functional Grouping	Population	Max. Exposed Indiv.
703	4.13E-08	1.03E-11
710	2.16E-09	5.37E-13
700	1.70E-09	4.21E-13
688	1.14E-09	2.82E-13
689	5.04E-10	1.25E-13

Functional Groupings 688, 700, 703, and 710 have higher risks (than the other analyzed functional groupings) over the entire 1000-year assessment period because these sites contain carcinogenic metals, such as chromium VI and nickel, which are relatively immobile.

Option 1 involves the greatest amount of remedial action (excavating wastes, backfilling the waste site[s], and usually covering the site[s] with a low-permeability cap) of the three closure options analyzed. All remedial action was assumed started and completed in 1986. The highest risk results in 1986 for the functional groupings when closed under Option 1 were as follows:

Functional Grouping	Population	Max. Exposed Indiv.
703	9.06E-04	1.52E-08
690	1.12E-06	1.89E-11
688	6.31E-07	1.12E-11
712	1.29E-07	2.31E-12
706	1.18E-07	2.10E-12

The major contributors to risk for these functional groupings were also carcinogenic metals.

To illustrate the effect that each of the three site closure options would have on the public carcinogenic risks, we calculated a "total" public carcinogenic risk value for each closure option for the three selected years in the assessment period--Years 1986, 2085, and 2985. These totals assume that either Option 1, Option 2, or Option 3 would be selected for all sites as a whole.

	Year 1986	Year 2085	Year 2985
Option 1			
Population	9.08E-04	1.81E-06	7.38E-10
Max. Exposed Indiv.	1.52E-08	4.48E-10	1.83E-13
Option 2			
Population	9.39E-04	9.28E-06	2.44E-09
Max. Exposed Indiv.	1.57E-08	2.30E-09	6.05E-13
Option 3			
Population	3.77E-03	7.09E-04	4.72E-08
Max. Exposed Indiv.	6.02E-08	1.75E-07	1.18E-11

We expected total risks from Option 1 to be higher than Option 2 for Year 1986. However, the total risks for Option 2 as shown are higher than those for Option 1, primarily because of the risks associated with Functional Grouping 690, Option 2. This occurs even though the calculated public risk for many of the waste sites was lower for Option 2 than for Option 1 in the Year 1986 (the year in which site remedial action was assumed to occur). (See Table 2.) Closure Option 2, for the thinly backfilled waste sites in Grouping 690, does not include the emplacement of additional backfill or a cap, so relatively more contamination would be released to the atmosphere from these sites than from other sites where more extensive remedial actions are planned for Option 2. As expected, the Option 1 risks in later years are lower than the Option 2 risks and the Option 3 risks.

For Years 1986, 2085, and 2985 in the assessment period, Table 5 presents the major contributors to risk by site closure option. For many of the functional groupings, chromium VI was the prevalent major contributor to risk for Options 1 (waste removal and closure) and 3 (no action) in 1986. For Option 2 (no waste removal and closure), 1986, the prevalent major contributors to risk were the volatile species, such as tetrachloroethylene and trichloroethylene. Chromium VI dominated the risk for Options 1 and 3 for 1986 because it is fairly immobile and it possesses a high UCR. Volatile species dominated the risk for Option 2 because upward volatilization through the backfill is the only release of contamination to the atmosphere for this option.

PUBLIC EXPOSURE AND RISK FROM NONCARCINOGENS

One measure of public risk was calculated for exposures to noncarcinogens: the risk to a maximally exposed individual. As with

Table 5 Summary of the Major Contributors to Public Carcinogenic Risk, by Option

		Waste Removal and Closure		No Waste Removal and Closure		No Action	
EID	Year	Contaminant	Percentage of Risk	Contaminant	Percentage of Risk	Contaminant	Percentage of Risk
688	1986	Arsenic	89	a		Arsenic	81
		Chromium VI	10			Chromium VI	17
	2085	Trichloroethylene	100	Trichloroethylene	100	Chromium VI	76
						Nickel	24
	2985	Trichloroethylene	100	Trichloroethylene	100	Nickel	100
689	1986	Chromium VI	65	a		Chromium VI	100
		Carbon tetrachloride	20				
	2085	Carbon tetrachloride	57	Carbon tetrachloride	57	Chromium VI	100
		1,1,1-Trichloroethane	40	1,1,1-Trichloroethane	40		
	2985	1,1,1-Trichloroethane	69	1,1,1-Trichloroethane	69	1,1,1-Trichloroethane	69
		Carbon tetrachloride	28	Carbon tetrachloride	28	Carbon tetrachloride	28
690	1986	Chromium VI	100	Chromium VI	100	Chromium VI	100
	2085	Chromium VI	100	Chromium VI	100	Chromium VI	100
	2985	Chromium	100	Chromium VI	100	Chromium VI	100
691	1986	Trichloroethylene	84	a		Trichloroethylene	83
	2085	Trichloroethylene	82	Trichloroethylene	82	Trichloroethylene	82
	2985	Trichloroethylene	70	Trichloroethylene	70	Trichloroethylene	70
		Tetrachloroethylene	30	Tetrachloroethylene	30	Tetrachloroethylene	30
692	1986	Cadmium	81	a		Cadmium	71
		Chromium VI	19			Chromium VI	29
	2085	Trichloroethylene	100	Trichloroethylene	100	Chromium VI	99
	2985	Trichloroethylene	100	Trichloroethylene	100	Chromium VI	100
693[b]		-		-		-	

[a] There were no major contributors to risk here because the calculated risk was 0.0 (zero).
[b] There were no carcinogens (among the nonradioactive contaminants) selected for analysis for this functional grouping.

Table 5 (continued)

EID	Year	Waste Removal and Closure: Contaminant	Waste Removal and Closure: Percentage of Risk	No Waste Removal and Closure: Contaminant	No Waste Removal and Closure: Percentage of Risk	No Action: Contaminant	No Action: Percentage of Risk
694	1986	Cadmium	100	a		a	
	2085	a		a		a	
	2985	a		a		a	
695[b]		-		-		-	
696[b]		-		-		-	
697[c]		-		-		-	
698	1986	Chromium VI	63	a		Chromium VI	55
		Nickel	37			Nickel	45
	2085	Chloroform	100	Chloroform	100	Nickel	76
						Chromium VI	24
	2985	a		a		Nickel	100
699[b]		-		-		-	
700	1986	Chromium VI	97	a		Chromium VI	97
	2085	Tetrachloroethylene	100	Tetrachloroethylene	100	Chromium VI	92
	2985	a		a		Nickel	100
701	1986	Tetrachloroethylene	100	Tetrachloroethylene	100	Tetrachloroethylene	100
	2085	Tetrachloroethylene	100	Tetrachloroethylene	100	Tetrachloroethylene	100
	2985	a		a		a	

[a] There were no major contributors to risk here because the calculated risk was 0.0 (zero).
[b] There were no carcinogens (among the nonradioactive contaminants) selected for analysis for this functional grouping.
[c] This functional grouping was not analyzed.

Table 5 (continued)

		Waste Removal and Closure		No Waste Removal and Closure		No Action	
EID	Year	Contaminant	Percentage of Risk	Contaminant	Percentage of Risk	Contaminant	Percentage of Risk
702	1986	Chloroform	63	a		Trichloroethylene	69
		Trichloroethylene	36			Chloroform	31
	2085	Trichloroethylene	78	Trichloroethylene	78	Trichloroethylene	78
		Chloroform	22	Chloroform	22	Chloroform	22
	2985	Trichloroethylene	96	Trichloroethylene	96	Trichloroethylene	96
703	1986	Trichloroethylene	84	Trichloroethylene	84	Trichloroethylene	55
		Tetrachloroethylene	15	Tetrachloroethylene	15	Nickel	27
	2085	Nickel	83	Nickel	83	Nickel	91
		Chromium VI	10	Chromium VI	10	Chromium VI	5
	2985	Nickel	68	PCB's	92	Nickel	81
		PCB's	32	Nickel	8	PCB's	18
704	1986	Chromium VI	96	a		Chromium VI	98
	2085	a		a		Chromium VI	100
	2985	a		a		Chromium VI	100
705	1986	Arsenic	71	Tetrachloroethylene	100	Arsenic	57
		Chromium VI	29			Chromium VI	43
	2085	Tetrachloroethylene	100	Tetrachloroethylene	100	Chromium VI	100
	2985	a		a		Chromium VI	100
706	1986	Chromium VI	100	a		Chromium VI	100
	2085	a		a		Chromium VI	100
	2985	a		a		Chromium VI	100
707[b]		-		-		-	

[a] There were no major contributors to risk here because the calculated risk was 0.0 (zero).
[b] There were no carcinogens (among the nonradioactive contaminants) selected for analysis for this functional grouping.

Table 5 (continued)

		Waste Removal and Closure		No Waste Removal and Closure		No Action	
EID	Year	Contaminant	Percentage of Risk	Contaminant	Percentage of Risk	Contaminant	Percentage of Risk
708[a]		-		-		-	
709	1986	Chromium VI	100	b		Chromium VI	100
	2085	b		b		Chromium VI	100
	2985	b		b		Chromium VI	100
710	1986	Chromium VI	94	b		Chromium VI	83
						Nickel	16
	2085	Trichloroethylene	97	Trichloroethylene	97	Chromium VI	56
						Nickel	44
	2985	b		b		Nickel	100
711[c]		-		-		-	
712	1986	Toxaphene	93	b		Toxaphene	99
	2085	Vinyl chloride	100	Vinyl chloride	100	Vinyl chloride	100
	2985	b		b		b	
713[a]		-		-		-	

[a]This functional grouping was not analyzed.

[b]There were no major contributors to risk here because the calculated risk was 0.0 (zero).

[c]There were no carcinogens (among the nonradioactive contaminants) selected for analysis for this functional grouping.

the public risk that is due to exposures to carcinogens, this measure is the maximum insult to any one individual. (The risk to the population was not calculated for noncarcinogens [as was the case for the carcinogens] because there was, and is, no accepted methodology for correctly relating individual toxic pollutant exposures to health effects in the population.)

For the Years 1986, 2085, and 2985 in the assessment period, Tables 6 through 8 contain summaries of the calculated noncarcinogenic risk, by site closure option, for the maximally exposed individual, for each functional grouping.

In these tables, the risks that are due to exposures to noncarcinogens are expressed relative to the acceptable daily intake (ADI) for the maximally exposed individual. The ADI is the recommended maximum amount (per unit time) of the specified contaminant that a person can intake without any deleterious health effects. The risk to the maximally exposed individual, for a given contaminant, is expressed as the fraction of the ADI. (This was calculated by dividing the annual daily dose for the specified contaminant by its ADI.) This value is a measure of the potential, adverse health effects associated with a noncarcinogen.

The risks in Tables 6 through 8 are cumulative totals for each functional grouping; that is, the risks to the maximally exposed individual associated with each noncarcinogen were summed for all waste sites in a functional grouping. Summing the ADI fractions in this manner gave a relative measure of the potential noncarcinogenic insult to the public. This relative measure is an EPA Hazard Index.

For Option 3, which involves the least amount of remedial action for the three closure options considered, the five functional groupings with the highest calculated risks are, by year:

Year 1986

Functional Grouping	Max. Exposed Indiv.
706	8.44E-05
704	3.53E-05
694	3.44E-05
703	1.55E-05
710	1.35E-05

Table 6 Summary of Public Risks Attributable to Atmospherically Released Noncarcinogens, by Option, for the Year 1986[a]

Functional Grouping	Waste Removal and Closure	No Waste Removal and Closure	No Action
688	2.22E-08[b]	0.00E-01	2.07E-06
689	4.76E-10	0.00E-01	1.40E-07
690	1.05E-08	2.24E-07	2.24E-07
691[c]	-	-	-
692	2.79E-09	0.00E-01	1.64E-07
693[c]	-	-	-
694	1.59E-07	0.00E-01	3.44E-05
695[c]	-	-	-
696	3.04E-10	2.02E-08	2.02E-08
697[d]	-	-	-
698	1.57E-08	0.00E-01	3.06E-06
699	1.41E-09	0.00E-01	0.00E-01
700	9.12E-09	0.00E-01	1.34E-06
701[c]	-	-	-
702	1.41E-09	0.00E-01	7.98E-08
703	1.69E-06	1.66E-06	1.55E-05
704	6.63E-07	0.00E-01	3.53E-05
705	5.89E-09	1.13E-17	6.66E-07
706	1.69E-06	2.11E-13	8.44E-05
707[c]	-	-	-
708[d]	-	-	-
709	2.70E-10	2.91E-18	3.99E-08
710	1.14E-08	0.00E-01	1.35E-05
711	1.01E-12	0.00E-01	0.00E-01
712	1.13E-09	0.00E-01	1.36E-09
713[d]	-	-	-

[a]These risks are risks to the maximally exposed individual. The risks for a functional grouping are the total risks posed by all sites in the functional grouping.
[b]The value 2.22E-08 is read 2.22×10^{-8}; this same notation applies to all values in this table.
[c]Noncarcinogens were not selected for analysis for this functional grouping.
[d]This functional grouping was not analyzed.

Table 7 Summary of Public Risks Attributable to Atmospherically Released Noncarcinogens, by Option, for the Year 2085[a]

Functional Grouping	Waste Removal and Closure	No Waste Removal and Closure	No Action
688	9.83E-15[b]	9.83E-13	5.24E-05
689	3.42E-16	3.42E-16	2.63E-06
690	3.37E-08	3.37E-06	3.37E-06
691[c]	-	-	-
692	1.00E-17	1.00E-15	2.97E-06
693[c]	-	-	-
694	4.76E-08	1.57E-06	1.57E-06
695[c]	-	-	-
696	3.46E-09	3.46E-07	3.46E-07
697[d]	-	-	-
698	0.00E-01	0.00E-01	2.75E-05
699	0.00E-01	0.00E-01	0.00E-01
700	6.01E-18	6.01E-16	1.72E-05
701[c]	-	-	-
702	0.00E-01	0.00E-01	1.40E-06
703	1.46E-06	1.46E-06	1.54E-04
704	2.92E-11	2.92E-09	1.19E-03
705	5.19E-18	5.19E-16	1.26E-05
706	9.65E-14	9.65E-12	3.63E-03
707[c]	-	0.00E-01	-
708[d]	-	-	-
709	1.34E-18	1.34E-16	1.24E-06
710	1.19E-15	1.19E-15	4.49E-04
711	0.00E-01	0.00E-01	0.00E-01
712	2.72E-17	1.01E-12	1.01E-12
713[d]	-	-	-

[a] These risks are risks to the maximally exposed individual. The risks for a functional grouping are the total risks posed by all sites in the functional grouping.

[b] The value 9.83E-15 is read 9.83×10^{-15}; this same notation applies to all values in this table.

[c] Noncarcinogens were not selected for analysis for this functional grouping.

[d] This functional grouping was not analyzed.

Table 8 Summary of Public Risks[a] Attributable to Atmospherically Released Noncarcinogens, by Option, for the Year 2985

Functional Grouping	Waste Removal and Closure	No Waste Removal and Closure	No Action
688	6.42E-11[b]	6.42E-09	2.32E-05
689	2.63E-16	2.63E-16	4.41E-07
690	3.12E-12	3.12E-10	3.12E-10
691[c]	-	-	-
692	7.88E-18	7.88E-16	2.57E-07
693[c]	-	-	-
694	1.90E-17	1.90E-15	1.90E-15
695[c]	-	-	-
696	4.30E-13	4.30E-11	4.30E-11
697[d]	-	-	-
698	0.00E-01	0.00E-01	5.42E-11
699	0.00E-01	0.00E-01	0.00E-01
700	4.74E-18	4.74E-16	1.36E-06
701[c]	-	-	-
702	0.00E-01	0.00E-01	1.77E-10
703	1.16E-07	1.16E-07	1.23E-05
704	3.35E-08	3.35E-06	7.45E-04
705	4.28E-18	4.28E-16	2.69E-06
706	7.57E-14	7.57E-12	2.74E-03
707	-	-	-
708[d]	-	-	-
709	1.11E-18	1.11E-16	8.63E-07
710	7.76E-12	7.76E-12	3.00E-04
711	0.00E-01	0.00E-01	0.00E-01
712	0.00E-01	3.39E-30	3.39E-30
713[d]	-	-	-

[a] These risks are risks to the maximally exposed individual. The risks for a functional grouping are the total risks posed by all sites in the functional grouping.
[b] The value 6.42E-11 is read 6.42×10^{-11}; this same notation applies to all values in this table.
[c] Noncarcinogens were not selected for analysis for this functional grouping.
[d] This functional grouping was not analyzed.

Year 2085

Functional Grouping	Max. Exposed Indiv.
706	3.63E-03
704	1.19E-03
710	4.49E-04
703	1.54E-04
688	5.24E-05

Year 2985

Functional Grouping	Max. Exposed Indiv.
706	2.74E-03
704	7.45E-04
710	3.00E-04
688	2.32E-05
703	1.23E-05

For Option 1, which involves the greatest amount of site remedial action of the three closure options analyzed, the five functional groupings with the highest calculated risk in 1986 were as follows:

Functional Grouping	Max. Exposed Indiv.
703	1.69E-06
706	1.69E-06
704	6.63E-07

The prevalent major contributors to risk for these functional groupings are lead and mercury.

To illustrate the effect that each of the three site closure options would have on the maximally exposed individual risks that are due to atmospherically released noncarcinogens, we calculated the total risk for all functional groupings (for each closure option), for the three years in the assessment period.

	Year 1986	Year 2085	Year 2985
Option 1	4.29E-06	1.54E-06	1.50E-07
Option 2	1.90E-06	6.75E-06	3.47E-06
Option 3	1.91E-04	5.55E-03	3.83E-03

These results revealed that noncarcinogenic risk is highest in all years for Option 3, lowest for Option 2 in Year 1986, and lowest for Option 1 in Years 2085 and 2985. Also, the risk to the maximally exposed individual increases in Year 2085 over the 1986 values for Options 2 and 3 but not for Option 1.

There are two reasons why these results occurred. First, in Year 2085, the maximally exposed individual will be much closer to the waste site than in the Year 1986. (We have assumed the site is inhabited by the public in 2085.) This causes higher exposures after 2085 even though the source strength may have decreased because of leaching over the previous 100 years. Second, Option 1 exposures and risks for 1986 included releases due to excavation (which usually generates a markedly higher source term for that year), so the maximally exposed individual received higher exposures for Option 1 than for Option 2 in 1986. In succeeding years, Option 1 exposures are less than those for Option 2 because the source strength in Option 1 has been reduced by the amount excavated. Thus, even though the maximally exposed individual will be closer to the waste sites in 2085 than in 1986, we do not see the same effect (of increased exposure and risk over the 1986 values) because the source strength for 1986 included excavation and the 2085 release has been reduced.

For the Years 1986, 2085, and 2985 in the assessment period, Table 9 presents the major contributors to risk for the cumulative results given in Tables 6 through 8. For many of the functional groupings, mercury and lead are the prevalent major contributors to risk. As shown in Table 9, mercury is a prevalent major contributor to risk in the later years of the assessment, especially for Options 1 and 2, which involve backfilling the sites. This is due to the volatile and immobile (because of leaching processes) nature of mercury.

WORKER EXPOSURE AND RISK

Option 1 (and, in some cases, Option 2) involves the excavation of contaminated soils from the waste sites. Workers participating in site remedial activities would be exposed to airborne contaminants that may pose a health risk. Two measures of risk were used to report these worker risks: (1) the maximally exposed individual worker risk and (2) the worker population risk. (Since workers would be in the area of the highest contaminant concentration during excavation, the average individual is the maximally exposed individual.) These two measures are (1) the maximum insult to an individual worker and (2) the total insult to the worker population as a whole.

The worker health risk results presented in the remainder of this section are for unprotected workers only; that is, no credit was given for workers wearing respirators. Risks to workers with respirator protection would be a factor of 50 less than the risks for unprotected workers, assuming workers wear a full facepiece, air purifying negative pressure respirator.

Table 9 Summary of the Major Contributors to Public Noncarcinogenic Risk, by Option

		Waste Removal and Closure		No Waste Removal and Closure		No Action	
EID	Year	Contaminant	Percentage of Risk	Contaminant	Percentage of Risk	Contaminant	Percentage of Risk
688	1986	Mercury	38	a		Mercury	39
		Lead	32			Lead	32
		Chromium	11			Chromium	11
	2085	Mercury	100	Mercury	100	Mercury	68
						Lead	21
	2985	Mercury	100	Mercury	100	Mercury	100
689	1986	Lead	85	a		Lead	84
	2085	Mercury	100	Mercury	100	Lead	77
						Mercury	22
	2985	Mercury	100	Mercury	100	Mercury	100
690	1986	Lead	85	Lead	85	Lead	85
		Chromium	15	Chromium	15	Chromium	15
	2085	Lead	96	Lead	96	Lead	96
	2985	Lead	100	Lead	100	Lead	100
691[b]		-		-		-	
692	1986	Sodium	77	a		Sodium	77
		Lead	15			Lead	15
	2085	Mercury	100	Mercury	100	Sodium	73
						Lead	14
						Mercury	11
	2985	Mercury	100	Mercury	100	Mercury	100

[a]There were no major contributors to risk here because the calculated risk was 0.0 (zero).
[b]There were no noncarcinogens selected for analysis for this functional grouping.

Table 9 (continued)

		Waste Removal and Closure		No Waste Removal and Closure		No Action	
EID	Year	Contaminant	Percentage of Risk	Contaminant	Percentage of Risk	Contaminant	Percentage of Risk
693[a]		-		-		-	
694	1986	Lead	65	b		Tributyl phosphate	96
		Tributyl phosphate	34				
	2085	Tributyl phosphate	100	Tributyl phosphate	100	Tributyl phosphate	100
	2985	Mercury	100	Mercury	100	Mercury	100
695[a]		-		-		-	
696	1986	Lead	99	Lead	99	Lead	99
	2085	Lead	99	Lead	99	Lead	99
	2985	Lead	81	Lead	81	Lead	81
		Fluoride	19	Fluoride	19	Fluoride	19
697[c]		-		-		-	
698	1986	Barium	99	b		Barium	99
	2085	b		b		Barium	98
	2985	b		b		Sodium	86
						Barium	14

[a] Noncarcinogens were not selected for analysis for this functional grouping.
[b] There were no major contributors to risk here because the calculated risk was 0.0 (zero).
[c] This functional grouping was not analyzed.

Table 9 (continued)

EID	Year	Waste Removal and Closure		No Waste Removal and Closure		No Action	
		Contaminant	Percentage of Risk	Contaminant	Percentage of Risk	Contaminant	Percentage of Risk
699	1986	Lead	100	a		a	
	2085	a		a		a	
	2985	a		a		a	
700	1986	Lead	55	a		Lead	55
		Chromium	42			Chromium	42
	2085	Mercury	100	Mercury	100	Lead	77
						Chromium	13
	2985	Mercury	100	Mercury	100	Mercury	100
701[b]		-		-		-	
702	1986	Lead	100	a		Lead	100
	2085	a		a		Lead	100
	2985	a		a		Lead	100
703	1986	Barium	94	Barium	96	Barium	90
	2085	Barium	83	Barium	83	Barium	79
						Lead	10
	2985	Mercury	100	Mercury	100	Mercury	100

[a]There were no major contributors to risk here because the calculated risk was 0.0 (zero).
[b]Noncarcinogens were not selected for analysis for this functional grouping.

Table 9 (continued)

EID	Year	Waste Removal and Closure		No Waste Removal and Closure		No Action	
		Contaminant	Percentage of Risk	Contaminant	Percentage of Risk	Contaminant	Percentage of Risk
704	1986	Mercury	58	a		Mercury	58
		Sodium	35			Sodium	34
	2085	Mercury	100	Mercury	100	Mercury	79
						Sodium	17
	2985	Mercury	100	Mercury	100	Mercury	100
705	1986	Lead	63	Mercury	100	Lead	65
		Sodium	14			Sodium	14
	2085	Mercury	100	Mercury	100	Lead	61
						Mercury	26
						Sodium	13
	2985	Mercury	100	Mercury	100	Mercury	100
706	1986	Mercury	91	Mercury	100	Mercury	90
		Lead	9			Lead	9
	2085	Mercury	100	Mercury	100	Mercury	96
	2985	Mercury	100	Mercury	100	Mercury	100
707[b]		-		-		-	
708[c]		-		-		-	

[a]There were no major contributors to risk here because the calculated risk was 0.0 (zero).
[b]Noncarcinogens were not selected for analysis for this functional grouping.
[c]This functional grouping was not analyzed.

Table 9 (continued)

		Waste Removal and Closure		No Waste Removal and Closure		No Action	
EID	Year	Contaminant	Percentage of Risk	Contaminant	Percentage of Risk	Contaminant	Percentage of Risk
709	1986	Mercury	57	Mercury	100	Mercury	57
		Lead	24			Lead	24
	2085	Mercury	100	Mercury	100	Mercury	65
						Lead	13
	2985	Mercury	100	Mercury	100	Mercury	100
710	1986	Mercury	43	a		Mercury	55
		Lead	35			Lead	44
		Chromium	22				
	2085	Mercury	100	Mercury	100	Mercury	77
						Lead	23
	2985	Mercury	100	Mercury	100	Mercury	100
711	1986	Nitrate	100	a		a	
	2085	a		a		a	
	2985	a		a		a	
712	1986	Lead	89	a		2,4,5-TP	99
	2085	Endrin	99	Freon	100	Freon	100
	2985	a		Freon	100	Freon	100
713[b]		-		-		-	

[a]There were no major contributors to risk here because the calculated risk was 0.0 (zero).
[b]This functional grouping was not analyzed.

WORKER RISK FROM CARCINOGENS

Table 10 contains a summary of the calculated carcinogenic risks for the maximally exposed individual worker and for the worker population for each functional grouping. The risk to the maximally exposed individual is the "health effects per lifetime," or the probability that a worker will suffer a health effect due to exposure to a specified carcinogen (if the individual were to receive the calculated dose over the time period estimated for site cleanup).

The risk to the worker population, a population that is the number of workers in the cleanup crew, is the "health effects" the population would experience in the time period estimated for site cleanup, health effects that are due to exposure to site releases of carcinogens.

The risks in Table 10 are cumulative for each functional grouping; that is, the risk to the maximally exposed individual worker that is due to each carcinogen present at the waste sites within a given functional grouping were summed. Carcinogenic risks to the worker populations for all the waste sites in a given functional grouping were also summed.

The five functional groupings with the highest worker risks are:

Functional Grouping	Max. Exposed Indiv. Risk	Population Risk
703	1.91E-07	1.72E-06
688	1.71E-07	1.54E-06
700	9.54E-08	8.59E-07
712	7.26E-08	6.53E-07
710	5.63E-08	5.07E-07

As was the case with the public risk results, chromium VI is a prevalent major contributor to risk for many of the functional groupings.

WORKER RISK FROM NONCARCINOGENS

Table 10 also summarizes the calculated noncarcinogenic risks to the maximally exposed individual worker for each of the functional groupings analyzed. These risks that are due to exposures to noncarcinogens are expressed relative to the acceptable daily intake (ADI) in a manner similar to that for the public risks that are due to exposures to noncarcinogens. The five functional groupings with the highest worker risks that are due to exposure to noncarcinogens are as follows:

Table 10 Summary of Worker Risks Attributable to Atmospheric Releases of Contaminants During Site Excavations

EID	Carcinogens[a] Max. Exposed Individual Worker Risk (Health Effects/Lifetime)	Carcinogens[a] Worker Population Risk (Health Effects)	Noncarcinogens[b]
688	1.71E-07	1.54E-06[c]	1.23E-02
689	8.85E-10	7.97E-09	5.41E-03
690	5.24E-09	6.60E-08	1.08E-04
691	7.19E-17	6.47E-16	d
692	1.65E-10	1.49E-09	7.12E-04
693	e	e	d
694	1.91E-10	1.03E-07	2.92E-05
695	e	e	d
696	e	e	1.14E-02
697[f]	-	-	-
698	1.13E-09	1.02E-08	1.14E-01
699	e	e	2.25E-03
700	9.54E-08	8.59E-07	4.35E-02
701	5.65E-18	5.09E-17	d
702	1.20E-16	1.08E-15	3.04E-05
703	1.91E-07	1.71E-06	4.36E-02
704	7.47E-10	6.72E-09	2.48E-02
705	2.24E-09	2.02E-08	2.19E-02
706	4.40E-09	3.96E-08	1.19E-02
707	e	e	d
708[f]	-	-	-
709	8.69E-09	7.82E-08	3.56E-02
710	5.63E-08	5.07E-07	8.51E-03
711	e	e	4.36E-06
712	7.26E-08	6.54E-07	1.36E-01
713[f]	-	-	-

[a]Risks to the population are the health effects; risks to the maximally exposed individual are the health effects per lifetime.

[b]These risks are risks to the maximally exposed individual, and they are expressed as EPA Hazard Indexes.

[c]The value 1.54E-06 is read 1.54×10^{-6}; this same notation applies to all values in this table.

[d]Noncarcinogens were not selected for analysis for this functional grouping.

[e]There were no carcinogens (among the nonradioactive contaminants) selected for analysis for this functional grouping.

[f]This functional grouping was not analyzed because no contaminants were selected for analysis.

Functional Grouping	Max. Exposed Indiv. Risk
712	1.36E-01
698	1.14E-01
703	4.36E-02
700	4.35E-02
709	3.56E-02

The dominant contributors to risk for these waste sites are lead and barium.

SUMMARY AND CONCLUSIONS

Assessing the health hazards posed by the various remedial actions considered for mixed waste sites has required the development of new and increasingly more efficient assessment techniques. This is particularly true because of the large number of chemicals and radionuclides that are potentially present at mixed waste sites. This paper has presented those techniques that apply to atmospherically released nonradioactive chemicals. Other models and health risk procedures are used to assess radioactive releases and other applicable environmental media--surface and ground water.

As expected, the risks from nonradioactive contaminants that we calculated from the atmospheric pathway are low--no site or site remediation option, taken individually or summed, posed an unacceptable risk to the public. Risks to workers were also well below "thresholds" that we as a society accept.

The results of this assessment provided much information useful for resource prioritization, information that has aided SRP personnel in determining what level of remedial action that was needed at each waste site and in determining the priority for site cleanups. In terms of remedial action, the results of this assessment also answered the somewhat philosophical question of whether it is better to do nothing or do everything. More importantly, however, is the very fact that the atmospheric environmental pathway was analyzed to quantify public and occupational risk in the first place. All too often a particular environmental pathway is not analyzed in an assessment because the assessors know it will be unimportant. Public scrutiny of such assessments does not accept such treatment, however. Analyzing the waste sites in a thorough, scientifically-recognized manner--which of course includes the atmospheric pathway--does much to foster public goodwill and faith in appropriate steps being taken to maintain a safe environment and to prevent potential problems from being overlooked.

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Reliability Analysis of a Hazardous Waste Incinerator Burner Management System

Presented by:

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Reliability Analysis of a Hazardous Waste Incinerator Burner Management System

Spurious trips of hazardous waste incinerators are undesirable in chemical processing plants because these trips typically disrupt the manufacturing process and increase toxic emissions to the environment. But altering the incinerator burner management system to minimize spurious trips could degrade the system's ability to safely shut down the burner in the event of a flameout. Two burner management system designs (one operational and the other proposed) were compared and analyzed for differences in the expected number of spurious shutdowns and the probability of failure to shut down on demand. The analysis revealed that using thermocouples in a two-out-of-three voting logic in conjunction with a flame scanner (proposed design) would significantly reduce the expected number of spurious shutdowns with no significant increase in the probability of failing to shut down on demand.

RELIABILITY ANALYSIS OF A HAZARDOUS WASTE INCINERATOR BURNER MANAGEMENT SYSTEM - Donald K. Lorenzo, JBF Associates, Inc., Knoxville, Tennessee; J. Randall Kirchner, JBF Associates, Inc., Knoxville, Tennessee

Spurious trips of hazardous waste incinerators are undesirable in chemical processing plants because such trips typically disrupt the manufacturing process and increase toxic emissions to the environment. But altering an incinerator burner management system to minimize spurious trips can degrade the system's ability to safely shut down the burner in the event of a flameout. This paper describes our analysis and comparison of two burner management system designs (one operational and one proposed) for a hazardous waste incinerator. The comparison was based on the following three reliability characteristics:

- the probability that the control system will fail to trip the fuel and waste gas valves on demand (when a flameout occurs)
- the expected frequency of inadvertent shutdowns caused by control system failures
- the expected frequency of fuel-rich flameouts caused by control system failures

The incinerator had been frequently experiencing spurious trips because of process upsets. For example, high waste gas flows would move the flame beyond the range of the flame scanner, resulting in a burner shutdown. Plant personnel used the results of our study to decide whether to implement the proposed burner management system for reducing spurious incinerator shutdowns.

Analysis Basis

We based the analysis on information provided by piping and instrument drawings and by instrument loop diagrams. Key operational, test, and maintenance characteristics of the control systems were provided by plant personnel.

The existing control system design featured independent control of fuel gas and combustion air flow to the burner and triggered an emergency shutdown under conditions such as (1) a loss of the flame scanner signal, (2) a high temperature indication from a single thermocouple, and (3) an indication of low cooling water flow to the scrubber.

The proposed control system design featured digital cross-limiting control of fuel gas and air flow to the burner. Some of the emergency shutdown conditions for this design were (1) a loss of flame indication from the flame scanner accompanied by low temperature indications from two out of three thermocouples, (2) high temperature indications from two of the same three thermocouples, (3) an indication of low cooling water flow to the scrubber that lasts for ten seconds or longer, and (4) a loss of the 24 V dc instrumentation power supply.

Technical Approach

The reliability analysis of the incinerator burner control system designs was performed using the following five-step approach: (1) problem definition, (2) fault tree construction, (3) minimal cut set determination, (4) quantification of the TOP events, and (5) development of conclusions.

The problem definition step involved establishing the physical and analytical bounds for the analysis and defining the system failures to be analyzed (the TOP events of the fault trees). For each of the control system designs, we calculated the probability that the emergency shutdown function of the system would fail to stop combustible gas flows (fuel gas and waste gas) to the burner, given a loss of flame. We also calculated, for each design, the expected frequency of inadvertent shutdowns due to malfunctions in the burner management system. We separately calculated one contribution to this frequency: the expected frequency of fuel-rich flameouts caused by control system malfunctions.

Fuel-rich flameouts create potentially explosive conditions in an incinerator, even if the control system responds correctly and shuts off all fuel flow. Air will continue to enter the incinerator and dilute the fuel-rich mixture into a flammable mixture, which could be ignited by the hot furnace refractory or the stack oxygen sensor.

In our analysis, the expected frequency of inadvertent shutdowns was calculated for normal operating conditions only. All other calculations were performed for both normal operation and startup. (Cold startup and hot restart employed the same procedure, and the reliability characteristics for both of these modes were identical.)

The analysis scope was strictly limited to the active control system equipment (sensors, relays, etc.) affected by the proposed design modifications. Only control system component failures were analyzed.

Incinerator trips resulting from process upsets were not considered failures in our analysis because the control system components responded correctly. Thus our calculated results were only the intrinsic reliabilities of the burner management system designs.

In this study we did not consider external events (fires, floods, earthquakes, losses of electric power, sabotage, etc.) that could disable the system. Analysis of common cause failures (single events, such as a technician miscalibrating multiple instruments, that result in multiple equipment failures) was also beyond the scope of this study.

In the second step of the analysis, we constructed fault trees for the TOP events for each system design. The TOP events were "Failure to Shut Down Given Flameout" and "Inadvertent Incinerator Burner Shutdown," as shown in Figures 1 and 2, respectively. These fault trees modeled the combinations of component failures and operator errors that will make the TOP events occur. Using the MOCUS computer algorithm,* we then determined the minimal cut sets (minimal combinations of component failures and operator errors that make the TOP event occur) for each fault tree (Step 3).

In Step 4, we quantified the TOP events for each system design. Using the minimal cut sets from Step 3, component and operator failure data,

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*J. B. Fussell et al., MOCUS - A Computer Program to Obtain Minimal Cut Sets from Fault Trees, USAEC Report ANCR-1156, Aerojet Nuclear Company, Idaho Falls, ID, August 1974.

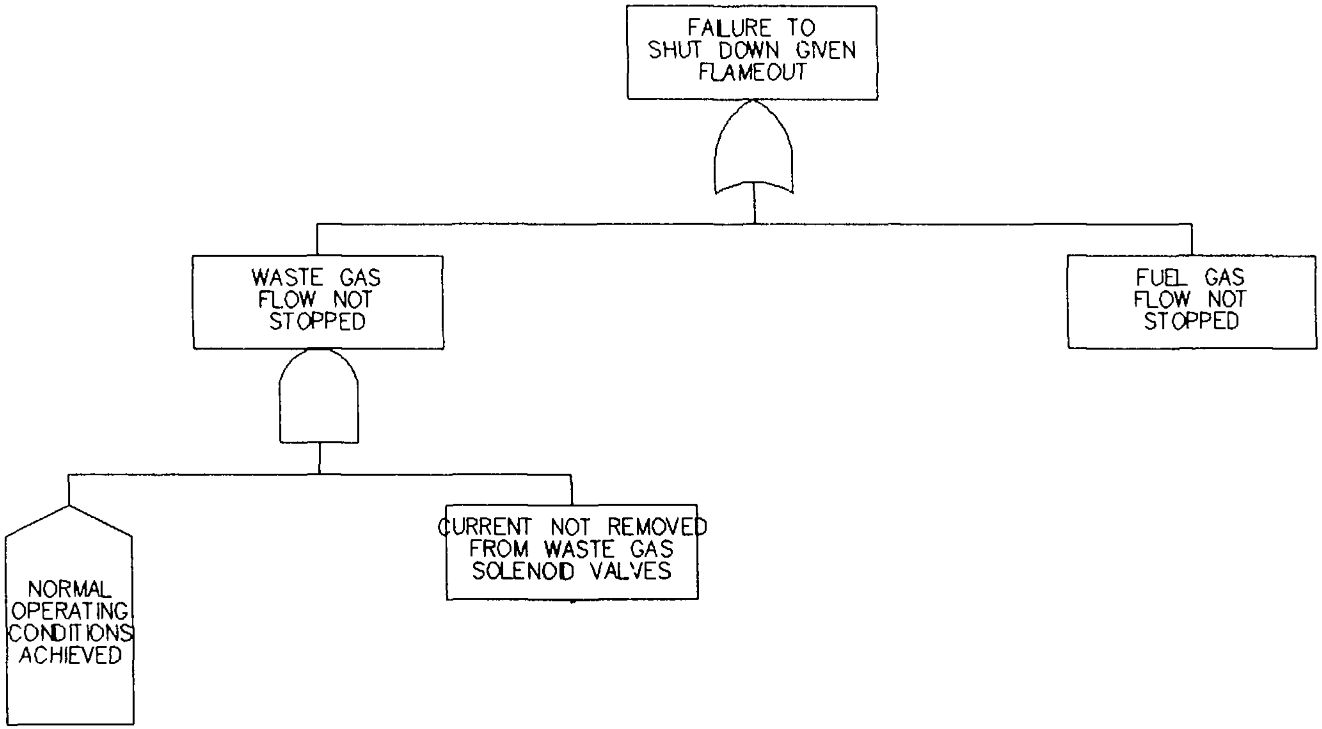

Figure 1 Top of Fault Tree for Failure to Shut Down Given Flameout

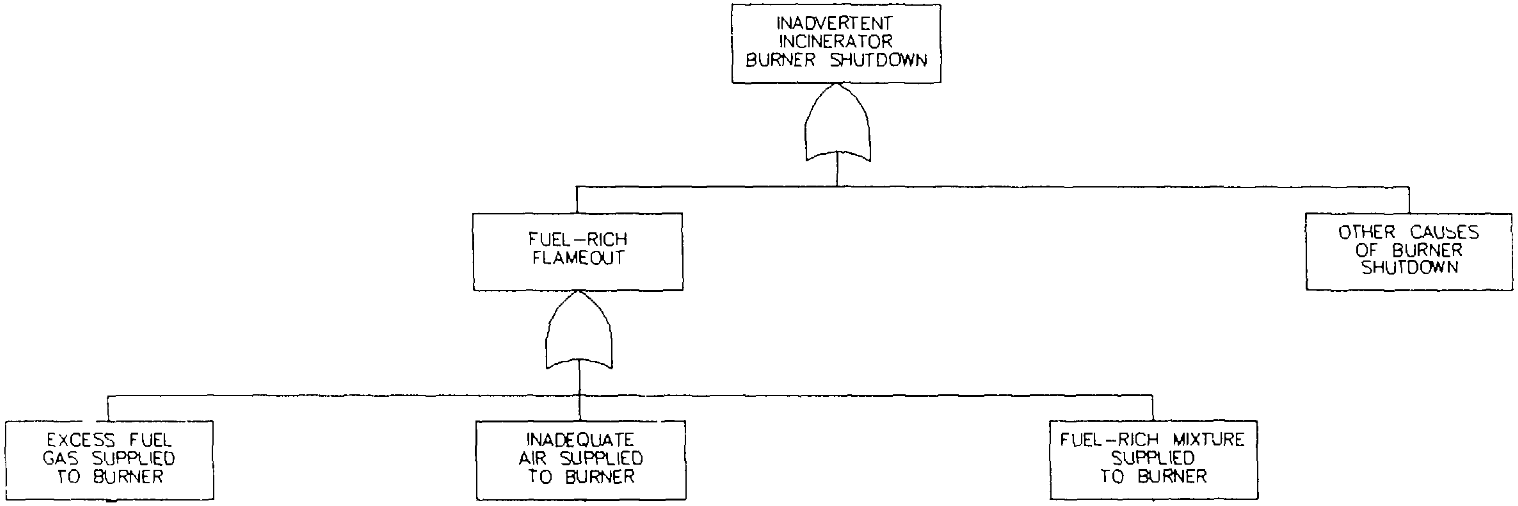

Figure 2 Top of Fault Tree for Inadvertent Shutdown/Fuel-Rich Flameout

and standard reliability mathematics,* we estimated for each system design (1) the probability of a failure to shut off combustible gas to the incinerator burner in the event of a flameout, (2) the expected frequency of inadvertent incinerator shutdowns due to control system malfunctions, and (3) the expected frequency of fuel-rich flameouts initiated by control system malfunctions.

In the final step, we reviewed the minimal cut sets and compared the quantitative results for each design case and operating mode, identifying the important factors that influence the reliability of the incinerator control system. We then made several observations that aided plant personnel in identifying the strengths and weaknesses of the two system designs.

<u>Results</u>

Our observations were based upon the analysis results shown in Table 1. The results indicated that the proposed design's reliability for emergency shutdown was roughly equal to that of the existing design. In the proposed design, three temperature switches were installed in a two-of-three voting logic to prevent inadvertent shutdowns. The failure probability for the proposed design slightly increased because two of the switches would have to fail to prevent an emergency shutdown. In both the existing system and the proposed system, flame scanner failures

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*J. B. Fussell, "How to Hand-Calculate System Reliability Characteristics," <u>IEEE Transactions on Reliability</u>, R-24(3), The Institute of Electrical and Electronics Engineers, New York, NY, 1975.

Table 1 Reliability Analysis Results for the Burner Management Systems

Top Event	Design	Operating Mode	Frequency	Probability
Failure to Shut Down Given Flameout	Existing	Startup		3.0E-4
		Normal		4.9E-3
	Proposed	Startup		3.0E-4
		Normal		4.9E-3
Inadvertent Shutdown[a]	Existing	Normal	.24/yr	
	Proposed	Normal	.20/yr	
Fuel-Rich Flameout	Existing	Startup	1.8E-8/start	
		Normal	4.0E-2/yr	
	Proposed	Startup	2.0E-8/start	
		Normal	4.3E-2/yr	

[a]This TOP event does not include inadvertent shutdowns due to process upset conditions (high waste gas flow causing the flame scanner to lose sight of the flame, cooling water pressure transients causing momentary low flow to the scrubber, etc.). The existing burner management system was causing approximately four spurious trips per year because of process upsets.

(in the "on" condition) contributed about 90% of the failure probability.

Our results also indicated that the proposed control system design should cause fewer inadvertent shutdowns and more fuel-rich flameouts than the existing design, but the differences were very small. The difference between the inadvertent shutdown frequencies was attributed to the proposed requirement for two of three temperature indicators to fall below 1900°F before shutting down the incinerator on a loss-of-flame signal. This design change eliminated the flame scanner as a single component failure that could cause an inadvertent shutdown. This change also eliminated the chance of an inadvertent shutdown due to the flame scanner merely losing sight of the flame during waste gas surges. These same three thermocouples would be used for high temperature shutdown as well, eliminating the single existing thermocouple as a single failure point for inadvertent shutdown. The proposed design was somewhat more likely to cause fuel-rich flameouts because it added some single failures involving the digital cross-limiting logic devices.

Based on the results and insights gained in performing this analysis, we recommended several additional modifications to the incinerator control system. These recommendations were as follows:

- Shut down the incinerator if the 24 V dc power supply to the instrumentation fails off. (This recommendation was incorporated into the proposed design and considered in the reliability analysis.)

- Use a self-checking flame scanner to significantly reduce (by approximately a factor of 10) the probability that the control system will fail to shut down the burner on demand.

- Add a low combustion air flow trip to ensure incinerator shutdown during low flow conditions under which the pressure does not decrease substantially.

- Move the combustion air flow sensor and low pressure switch downstream of the flow control damper. These changes will help ensure (1) better air flow control and (2) rapid incinerator shutdown in the event the damper transfers closed.

Conclusions

As environmental regulations become more stringent, plant operators are increasingly motivated to improve the reliability of their hazardous waste incinerators. Our analysis showed that modifying a burner management system to reduce the number of inadvertent shutdowns can be done without jeopardizing the essential safety function of shutting down the burner in the event of an actual flameout. In addition, our analysis identified several ways to improve the reliability of the emergency shutdown functions of the burner management system. However, because each burner management system has unique features, these specific results may not be applicable in all situations. Analysis is required to ensure that any proposed modification to a hazardous waste incinerator does not degrade the safety functions of its burner management system.

Toxic Discharges From Landfill Leachate, Hazardous Waste Incinerator Scrubber Wastes, and Hazardous Liquid Treaters

Barry Langer,
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"Toxic Discharges from Landfill Leachate, Hazardous Waste Incinerator Scrubber Wastes, and Hazardous Liquid Treaters." Barry Langer, SAIC, Oak Ridge, TN; Don Anderson, EPA

Under The Resource Conservation and Recovery Act (RCRA), there are three wastewater exemptions:

- o Domestic sewage exemption
- o Direct discharge exclusion
- o Wastewater treatment exemption

As a result, wastewater discharges from hazardous waste treatment and disposal facilities are not now covered by any national environmental regulation. Therefore, EPA has undertaken a study of this industry to determine if national regulations, under the Water Quality Act, is warrented. This industry is defined as follows:

- o Landfills with leachate collection and treatment facilities. In this study the term leachate is used to describe all aqueous discharges from landfills. These discharges can include both leachates collected from the bottom of the landfill and any groundwater recovered at the site.
- o Incinerators with wet scrubbers.
- o Aqueous hazardous waste treaters.

As part of EPA's study, 12 facilities were sampled for over 500 toxic substances. This paper will present a summary of the data collected during these 12 sampling episodes.

TOXIC DISCHARGES FROM LANDFILL LEACHATE, HAZARDOUS WASTE INCINERATOR SCRUBBER WASTES, AND HAZARDOUS LIQUID TREATERS

Barry Langer, SAIC, and
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The Industrial Technology Division (ITD), in EPA's Office of Water has undertaken a study of the hazardous waste treatment (HWT) industry to determine if effluent guidelines and standards are necessary to control the discharge of pollutants to our nation's waters from this industry.

As part of this study, EPA has collected existing data on the presence of toxic pollutants in the discharge of these facilities, and has sampled 12 sites for more than 500 toxic pollutants. This paper presents the regulatory background for this study and the results of the data collection efforts.

SUMMARY OF HAZARDOUS WASTE AND WASTEWATER REGULATIONS

Subtitle C of the Resource Conservation and Recovery Act (RCRA) of 1976 directed EPA to promulgate regulations to protect human health and the environment from the improper management of hazardous wastes. Based on this statutory mandate, the goal of the RCRA program is to provide comprehensive, "cradle-to-grave" management of hazardous waste. Key statutory provisions in RCRA Subtitle C include:

- Section 3001 - requiring the promulgation of regulations identifying the characteristics of hazardous waste and listing particular hazardous wastes.
- Section 3002 - requiring the promulgation of standards (e.g., manifesting, recordkeeping, etc.) applicable to generators of hazardous wastes.
- Section 3003 - requiring the promulgation of standards (e.g., manifesting, recordkeeping, etc.) applicable to transporters of hazardous wastes.

- Section 3004 - requiring the promulgation of performance standards applicable to the owners and operators of facilities for the treatment, storage, or disposal of hazardous wastes.

- Section 3005 - requiring the promulgation of regulations requiring each person owning or operating a treatment, storage, or disposal facility (TSDF) to obtain a permit issued pursuant to Section 3005.

In interpreting relevant statutory provisions of RCRA, EPA has granted broad exemptions from RCRA requirements in areas relating to wastewater management. The three key wastewater exemptions include:

- Domestic sewage exclusion - excludes from regulation as either a solid or hazardous waste any mixture of domestic sewage and other wastes that passes through a sewer system to a POTW for treatment. Based on current Agency interpretation, the exemption begins when the waste first enters a sewer system that will mix it with sanitary wastes prior to POTW storage or treatment, but does not exclude industrial wastewaters while they are being collected, stored, or treated prior to discharge to a POTW.

- Direct discharge exclusion - excludes from regulation as either a solid or hazardous waste any industrial wastewater dischargers that are point source discharges subject to regulation under WQA Section 402. This exemption begins when the wastewater is first discharged to surface waters, but does not exclude industrial wastewaters while they are being collected, stored, or treated prior to discharge to surface waters.

- Wastewater treatment exemption - exempts wastewater treatment units from TSDF performance standards and permitting requirements. A wastewater treatment unit is defined as a device that is part of a wastewater treatment facility subject to regulation under WQA Sections 402(a) or 307(b); that treats or stores influent wastewaters or wastewater treatment sludges that are hazardous; and that meet the definition of tank contained in 40 CFR Part 260. The term "tank" is defined as a stationary device constructed primarily of non-earthen materials (e.g., wood, concrete, steel, plastic) that provides structural support.

The basic rationale for these exemptions rests in the belief that most aspects of wastewater management systems can be adequately regulated under existing National Pollutant Discharge Elimination System (NPDES) and Pretreatment provisions. Certain treatment units such as surface impoundments are nonetheless fully regulated under RCRA due to their potential effects on other environmental media, especially groundwater.

Under the Water Quality Act (WQA), direct discharges to surface waters are controlled through the imposition of effluent limitations contained in NPDES permits issued by authority of WQA Section 402. Effluent limits developed by a permit writer may be based on the following guidelines promulgated by authority of WQA Sections 301 or 306:

- Best practicable control technology currently available (BPT) - intended to provide an initial set of discharge controls on the discharge of conventional pollutants from existing sources.
- Best available technology economically achievable (BAT) - intended to provide additional controls on the discharge of toxic and nonconventional pollutants.
- Best conventional pollutant control technology (BCT) - intended to provide additional controls on the discharge of conventional pollutants (i.e., BOD, TSS, pH, fecal coliform, and oil/grease).
- New source performance standards (NSPS) - intended to provide discharge controls for new sources.

The current framework for control of toxic pollutants is contained in a settlement agreement negotiated in 1976 between EPA and plaintiff environmental groups. This agreement required EPA to develop a program and adhere to a schedule for promulgating BAT effluent guidelines, pretreatment standards (for indirect dischargers), and new source performance standards for 65 pollutants and pollutant classes potentially discharged by 21 major industries [see Natural Resources Defense Council v. Train, 8 ERC 2120 (D.D.C.)]. The basic elements of the NRDC consent decree were subsequently codified in the 1977 Clean Water Act amendments.

The "Report to Congress on the Discharges of Hazardous Wastes to Publicly Owned Treatment Works" found that POTWs were handling significant quantities of hazardous constituents discharged by categorical industries, that improvements to the pretreatment programs would result in enhancing POTW capability to control such discharges, and that further study was necessary, particularly with respect to the rates and effect of those pollutants. The report did not address the quantity, type, fate, and effects of hazardous waste constituents discharged by direct dischargers; however, existing data on the practices of hazardous waste handlers suggest that wastewater systems of direct dischargers are used to treat hazardous constituents.

EPA has not yet promulgated effluent guidelines to assist permit writers in formulating NPDES permits for hazardous waste treatment facilities. In the absence of these guidelines, permit writers must rely wholly on their own best professional judgments (BPJs) in setting limits for discharges by these facilities. This process requires a permit writer to make complex, site-specific determinations often evaluating factors such as wastewater characteristics, pollutant concentrations, available pollution control technologies, and water quality constraints.

Wastewaters generated by onsite hazardous waste treatment units such as landfills with leachate collection and incinerators with wet scrubbers are not specifically addressed by effluent guidelines for specific industrial categories covered by the NRDC consent decree. For example, effluent guidelines do not establish process-specific limits for scrubber wastewaters from onsite hazardous waste incinerators or leachate from onsite industrial landfills.

Under the WQA, dischargers to Publicly Owned Treatment Works (POTWs) are controlled through the imposition of pretreatment standards promulgated by authority of CWA Section 307. These standards apply to wastewater discharged by an industrial facility to a POTW collection system. Certain types of pretreatment standards, referred to as national categorical standards, apply uniformly to all facilities determined to be within the scope of the regulated industrial category. Categorical standards include:

- <u>Pretreatment standards for existing sources</u> (PSES) - intended to provide controls on pollutant discharges by existing sources.
- <u>Pretreatment standards for new sources</u> (PSNS) - intended to provide controls on pollutant discharges by new sources.

Again, there are no national pretreatment standards in force by EPA for this industry.

DESCRIPTION OF THE HWT INDUSTRY

The HWT industry can be divided into three major subcategories for the purpose of this study:

- <u>Leachate treatment facilities</u> - provide collection and treatment of aqueous discharge from onsite, commercial, municipal, private, hazardous waste, industrial, and/or Subtitle D landfills. These discharges can include leachate collected at the bottom of the landfill and any groundwater removed from the water table.
- <u>Incinerator scrubber wastewater treatment facilities</u> - limited to those treating only incinerator scrubber wastewater or onsite generators of incinerator scrubber wastewater that combine the incinerator scrubber wastes with other wastewaters for treatment.
- <u>Aqueous hazardous waste treatment facilities</u> - provide physical, chemical, and/or biological treatment of hazardous and nonhazardous wastewaters, including leachate from onsite and offsite landfills and process wastewaters from onsite and offsite manufacturing operations. Whereas leachate treatment facilities only handle onsite-generated wastewaters, commercial aqueous treaters handle a variety of wastewaters, including leachate.

Table 1 presents EPA's current estimate of the number of facilities that would be covered by regulation promulgated under the Water Quality Act, i.e., facilities that have a wastewater discharge. In the case of Subtitle D landfills, the 604 facilities with liquid discharges represent only 1 percent of the total number of Subtitle D landfills.

WASTEWATER QUALITY DATA

The following presents and discusses the raw wastewater data collected as part of this study.

Landfill Leachates

The newest source for analytical data characterizing the raw leachate is the 1986-1987 EPA ITD study sampling effort. Six landfills with leachate collection were sampled during this program. The landfills sampled contained municipal refuse, industrial wastes, and hazardous wastes. The ITD sampling data for organic pollutants are supplemented by analytical data obtained from:

- EPA Office of Research and Development/Hazardous Waste Environmental Lab (ORD/HWERL) sampling efforts at 13 hazardous waste landfills in 1985
- Wisconsin Department of Natural Resources sampling efforts at 20 municipal landfills containing municipal, industrial, and hazardous wastes during 1983
- EPA Office of Emergency and Remedial Response (Superfund Program) Contract Laboratory Program (CLP) Statistical Data base, "Most Commonly Occurring Analytes in 56 Leachate Samples," 1980-1983 data
- National Enforcement Investigations Center (NEIC) sampling program conducted for the Hazardous Waste Groundwater Task Force during 1985,
- Subtitle D leachate data for miscellaneous Subtitle D landfills, compiled by OSW.

TABLE 1

HWT Industry Profile

Subcategory: Leachate Collection and Treatment	
Commercial Hazardous Waste Landfills	67
Noncommercial Hazardous Waste Landfills	240
Subtitle D Landfills	604
Total	911
Subcategory: Scrubber Wastewater Treatment	
Hazardous Waste Incinerators with Scrubber Wastewater	273
Subcategory: Aqueous Hazardous Waste Treatment	
Commercial Treaters	125
Noncommercial Treaters	600
Total	725
HWT Industry Total	1,909

Table 2 summarizes the conventional, nonconventional, and metal pollutant data collected from the ITD study only. The data show that leachates contain high concentrations of BOD_5, COD, and TOC. These pollutants are an indicator that there are high concentrations of both inorganic and organic compounds in leachates.

The fact that leachates are high strength wastes is also reflected in the presence of other pollutants, specifically TSS, TDS, chloride, TKN, and ammonia. These pollutants were found in a wide range of concentrations.

More than 20 metals were found in landfill leachates, with many well over 1 mg/l. In addition, metals in Subtitle D landfills were found to be present at concentrations equivalent to hazardous waste landfills.

In addition to the ITD study, the EPA ORD/HWERL study found arsenic at concentrations over 100 mg/l, copper over 15 mg/l, selenium over 3 mg/l, and zinc over 24 mg/l.

Tables 3 and 4 present organic pollutant data from the six studies evaluated in this project. Table 3 summarizes data from primarily Subtitle D landfills whereas Table 4 presents data from hazardous waste landfills.

One hundred sixty-two organic compounds were found in the ORD/HWERL and NEIC studies, which sampled hazardous waste landfill leachates utilizing the Office of Solid Waste RCRA analytical methods. This compared to 97 organic compounds in the Subtitle D landfill leachates using water program analytical methods. The concentrations of individual compounds were also significantly higher in the hazardous waste landfills. This suggests that leachates from hazardous waste landfills contain more toxic organic compounds and at higher concentrations than Subtitle D

TABLE 2

Conventional and Nonconventional Pollutants
and Metals Summary in Raw Leachate-HWT
Study Sampling Results

Pollutant	Range of Concentrations* Minimum	Maximum	Mean	Percent of Samples Where Pollutant Was Detected
BOD_5, mg/l	24	5040	1001	100
COD, mg/l	36	17,300	3225	100
TOC, mg/l	63	5,500	912	100
TSS, mg/l	5	4187	1467	100
TDS, mg/l	1,554	13,800	5,245	100
Chloride, mg/l	72	1839	855	100
O&G, mg/l	<1.0	552	69	67
Ammonia-N, mg/l	14	350	154	100
TKN, mg/l	14	479	165	100
NO_2 and NO_3-N, mg/l	--	--	--	--
Fluoride, mg/l	<0.1	8.7	1.2	33
Sulfide, mg/l	<0.1	0.75	0.21	17
pH, SU	6.7	8.66	--	100
Phenols, mg/l	<0.05	1.95	0.76	75
Cyanide, mg/l	<0.01	0.07	0.04	67
TVO, mg/l	--	--	--	--
Calcium, mg/l	43	1,600	346	100
Magnesium, mg/l	39	335	137	100
Sodium, mg/l	87	1,520	623	100
Aluminum	20	2,700	1,300	92
Iron	6,800	718,000	134,700	100
Manganese	450	59,300	11,800	100
Boron	170	13,000	4,980	100
Barium	57	975	366	100
Molybdenum	<10	18	18	8
Antimony	<10	<10	<10	0
Arsenic	<5	63	32	75
Beryllium	<1	2	2	17
Cadmium	<5	<5	<5	0
Chromium	<10	214	74	92
Cobalt	6.6	217	70	67
Copper	<2	46	36	50
Lead	<50	<50	<50	0
Mercury	<0.2	<0.2	<0.2	0
Nickel	33	200	174	83
Selenium	<5	<5	<5	0
Silver	<1	7.0	7.0	8
Thallium	<10	<10	<10	0
Tin	<13	<13	<13	0
Titanium	15	100	59	75
Vanadium	4.4	92	41	67
Yttrium	<10	64	42	33
Zinc	4.1	26,600	4,380	100

*All concentrations in ug/l unless noted otherwise

TABLE 3

Organic Compounds Found in Raw Leachate - Subtitle D Landfills

Poll No.	Pollutant Name	HWI Study No.	HWI Study Min.	HWI Study Max.	HWI Study Mean	CLP Database No.	CLP Database Min.	CLP Database Max.	CLP Database Mean	Wisconsin Study No.	Wisconsin Study Min.	Wisconsin Study Max.	Wisconsin Study Mean	Misc. Subtitle D No.	Misc. Subtitle D Min.	Misc. Subtitle D Max.	Misc. Subtitle D Mean
44	Methylene Chloride	12	<10	1220	230	20	1	12000	1030	19	7	20000	1910	8	<2	3300	615
25	Dichlorobenzene, 1,2-	0			0	0			0	3	9	13	11	0			0
11	Trichloroethane, 1,1,1-	0			0	0			0	7	16	2400	210	8	8	200	38
87	Trichloroethylene	0			0	7	1	96	46	11	16	1120	170	6	1	63	16
23	Chloroform	0			0	3	310	310	310	8	8	1300	80	5	<2	100	51
7	Chlorobenzene	0			0	1	2	140	57	5	1	7	[illegible]	5	<2	237	63
10	Dichloroethane, 1,2-	0			0	0			0	3	1	11000	590	0			0
13	Dichloroethane, 1,1-	12	<10	25	11	0			0	13	5	8300	560	5	<2	140	47
27	Dichlorobenzene, 1,4-	0			0	0			0	7	1	31	11	0			0
85	Tetrachloroethylene	0			0	4	27	97	62	9	2	620	75	6	<2	100	55
30	Trans,-1,2-Dichloroethylene	12	<10	191	33	7	2	336	76	13	17	2760	530	5	4	230	52
6	Carbon Tetrachloride	0			0	0			0	0			0	6	<2	390	73
14	Trichloroethane, 1,1,2-	0			0	0			0	3	30	500	55	0			0
32	Dichloropropane, 1,2-	0			0	0			0	7	2	86	17	0			0
20	Chloronapthalene,2-	0			0	0			0	1		46	46	0			0
16	Chloroethane	0			0	4	12	20	16	6	16	860	85	0			0
552	Trichlorofluoromethane	0			0	0			0	4	8	110	22	0			0
R138	Dichloropropylene, 1,3-	0			0	0			0	2	10	30	13	0			0
88	Vinyl Chloride	12	<10	869	63	3	19	100	63	2	47	81	13	0			0
15	Tetrachloroethane, 1,1,2,2-	0			0	0			0	1		210	210	0			0
46	Methyl Bromide (Bromoethane)	0			0	0			0	1		170	170	0			0
45	Methyl Chloride (Chloromethane)	0			0	0			0	1		170	170	0			0
R366	Fluorotrichloromethane	0			0	3	11	33	19	0			0	0			0
29	Dichloroethane, 1,1-	0			0	3	5	5	5	0			0	0			0
50	Dichlorodifluoromethane	0			0	1		205	205	0			0	1		369	369
	Oxirane,Chloromethyl-	0			0	1		100	100	0			0	0			0
86	Toluene	12	<10	132	39	15	5	3700	894	21	8	3200	720	8	<2	510	115
NC250	Total Xylenes	0			0	3	0	2500	850	0			0	0			0
55	Napthalene	8	<10	13	10	10		26	22	7	2	60	15	1			4
4	Benzene	12	<10	24	12	12	3	25	15	17	4	1080	250	4	<2	26	10
38	Ethylbenzene	12	<10	95	21	9	20	460	200	13	6	4900	440	7	<5	500	100
81	Phenanthrene	0			0	4	24	25	25	0			0	0			0
77	Acenaphthylene	0			0	1		15	15	0			0	0			0
56	Nitrobenzene	0			0	1		10	10	2	40	120	10	0			0
	Benzene, 1,3-Dimethyl	0			0	1		4600	4600	0			0	0			0
78	Anthracene	0			0	4	16	25	20	0			0	0			0
1	Acenaphthene	0			0	3	45	45	45	0			0	0			0
39	Fluoranthene	0			0	3	10	40	20	0			0	0			0
84	Pyrene	0			0	3	0	53	25	0			0	0			0
72	Benzo(a)Anthracene	0			0	2	13	16	14	0			0	0			0
74	Benzo(b)Fluoranthene	0			0	2	11	11	11	0			0	0			0
75	Benzo(k)Fluoranthene	0			0	2	11	11	11	0			0	0			0
76	Chrysene	0			0	2	16	16	16	0			0	0			0
557	Aniline	0			0	1		74	74	0			0	0			0
65	Phenol	0			0	9	13	11300	467	16	13	11300	1713	7	<15	20000	5757

TABLE 3, Continued

Poll No.	Pollutant Name	HWI Study No	HWI Study Min	HWI Study Max	HWI Study Mean	CLP Database No	CLP Database Min.	CLP Database Max.	CLP Database Mean	Wisconsin Study No.	Wisconsin Study Min	Wisconsin Study Max.	Wisconsin Study Mean	Misc Subtitle D No	Misc Subtitle D Min	Misc Subtitle D Max.	Misc Subtitle D Mean
944	Methylphenol, 4- (P-Cresol)	0			0	4	6	6700	1792	0			0	0			0
	Butanoic Acid	0			0	2	36	1600	818	0			0	0			9
447	Hexanoic Acid	0			0	1		2300	2300	0			0	0			0
34	Dimethylphenol, 2,4-	0			0	2	18	28	22	2	10	28	24	0			0
	Butanoic Acid,2-Methyl-	0			0	1		63	63	0			0	0			0
64	Pentachlorophenol	0			0	4	3	470	301	3	3	470	46	0			0
22	Chloro-3-Methylphenol,4-	4	<10	16	11	0			0	0			0	0			0
58	Nitrophenol,4-	0			0	0			0	1		17	17	0			0
	Benzeneacetic Acid	0			0	2	4	350	196	0			0	0			0
	Butanoic Acid,Ethyl Ester	0			0	1		23	23	0			0	0			0
	Butanoic Acid, Methyl Ester	0			0	1		12	12	0			0	0			0
	Hexanoic Acid,2-Methyl	0			0	1		480	480	0			0	0			0
516	Acetone	12	<50	1671	252	4	430	850	727	0			0	0			0
514	Butanone, 2-	12	<50	7055	1025	2	960	2400	1680	0			0	0			0
564	Benzyl Alcohol	9	<10	63	16	1		3800	3800	0			0	0			0
	Pentanol, 4-Methyl-,2	0			0	2	130	580	355	0			0	0			0
550	Methyl-2-Pentanone,4-	0			0	3	150	380	265	0			0	0			0
54	Isophorone	10	<10	2396	255	2	5	118	42	11	4	16000	1188	0			0
68	Di-n-Butylphthalate	0			0	0			0	4	12	150	23	0			0
66	Bis(2-Ethylhexyl) Phthalate	0			0	14	12	3700	768	4	32	150	32	0			0
71	Dimethyl Phthalate	0			0	2	26	28	26	2	38	55	14	0			0
19	2-Chloroethyl Vinyl Ether	0			0	0			0	2	2	<100	78	0			0
43	Bis(2-Chloroethoxy) Methane	0			0	0			0	2	18	25	11	0			0
17	Bis(Chloromethyl) Ether	0			0	0			0	1		250	250	0			0
70	Diethyl Phthalate	8	<10	38	14	7	25	84	45	16	3	330	104	0			0
67	Butyl Benzyl Phthalate	0			0	0			0	3	21	150	24	0			0
	Hydroxy-4-Methyl-2-Pentanone,4-	0			0	2	710	76000	38355	0			0	0			0
	Ethanol	0			0	1		42	42	0			0	0			0
	Bis(2-Chloroethoxy) Ethane	0			0	1		13	13	0			0	0			0
	Ethane,1,1'-Oxybis-2-Ethoxy	0			0	1		460	460	0			0	0			0
	Methane, Thiobis	0			0	1		47	47	0			0	0			0
505	Formamide,N,N-Dimethyl	0			0	1		15000	15000	0			0	0			0
	Heptane,2,4-Dimethyl-	0			0	1		150	150	0			0	0			0
	Hexane,2,3,5-Trimethyl	0			0	1		29	29	0			0	0			0
	Hexane,4-Ethyl-2-Methyl	0			0	1		160	160	0			0	0			0
91	Chlordane	0			0	1		200	200	0			0	0			0
112	PCB-1016	0			0	1		629	629	0			0	0			0
	MCPP	1			0	0			0	0			0	0			0
	TEPP	2			928	0			0	0			0	0			0
2	Acrolein (2-Propanol)	0			0	0			0	1		270	270	0			0
515	Ethyl Ether (Diethyl Ether)	12	<50	1795	243	0			0	0			0	0			0
8	1,2,4, Trichlorobenzene	0			0	2	80	88	88	0			0	0			0
571	O-Cresol (Methylphenol, 2-)	9	<10	25	12	3	5	360	140	0			0	0			0
113	Toxaphene	0			0	0			0	0			0	1		1	1
509	Alpha-Terpineol	8	<10	121	28	0			0	0			0	0			0

TABLE 3, Continued

Poll No	Pollutant Name	HMT Study				CLP Database				Wisconsin Study				Misc. Subtitle D			
		No.	Min	Max	Mean	No	Min.	Max.	Mean	No.	Min.	Max.	Mean	No	Min.	Max	Mean
506	N-Dodecane (N-C12)	8	<10	62	17	0			0	0			0	0			0
513	P-Cymene	6	<10	17	11	0			0	0			0	0			0
936	Thioxanthone	9	<10	286	58	0			0	0			0	0			0
554	Vinyl Acetate	12	<10	17	11	0			0	0			0	0			0
323	N-Tetracosane(N-C24)	8	<10	353	29	0			0	0			0	0			0
18	Bis(2-Chloroethyl)ether)	8	<10	12	10	0			0	0			0	0			0
580	Diepoxybutane, 1,2,3,4-	1	<10	330	43	0			0	0			0	0			0

TABLE 4

Organic Compounds Found in Raw Leachate - Hazardous Waste Landfills

Poll. No	Pollutant Name	ORD/HWERL Study No	Min.	Max.	Mean	NEIC Study No.	Min.	Max.	Mean
44	Methylene Chloride	13	19	56800	14100	13	<25	620000	111344
25	Dichlorobenzene, 1,2-	2	173	46000	18980	3	100	20000	13667
11	Trichloroethane, 1,1,1-	5	37	22000	2980	11	13	100000	12719
87	Trichloroethylene	11	13	11300	2040	14	<5	300000	28089
23	Chloroform	10	3	7250	2100	8	5	55000	12744
7	Chlorobenzene	6	107	2480	700	12	<5	70000	9177
10	Dichloroethane, 1,2-	1		9040	9040	5	3100	57000	23020
13	Dichloroethane, 1,1-	4	47	1620	350	9	10	2600	960
27	Dichlorobenzene, 1,4-	2	186	6300	1500	3	<10	9000	5670
85	Tetrachloroethylene	7	5	1800	520	11	<5	210000	22673
30	Trans,-1,2-Dichloroethylene	5	11	1610	280	8	<5	6900	1231
26	Dichlorobenzene 1,3-	2	150	990	410	0			0
6	Carbon Tetrachloride	1		879	879	3	310	70000	25437
14	Trichloroethane, 1,1,2-	2	42	231	57	6	1000	70000	35700
32	Dichloropropane, 1,2-	3	82	186	78	1		260	260
88	Vinyl Chloride	0			0	3	<50	2700	933
15	Tetrachloroethane, 1,1,2,2-	0			0	5	230	500000	136874
29	Dichloroethene, 1,1-	0			0	1		300	300
86	Toluene	13	31	33600	8340	17	15	510000	40184
HC250	Total Xylenes	11	60	5160	1670	13	7	370000	64991
55	Napthalene	4	27	5200	1240	6	<10	35000	6363
4	Benzene	12	9	720	303	13	7	6900	2429
38	Ethylbenzene	10	16	7100	366	13	<5	100000	17608
V074	Trimethyl Benzene, Isomer	2	143	300	34	0			0
904	Methylnapthalene, 2-	2	120	3400	222	4	<5	480	143
	Benzene, 1,2,3-Trimethyl-	1		2240	2240	0			0
81	Phenanthrene	1		300	300	2	32	53	43
	Benzene, 1-Ethyl-2 Methyl	1		346	346	0			0
77	Acenaphthylene	1		150	150	2	<10	50	30
	Tetramethyl Benzene Isomer	1		255	255	0			0
	Benzene, Propyl-	1		176	176	0			0
39	Fluoranthene	0			0	1		12	12
557	Aniline	3	14700	56000	20200	5	1200	820000	330840
	Acetamide,N,N Dimethyl-	1		13800	13800	0			0
569	Chloroaniline, 4-	2	12000	15500	6920	0			0
	Pyrrolidinone, 1-Methyl-,2-	1	360	14400	6150	0			0
	Isoquinoline	1		3020	3020	0			0
	Azepin-2-One,Hexahydro-,2H-	1		7410	7410	0			0
930	Pyridine	1		11500	11500	0			0
	Pyridine, 2-Chloro-	2	3880	6200	5040	0			0
	Benzenesulfonamide, 4-Methyl	5	202	6020	1720	0			0
65	Phenol	13	2406	110000	21590	10	140	140000	41434
944	Methylphenol, 4- (P-Cresol)	12	110	47000	12300	5	12	46000	15736
943	Benzoic Acid	8	3090	30600	11560	11	1000	520000	145182
	Butanoic Acid	4	2400	63400	19900	0			0

TABLE 4, Continued

Poll No.	Pollutant Name	ORD/HWERL Study No.	Min.	Max.	Mean	NEIC Study No.	Min.	Max.	Mean
	Hexanol,2-Ethyl-,1-	3	434	1860	960	0			0
	Propanol, 1-(2-Methoxy-1-Methylethoxy),-2-	2	112	1550	830	0			0
	Tetrathiepane, 1,2,4,6-	1		3020	3020	0			0
	Ethanol, 1-(2-Butoxyethoxy)-	2	1230	8860	5040	0			0
	Ethanol,2,2'-Thiobis-	1		3930	3930	0			0
	Benzaldehyde, 4-Hydroxy-3-Methoxy-	1		770	770	0			0
	Isoindole-1,3(2H)-Dione,1H-	1		1490	1,[illegible]	0			0
	Naptho(1,8-CD)Pyran-1,3-Dione,1H,3H	2	31	692	360	0			0
	Methane, Sulfonylbis-	1		1560	1560	0			0
	Pentanediol, 2-Methyl-,2,4-	1		2660	2660	0			0
68	Di-n-Butylphthalate	9	23	996	300	2	<10	31	21
	Ethanol,2-[2-(2-Ethoxy-ethoxy)Ethoxy]-	1		1560	1560	0			0
	Anthracenedione,9,10-	1		750	750	0			0
	Isoindole-1,3(2H)-Dione,3A,4,7,7A-Tetrahydro	1		1630	1630	0			0
	Phosphineoxide, Triphenyl-	1		2390	2390	0			0
	Propan-2-01,2-Phenyl-	2	226	402	318	0			0
	Cyclohexan-1,2-Dicarboxylic Acid Anhydride	1		1030	1030	0			0
	Alkanol	1		1020	1020	0			0
66	Bis(2-Ethylhexyl) Phthalate	1		1400	1400	5	65	10000	2372
71	Dimethyl Phthalate	1		820	820	1		2280	2280
	Methyl Acetophenone	1		137	137	0			0
69	Di-n-Octyl P[illegible]late	1		31	31	1		13	13
70	Diethyl P[illegible]late	0			0	1		2100	2100
67	Butyl B[illegible]yl Phthalate	0			0	1		490	490
	Benzene,2-Ethyl-1,4-Dimethy-	1		965	965	0			0
510	Styrene	1		637	637	3	100	43000	14627
	Benzene,1,3-Diamino-4-Methyl	1		2400	2400	0			0
	Benzene, 1,4- Diamino-	1		1940	1940	0			0
	Benzene, 1,2-Diamino-	1		835	835	0			0
	Benzamide	1		1500	1500	0			0
578	Aniline, 2,3- Dichloro-	1		1150	1150	0			0
582	Naphthaline, 2-Amino	1		942	942	0			0
	Aniline, 2-Methoxy	1		515	515	0			0
	Benzenesulfonamide,2-Methyl	1		114	114	0			0
	Pyridinamine,2-	1		560	560	0			0
	Morpholine,4-Ethyl-	1		520	520	0			0
	Bycyclo(2.2.1)Hept-2-ene,1,7,7-Trimethyl	1		17300	17300	0			0
	n-Alkanes(c)*	1		9540	9540	0			0
	Heptane,2,2,4,6,6-Pentamethyl-	1		4760	4760	0			0
	Heptadecane	2	575	5440	3010	0			0
	n-Alkanes(A)*	1		3300	3300	0			0
	n-Alkanes(D)*	1		3740	3740	0			0
	n-Alkanes(B)*	1		2700	2700	0			0
	Cyclobutene,2-Propenylidene-	1		75	75	0			0
106	PCB-1242	0			0	3	300	240000	86767

TABLE 4, Continued

Poll No	Pollutant Name	ORD/HWERL Study No	Min.	Max.	Mean	NEIC Study No.	Min.	Max.	Mean
	Propanoic Acid,2-Methyl-	4	3660	17000	8385	0			0
	Pentanoic Acid	3	6180	21500	13990	0			0
	Alkanoic Acid	2	1120	50100	25610	0			0
947	Hexanoic Acid	2	3600	39700	21650	0			0
34	Dimethylphenol, 2,4-	8	30	12000	3140	6	77	15000	3186
	Phenylacetic Acid	5	1600	6400	3740	0			0
	Phenol, 4-(Methylthio)-	1		770	770	0			0
	Octanoic Acid	1		9440	9440	0			0
	Butanoic Acid,2-Methyl-	3	510	2610	1820	0			0
31	Dichlorophenol,2,4-	4	87	2900	1240	0			0
	Phenol, 2,4,6-Trimethyl-	1		5720	5720	0			0
	Phenolpropanoic Acid	4	27	2230	890	0			0
64	Pentachlorophenol	1		1900	1900	0			0
	Propanoic Acid,2,2-Dimethyl-	1		220	220	0			0
	Benzoic Acid,4-Chloro-	1		8220	8220	0			0
21	Trichlorophenol, 2,4,6-	1		3860	3860	0			0
R132	Acetic Acid,(2,4-Dichlorophenoxy)-	1		890	890	2	80	440	260
531	Trichlorophenol, 2,4,5-	1		3440	3440	0			0
	Phenol,2,5-Dichloro	1		2760	2760	0			0
	Naphthalene Carboxylic Acid,1-	1		610	610	0			0
	Phenol,4,4'-Methylenebis-	1		5540	5540	0			0
24	Chlorophenol,2-	1		1790	1790	3	<10	130	62
	Benzoic Acid,4-(1,1-Dimethyl-ethyl)-	1		675	675	0			0
	Phenylacetic Acid, 4-Methoxy-	1		710	710	0			0
	Benzoic Acid, 3,4,Dichloro-	1		1210	1210	0			0
	Phenol,3-(1,1-Dimethylethyl)-	1		525	525	0			0
	Benzene-1,2-dicarboxylic Acid	1		33	33	0			0
	Phenol,2,5-Dimethyl	1		310	310	0			0
22	Chloro-3-Methylphenol,4-	1		36	36	0			0
516	Acetone	13	344	77500	23200	15	100	1000000	202273
514	Butanone, 2-	12	62	42900	14710	12	6000	390000	190042
564	Benzyl Alcohol	6	1700	60000	18110	0	<40	130000	0
545	Hexanone, 2-	13	17	17200	4610	1		15000	15000
	Pentanol, 4-Methyl-,2	2	2450	33000	17720	4	3000	24000	12750
	Cyclopentanol,2-Methyl	2	1130	17800	9460	0			0
	Ethane, 1,1'-Oxybis (2-Methoxy-)	2	540	16600	8570	0			0
	Ethanol, 2-Butoxy-	2	1560	3740	2650	0			0
550	Methyl-2-Pentanone,4-	11	9	3730	840	12	240	71000	16636
	Ethanol 2-(2-Butoxyethoxy)-	3	940	10800	5500	0			0
	Cyclohexanone	3	1650	3930	3067	0			0
	Benzene-1,2-Dicarboxylic Acid Anhydride	3	1020	6720	3970	0			0
	Pentanediol, 2,2,4-Trimethyl-,1,3-	2	810	5490	3150	0			0
54	Isophorone	1		15000	15000	5	<10	1500	310
	Propanediol, 2,2-Dimethyl-,1,3-	2	580	2440	1510	0			0
	Phosphoric Acid Tributylester	1		10200	10200	0			0

TABLE 4, Continued

Poll. No	Pollutant Name	ORD/HWERL Study				NEIC Study			
		No.	Min.	Max.	Mean	No.	Min.	Max.	Mean
107	PCB-1254	0			0	1		100	100
	Tetrahydrofuran	0			0	8	4000	690000	137875
530	1,2 Dibromoethane (EDB)	0			0	3	2200	19000	9733
2	Acrolein (2-Propenol)	0			0	9	100	3000000	541502
	2-Methyl-2-Butanol	0			0	1	<500	71000	71000
515	Ethyl Ether (Diethyl Ether)	0			0	2	3000	14000	8500
	2-Butanol	0			0	6	20000	490000	140000
8	1,2,4, Trichlorobenzene	0			0	3	500	29000	10193
9	Hexachlorobenzene	0			0	1		10000	10000
12	Hexachloroethane	0			0	1		10000	10000
52	Hexachlorobutadiene	0			0	1		30000	30000
533	Tetrachlorobenzene 1,2,4,5-	0			0	1		10000	10000
571	O-Cresol (Methylphenol, 2-)	10	91	24000	5300	5	14	21000	3502
8071	P-Chloroaniline	0			0	1		1600	1600
921	Pentachlorobenzene	0			0	1		2000	20000
	Bromochloromethane	0			0	1		130000	130000
48	Bromodichloromethane	0			0	1		360	360
533	Carbon Disulfide	0			0	2	40	2500	1147
505	Dibenzofuran	0			0	2	<11	32	22
80	Fluorene	0			0	2	13	38	26
547	Isobutyl Alcohol	0			0	1		1000	1000
3	Acrylonitrile	0			0	2	3	6	4
527	1,4,Dioxane	0			0	6	400	88000	23117
	Compound A	1		1630	1630	0			0
100	Gamma-BHC	0			0	1		5400	5400
102	Alpha-BHC	0			0	1		7000	7000
	Ethanol, 2-(2-Ethoxyethoxy)	1		1210	1210	0			0

landfill leachates. However, the use of different analytical methods may have also contributed somewhat to the difference in analytical results. Another factor is that the list of analytes differed for each study; however, the EPA ITD study, which used the most extensive list of analytes, found both the fewest organic compounds in the leachates and some of the lowest concentrations.

Table 5 lists the most frequently found organic compounds in leachates (i.e., those found in at least 50 percent of the leachates sampled). These data show that approximately 25 toxic organic compounds are frequently found in landfill leachates. The compounds (methylene chloride, toluene, and benzene) were found in 50 percent or more of the leachate samples from four or more of the studies reported in Tables 3 and 4.

Incinerator Scrubber Wastewaters

Chemical characteristics of raw incinerator scrubber wastewaters are a function of the operation of the scrubber water system. The amount of scrubber water that can be recirculated depends on the amount of solids being removed from the gas stream. In one mode of operation, TSS is maintained between 6,000 and 10,000 ppm or TDS less than 10 percent. Ammonia is often added to the recirculating water to neutralize the acids from the gases being scrubbed. At other operations, scrubber effluent is treated using lime precipitation prior to recycle. This results in a low TSS concentration in the recirculating scrubber water.

These two different modes of operation result in different chemical characteristics of raw scrubber wastewaters as summarized in Table 6. TSS concentrations range from 2 to 58,000 mg/l; the higher concentrations involved systems that operated without lime precipitation. Ammonia concentrations range from 0.1 to 3100 mg/l, the result of ammonia used to neutralize the acids. The pH of most raw scrubber

TABLE 5

Most Frequently Found Organic Compounds in Leachates*

In 4 or More Studies	In 1 Study
Methylene Chloride	Hexanone, 2-
Toluene	Methylphenol, 4-
Benzene	O-Cresol (2-Methylphenol)
	Chloroform
	Dimethylphenol, 2,4-
In 3 Studies	Di-N-Butyl Phthalate
	Benzoic Acid
Ethylbenzene	Tetrachloroethylene
	Diethyl Phthalate
	Trans-1,2-Dichloroehtylene
In 2 Studies	Dichloroethane, 1,1-
	Alpha-Terpineol
Phenol	Isophorone
Acetone	Bis(2-Ethylhexyl) Phthalate
Butanone, 2-	Chlorobenzene
Methyl-2-Pentanone, 4-	
Trichloroethene	
Total Xylenes	

*Compound found in 50% or more of the samples.

TABLE 6

Conventional and Nonconventional Pollutants in Raw Scrubber Wastewaters

Pollutant	Range of Detected Pollutant*		
	Minimum	Maximum	Mean
BOD_5	18	300	88
COD	110	760	410
TOC	17	630	195
TSS	2	58,000	12,700
TDS	4,007	11,700	6,710
Chloride	2,400	9,000	5,550
O&G	1.0	1.8	1.1
Ammonia-N	0.1	3,100	733
TKN	1.6	200	56
NO_2 and NO_3-N	0.25	3.9	1.7
Fluoride	2.75	400	100
Sulfide	0.1	0.1	0.1
pH	1.2	7.3	
Phenols	0.05	0.22	0.12
Cyanide	0.01	0.02	0.01
TVO	0.1	0.1	0.1
Calcium	440	3,410	1,660
Magnesium	5.16	320	203
Sodium	150	500	330

*All concentrations in mg/l except pH (S.U.)

wastewaters is very low due to the hydrogen chloride gases generated by burning wastes and removed by the wet scrubbers.

High TDS and chlorides are characteristics of all scrubber wastewaters. The high TDS is caused by the removal of gases containing chloride and SO_2 (producing sulfate in water); by the addition of chemicals to neutralize the acids in the stack gases; and by the dissolution of solids in the particulates removed by the scrubbers.

Tables 7 and 8 summarize the metals and organic pollutants in raw scrubber wastewaters. These data indicate that scrubber wastewaters contain high concentrations of metals but very few organic pollutants. The metals concentrations are also a function of the operation of the scrubber water system, with the high concentrations again occurring at the facility that recirculates a high TSS and TDS load in the water.

Scrubber wastewaters can contain extremely high concentrations of aluminum, iron, lead, zinc, mercury, and copper (i.e., 20,000 - 50,000 ug/l). Manganese, boron, molybdenum, tin, titanium, and nickel occur in significant but lesser concentrations (but still well over 1 mg/l).

The absence of all but a few organic pollutants in the raw scrubber wastewaters is expected if the RCRA and the Toxic Substances Control Act (TSCA) incinerators are achieving the required destruction levels. The TOC data support the relative absence of organics except at one facility. In this facility, which recirculates the high TSS concentrations in the scrubber water, the TOC concentrations are relatively high; however, the high TOCs may be due to carbon particles in the TSS from fly ash rather than organic compounds, because carbon particles are measured by the TOC test.

TABLE 7

Metals in Raw Scrubber Wastewater*

Metal	Range of Detected Metal			Percent of Samples Where Metal was Detected
	Minimum	Maximum	Mean	
Aluminum	2,130	170,000	48,100	100
Iron	3,400	520,000	164,000	100
Manganese	269	12,000	3,420	100
Boron	260	18,000	4,980	100
Barium	190	6,000	2,070	100
Molybdenum	130	12,000	3,580	100
Antimony	28	4,420	1,500	100
Arsenic	6	3,460	1,040	100
Beryllium	<1.0	14	4.2	67
Cadmium	12	2,000	600	100
Chromium	45	2,800	970	100
Cobalt	<4.0	860	282	67
Copper	84	23,000	6,430	100
Lead	88	75,000	21,200	100
Mercury	0.26	318	71	100
Nickel	78	8,300	970	100
Selenium	<5	13	6.6	20
Silver	2	58	35	100
Thallium	<10	17	11	17
Tin	<13	4,900	1,580	83
Titanium	59	8,300	2,790	100
Vanadium	4	110	46	100
Yttrium	<10	42	18	33
Zinc	350	660,000	159,000	100

*All concentrations in ug/l.

TABLE 8

Organics in Raw Incinerator Scrubber Wastewater*

Compound	Range of Detected Compound		Number of Samples Where Compound was Detected
	Minimum	Maximum	
Acetone	--	65	1
Benzene	--	61	1
Bromoform	--	15	1
Fluoranthene	--	109	1
N-Nitrosodi-N-Propylamine	--	907	1
Pyrene	--	326	1
Thioxanthone	--	4,067	1

--Not Detected

*All concewntrations in ug/l

Aqueous Hazardous Waste Treaters

The primary source for analytical data characterizing aqueous hazardous wastes is the 1986-1987 EPA ITD study sampling effort. Four aqueous hazardous waste treatment facilities were sampled during this program. The aqueous treaters accepted and treated inorganic industrial wastes (plating baths, pickle liquors), organic wastes (food and pharmaceutical manufacturing, solvent reclaiming, detergent manufacturing), oil wastes, tank washings, leachates (hazardous and Subtitle D landfills), brines, scrubber wastewaters, miscellaneous waste acids, and caustics.

The EPA ITD study sampling data have been supplemented by analytical data obtained from two aqueous treaters sampled during an OSW study to support OSW's Land Disposal Restriction Rules. While the EPA ITD study analyzed the wastewaters for over 500 compounds listed in its 1986 List of Analytes, plus conventionals and nonconventionals, the ORD/HWERL samples were only analyzed for 15 toxic metals, 29 volatile organic compounds, 29 extractables, and selected conventional and nonconventional pollutants. QA/QC data are available for both the EPA ITD and OSW sampling efforts.

Table 9 summarizes the conventional and nonconventional pollutant data from the previously discussed sources. The data show that aqueous hazardous wastes contain high concentrations of BOD_5, COD, and TOC. These data show that these facilities have a wide range of concentrations for these pollutants. In addition, the concentrations of these pollutants vary widely from day to day. This is due to the rapidly changing wastes being processed by these facilities. The mean concentrations of BOD_5, COD, and TOC are very high, with concentrations in the range of 1500 to 15,000 mg/l.

Metals data for the raw aqueous hazardous wastes are summarized in Table 10. Like the conventional and nonconventional pollutant data, the

TABLE 9

Conventional and Nonconventional Pollutants in Aqueous Hazardous Wastes - Summary*

Pollutant	HWT Study Minimum	HWT Study Maximum	HWT Study Mean	HWT Study No. of Samples	OSW Study Minimum	OSW Study Maximum	OSW Study Mean	OSW Study No. of Samples	Overall Mean	Overall No. of Samples
BOD	330	3,720	2,000	8	—	—	—	—	2,000	8
COD	4,160	14,100	8,360	8	11,000	70,000	39,300	3	16,800	11
TOC	450	1,600	985	7	52	19,000	4,180	14	3,115	21
Total Solids	—	—	—	—	200,000	250,000	223,000	3	223,000	3
TDS	2,700	70,400	23,400	8	10,000	170,000	107,000	3	46,200	11
TSS	130	9,240	1,570	8	46,000	240,000	115,000	3	32,500	11
Chloride	300	11,500	4,720	8	—	—	—	—	4,720	8
O&G	4.7	1,390	385	8	2,600	18,000	11,200	3	3,330	11
Total Organic Halides	—	—	—	—	0	0.36	0.144	15	0.144	15
Ammonia	8.1	1,000	475	8	20	100	52	3	360	11
TKN	2.5	1,210	382	8	—	—	—	—	382	8
NO_2 and NO_3-N					—	—	—	—		
Fluoride	2.3	500	138	8	19	52	35	3	110	11
Sulfide										
Phenols	1.4	18.7	8.64	8	—	—	—	—	8.64	8
Cyanide	0.1	5.0	1.18	8	<20	450	235	2	48	10
Silica	—	—	—	—	0.4	1.32	0.81	3	0.81	3
TVO					—	—	—	—		
Calcium	59	711	389	8	—	—	—	—	389	8
Magnesium	5.0	136	48	8	—	—	—	—	48	8
Sodium	527	6,500	2,270	8	—	—	—	—	2,270	8

*All concentrations in mg/l except pH (S.U.), total organic halides (weight %), and silica (weight %)

TABLE 10

Metals in Aqueous Hazardous Wastes - Summary*

	HWT Study				OSW Study				Overall	
Pollutant	Minimum	Maximum	Mean	% Detected	Minimum	Maximum	Mean	% Detected	Mean	No. of Samples
Aluminum	730	63,400	29,300	100	—	—	—	—	29,300	8
Iron	3,780	11,200,000	2,560,000	100	—	—	—	—	2,560,000	8
Manganese	380	68,400	16,900	100	—	—	—	—	16,900	8
Boron	8,800	63,500	26,300	100	—	—	—	—	26,300	8
Barium	205	1,100	522	100	<10,000	12,000		8	1,800	9
Molybdenum	608	2,290	1,080	10	—	—	—	—	1,080	8
Antimony	22	2,140	477	100	<10,000	40,000	—	8	4,870	9
Arsenic	<25	1,051	248	86	—	<1,000	—	0	248	6
Beryllium	<1	16	14	25	—	<2,000	—	0	14	2
Cadmium	16	1,190	363	100	3,900	225,000	58,800	53	29,600	16
Chromium, total	108	99,900	35,600	100	12,000	2,581,000	1,205,000	100	798,000	23
Chromium, hex.	—	—	—	—	50	893,000	408,000	100	408,000	12
Cobalt	<50	1,310	547	62	—	—	—	—	547	5
Copper	296	[illegible]69,000	221,000	100	72,000	1,500,000	294,000	100	269,000	23
Lead	<200	17,100	6,940	75	1,100	212,000	60,900	67	25,000	16
Mercury	1.1	92	25	100	—	<1,000	—	0	25	8
Nickel	252	93,700	22,500	100	4,300	16,330,000	1,992000	100	1,307,000	23
Selenium	<5	3,270	685	62	—	<10,000	—	0	685	5
Silver	2.2	525	177	62	—	<2,000	—	0	177	5
Thallium	—	<10	—	0	—	<10,000	—	0	0	0
Tin	<40	3,520	2,000	50	—	—	—	—	2,000	4
Titanium	<50	2,280	806	75	—	—	—	—	806	6
Vanadium	47	641	227	75	—	—	—	—	227	6
Yttrium	<10	430	206	38	—	—	—	—	206	3
Zinc	334	6,570,000	1,330,000	100	[illegible].900	1,700,000	194,000	100	589,000	23

*All concentrations in µg/l

metals show a wide range of concentrations from facility to facility and from day to day. Metals such as aluminum, iron, boron, copper, zinc, chromium, lead, cadmium, nickel, and manganese were found at concentrations as high as 11,000 mg/l. Copper, chromium, cadimum, lead, nickel, and zinc are common toxic metals with numerous industrial uses, which accounts for their presence in all raw waste samples. Aluminum, iron, boron, and manganese are also present in many industrial wastewaters. Less commonly used industrial metals such as beryllium, selenium, silver, thallium, tin, vanadium, cobalt, arsenic, and yttrium were found at lower concentrations.

Table 11 summarizes the organic pollutants found in the raw aqueous hazardous wastes. Like the metals, the organic compounds are found in a wide range of concentrations and in many cases, at very high concentrations. Common organic solvents such as acetone, 2-butanone (MEK), methylene chloride, benzene, 1,1,2,2-tetrachloroethane and toluene were found in the highest concentrations. These compounds were also among the most frequently detected organic pollutants (i.e., found in 38 to 75 percent of the samples taken). In addition, several extractable organics, thioxanthone, 2-chloronaphthalene, alpha-terpineol, phenol, and 4-chloro-3-methylphenol were found in high concentrations (e.g. as high as 28,000 ug/l) but usually in less than half of the samples. The most commonly found extractable compound was di-N-butyl phthalate which was detected in 63 percent of the samples tested. Phenol was detected in two of the three OSW study samples but in only two of eight EPA ITD study samples.

Summary

In summary, the following observations and conclusions have been drawn regarding toxics in wastewater from the hazardous waste treater industry:

TABLE 11

Pollutants in Aqueous Hazardous Wastes - Summary

Pollutant	HWT Study Minimum	HWT Study Maximum	HWT Study Mean	HWT Study % Detected	OSW Study Minimum	OSW Study Maximum	OSW Study Mean	OSW Study % Detected	Overall Mean	Overall No. of* Samples
Volatiles										
Acetone	<50	1,719,690	254,177	63	-	22,000	22,000	33	228,380	9
Benzene	<10	17,171	2,241	75					2,241	8
Butanone, 2- (MEK)	<50	156,973	48,225	63					48,225	8
Carbon Tetrachloride	<10	329	54	25					54	8
Chlorobenzene	<10	650	94	25					94	8
Chloroform	<10	1,151	285	38	<10	110	18	8	125	20
Dichloroethane, 1,1-	<10	839	150	25	<10	340	64	27	98	20
Dichloroethane, 1,2-	<10	263	62	38					62	8
Dichloroethene, 1,1-	<10	1,517	198	13					198	8
Diethyl Ether	<50	81	54	13					54	8
Dibromoethane, 1,2- (EDB)	<10	20	11	13					11	8
Ethylbenzene	<10	934	378	63	<10	200	49	40	181	20
Hexanone, 2-	<10	200	57	25					57	8
Methylene Chloride	<10	4,094	1,388	75	<10	63,000	6,875	20	4,966	23
Tetrachloroethane, 1,1,2,2-	<10	108,716	13,635	38					13,635	8
Tetrachloroethene	<10	3,043	407	25	<10	2,300	200	33	279	21
Toluene	<10	115,068	16,281	75	<10	2,300	298	47	6,110	22
Trans-1,2-Dichloroethene	<10	190	55	38	<10	25	11	8	29	20
Trichloroethane, 1,1,1-	<10	4,163	1,063	75	<10	9,400	1,182	40	1,139	22
Trichloroethane, 1,1,2-	<10	332	52	25	<10	46	13	8	29	20
Trichloroethene	<10	5,060	673	63	<10	1,100	123	20	333	21
Vinyl Acetate	<10	814	111	13					111	8
Extractables										
Alpha-Terpineol	<10	5,701	1,446	38					1,446	4
Isophorone	<10	2,372	501	38					501	6
N-Dodecane (N-C12)	<10	47	19	13					19	4

TABLE 11, Continued

Pollutant	BWT Study				OSW Study				Overall	
	Minimum	Maximum	Mean	% Detected	Minimum	Maximum	Mean	% Detected	Mean	No. of* Samples
N-Hexadecane (N-C16)	<10	2,969	869	25					869	5
N-Docosane (N-C22)	<10	5,056	1,019	13					1,019	5
Benzoic Acid	<10	1,129	540	25					540	4
P-Cresol	<10	64	24	25					24	4
O-Cresol	<10	1,703	222	13					222	8
Thioxanthone	<10	28,625	7,996	25					7,996	7
Di-N-Butyl Phthalate	<10	1,059	220	63					220	5
Pentachlorophenol	<50	117	67	13					67	4
Phenol	<24	4,442	1,560	75	3,900	4,400	4,150	67	2,208	8
Chlorophenol, 2-	<10	10	10	13					10	4
Chloronaphthalene, 2-	<10	16,480	3,519	25					3,519	6
Chloro-3-Methylphenol, 4-	<10	3,397	1,322	25	—	3,100	3,100	33	1,678	5
Benzyl Alcohol	<10	2,601	795	38					795	8
Hexanoic Acid	<10	2,443	928	38					928	5
Isobutyl Alcohol	<10	187	35	25					35	8
Methyl Methacrylate	<10	12	10	13					10	8
Bis (2-Ethylhexyl) Phthalate	<10	380	129	38					129	6
Fluorene	<10	20	13	13					13	4
Naphthalene	<10	285	75	25					75	5
Styrene	<10	1,003	224	38					224	6
Diphenylhydrazine, 1,2-	<10	26	19	13					19	4
Dinitrotoluene, 2,4-	<10	192	57	25					57	4
Bis (2-Chloroethyl) Ether	<10	1,391	286	13					286	5
Diphenylamine	<10	22	13	13					13	4
Hexachloro-1,3-Butadiene	<10	599	157	13					157	4
Hexachlorobenzene	<10	14	11	13					11	4
Hexachloroethane	<10	132	41	13					41	4
Dichlorobenzene, 1,2-	<10	106	34	13					34	4
Methylnaphthalene, 2-	<10	2,444	358	13					358	7

TABLE 11, Continued

	BWT Study				OSW Study				Overall	
Pollutant	Minimum	Maximum	Mean	% Detected	Minimum	Maximum	Mean	% Detected	Mean	No. of* Samples
N-Octadecane (N-C18)	<10	449	98	20					98	5
N-Decane (N-C10)	<10	670	208	33					208	6
Butyl Benzyl Phthalate	<10	785	165	20					165	5
Nitrophenol, 2-	<20	202	66	25					66	4
N-Nitrosodi-N-Butylamine	<10	200	37	14					37	7
P-Cresol	<10	64	24	50					24	4

All concentrations in µg/l
*Number of samples used to calculate the mean

- o Some landfill leachates contain very high concentrations (>100,000 ug/l) of toxic organic compounds.

- o The analytical methods used to identify and quantify organic pollutants in leachate may have an effect on the quantification of the organics found.

- o Hazardous waste landfill leachates appear to contain more toxic organic compounds than leachate from Subtitle D landfills in terms of organic pollutants, but this observation may be due to the list of analytes and/or analytical methodology problems. In terms of COD and TOC, however, there is no apparent difference between hazardous waste and Subtile D landfills.

- o Leachates generally contain high concentrations of aluminum, iron, zinc, manganese, and boron with the concentrations of many heavy metals appearing over 1 mg/l.

- o Incineration scrubber wastewaters contain high concentrations of metals. The metals detected at the highest concentrations include aluminum, iron, lead, zinc, mercury, and copper.

- o Scrubber wastewaters contain very few organic pollutants.

- o Both metals and organic compounds were found in effluents from aqueous treaters in a wide range of concentrations and, in some cases, at very high concentrations.

- o The organics found most frequently and at the highest concentrations at aqueous treaters were industrial solvents. The metals found at the highest concentrations and most frequently were chromium, copper, nickel, zinc, iron, aluminum, boron, and manganese.

- o The wide range of concentrations of the toxic pollutants in the raw waste samples can be attributed to the high variability of wastes received and treated by aqueous treater facilities.

The ORNL Ground-Water Monitoring Program

Presented by:

D. D. Huff, ORNL

THE ORNL GROUND-WATER MONITORING PROGRAM[1]

D. D. Huff[2], G. K. Moore[3], R. H. Ketelle[4], and L. D. Hyde[5]

Oak Ridge National Laboratory, Oak Ridge, Tennessee

The monitoring of waste storage at Oak Ridge National Laboratory requires a program that characterizes occurrence and movement of groundwater and contaminants, then supports design of corrective actions where needed. The characterization phase of this program has included an aerial radiological survey, dye tracing, piezometer well investigations, core drilling and logging, and well-cluster studies to determine vertical hydraulic gradients.

More than 320 small-diameter piezometer wells have been installed in and near waste area groupings. Although primarily intended to determine the spatial and temporal range of water-level elevations, to monitor water-table fluctuations, and thus to identify location and design of water quality monitoring wells, the piezometer wells are also proving useful for characterization of chemical groundwater quality, hydraulic gradient, fracture distribution, aquifer permeability, and aquifer storage capacity.

The locations for water quality monitoring wells are now being selected, and a well construction program is underway. The wells will be used to assess radionuclide and hazardous wastes in groundwater at waste area groupings. The detailed plans for well construction include material specifications and certification, cuttings containment, and health physics and industrial hygiene evaluations. Thus, the wells should produce representative water quality samples that will aid in setting priorities for Remedial Investigation/Feasibility Studies and remedial actions.

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[1] Based on work performed at Oak Ridge National Laboratory, operated by Martin Marietta Energy Systems, Inc., under Contract No. DE-AC05-84OR21400 with the U.S. Department of Energy.

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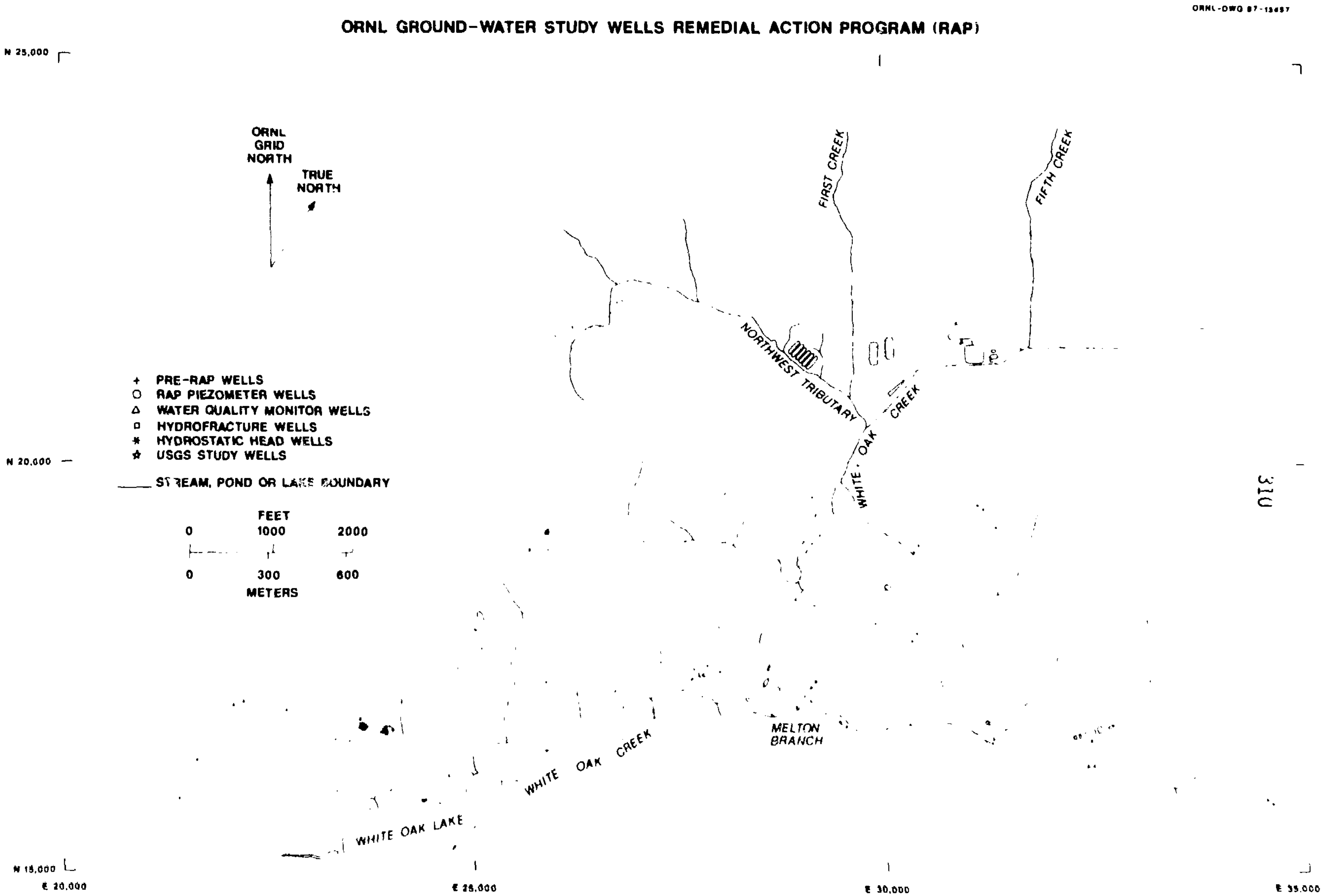

FIG 13 WELLS INCLUDED IN THE ORNL RAP DATA BASE MANAGEMENT SYSTEM

Comprehensive Sampling Program for the Y-12 Plant Area Source Pollution Assessment and Control Plan

Presented by:

E. F. Arniella, Camp, Dresser & McKee

COMPREHENSIVE SAMPLING PROGRAM FOR THE Y-12 PLANT AREA SOURCE POLLUTION ASSESSMENT AND CONTROL PLAN

Rodney H. Kingrea

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ABSTRACT

The current National Pollutant Discharge Elimination System (NPDES) permit requires an evaluation of the impact of area source discharges from the Y-12 Plant on the water quality of East Fork Poplar Creek (EFPC). Area source discharges, also referred to as nonpoint source pollution, results when uncontaminated surface or groundwater flows over or through contaminated surfaces resulting in the transfer of pollutants to a receiving stream.

A comprehensive sampling program has been developed by the Y-12 Plant with the assistance of Camp Dresser & McKee Inc. (CDM) to evaluate nonpoint sources of pollution to EFPC. The major goals of the program are to identify locations of potential area source discharges, to determine pollution loadings from various sources, and to identify appropriate corrective actions. The comprehensive sampling program was developed after the completion of a preliminary sampling program which provided an initial understanding of flow quantities and pollutant loads from major drainage systems. The application of a storm water runoff model assisted in the development of the program. The RUNOFF model has been extracted from the USEPA Storm Water Management Model and has been modified and enhanced by CDM Inc.

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*Operated for the U.S. Department of Energy by Martin Marietta Energy Systems, Inc., under contract DE-AC05-84OR21400.

Y/TS-315

Y-12

OAK RIDGE Y-12 PLANT

MARTIN MARIETTA

COMPREHENSIVE SAMPLING PROGRAM FOR THE Y-12 PLANT AREA SOURCE POLLUTION ASSESSMENT AND CONTROL PLAN

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October 15, 1987

Preprint for submission to:

Oak Ridge Model Conference
American Museum of Science and Energy

Thursday, October 15, 1987

Prepared by the
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under Contract No. DE-AC05-84OR21400

OPERATED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
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COMPREHENSIVE SAMPLING PROGRAM FOR THE Y-12 PLANT AREA SOURCE POLLUTION ASSESSMENT AND CONTROL PLAN

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1.0 INTRODUCTION

On February 4, 1987, the 100th Congress enacted the Water Quality Act of 1987, overriding the President's veto by an overwhelming majority. Two of the major provisions of the act are directed at storm water management and permitting and nonpoint source pollution. In anticipation of this Act and requirements of the current National Pollutant Discharge Elimination System (NPDES) permit, the Y-12 Plant has begun an aggressive program for identifying and controlling nonpoint pollution discharges to East Fork Poplar Creek (EFPC). Nonpoint source discharges, also referred to as area source discharges, result when surface water or ground water flows through contaminated surfaces resulting in the transport of pollutants to a receiving stream.

The Oak Ridge Y-12 plant, originally constructed in 1943 as part of the Manhattan Project, occupies approximately 800 acres with over 200 buildings and 7,000 people. The plant is currently managed by Martin Marietta Energy Systems (Energy Systems, Inc.) for the U.S. Department of Energy (DOE). The plant is primarily involved in the production of nuclear weapon components and processing source and special nuclear materials.

Energy Systems contracted Camp Dresser & McKee Inc. (CDM) to perform an Area Source Pollution Assessment and Control Plan for the Y-12 Plant drainage area.

Purpose

This paper presents the approach undertaken by the project team to implement a comprehensive sampling program of the EFPC drainage area. The results of the comprehensive sampling program will be used to establish best management practices for the control of nonpoint sources in the EFPC drainage area.

The drainage area of EFPC consists of approximately 750 acres and includes the area shown on **Figure 1**. The headwaters of EFPC originate on the northwestern slopes of Chestnut Ridge in the vicinity of the Y-12 Plant. The creek is contained in culverts through about half of the plant area before it emerges in a rip-rapped ditch approximately 8 feet high by 10 to 15 feet wide. Y-12 discharges contribute to the majority of the stream flow of EFPC. The flow rate of EFPC ranges from 4 to 2,000 cubic feet per second (CFS). Stream flow is presently controlled by New Hope Pond, an approximately 5 acre pond on the east end of the plant that serves as a settling basin. EFPC flows through the city of Oak Ridge, where it receives discharges from the Oak Ridge sewage treatment plant, industrial discharges, and area runoff before discharging into Poplar Creek.

Poplar Creek is the largest stream flowing into the Clinch River from the Oak Ridge Reservation with a flow rate ranging from 5.0 to 6,356.0 CFS at the mouth of Poplar Creek. It has a drainage area encompassing 136 square miles.

2.0 PRELIMINARY SAMPLING PROGRAM

The sampling program, designed to assess area source pollution at the Y-12 Plant, is divided into two tiers: the preliminary sampling program and the comprehensive sampling program. The preliminary sampling program was designed to assist in developing an initial understanding of flow quantities and pollutant loads from major drainage systems.

Prior to the development of the preliminary sampling program, an extensive review of plant operations and all available stream and storm sewer data was performed. The review provided information on pollutants of concern and identified general areas of the plant which may be contributing pollutant loads.

In order to better understand the sources of pollutant contributions to EFPC, a preliminary water balance (see **Figure 2**) was performed during dry weather. The preliminary water balance used annual average estimates for major water and wastewater sources discharging into EFPC. The difference between measured stream flow and estimated discharges into the stream from plant operations was assumed to represent groundwater contribution. The preliminary water balance indicates that from 70 to 85 percent of the EFPC dry weather flow is from multiple plant sources, primarily cooling waters. The remaining 15 to 30 percent of the flow is therefore derived from ground water such as infiltration and seepage into outfall systems or into the stream channel. Since ground water may be a significant portion of the flow and pollutant loadings, a more detailed water balance and pollutant transport analysis are currently being planned.

The preliminary sampling program was conducted from September 1986 to December 1986 and consisted of 17 water quality monitoring stations and two instream flow monitoring stations. Figure 1 shows the approximate locations of the monitoring sites and the associated drainage areas. Parameters identified in

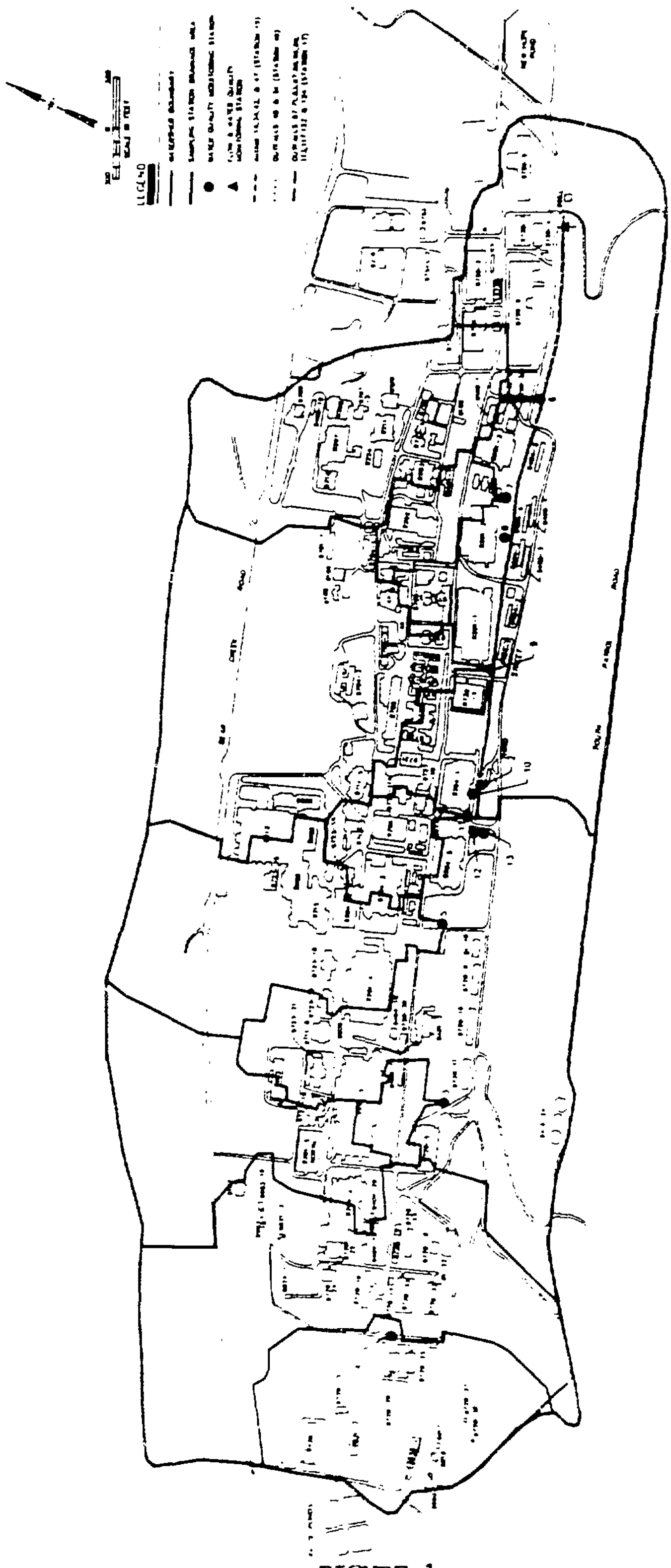

FIGURE 1
PRELIMINARY SAMPLING PROGRAM MONITORING STATIONS

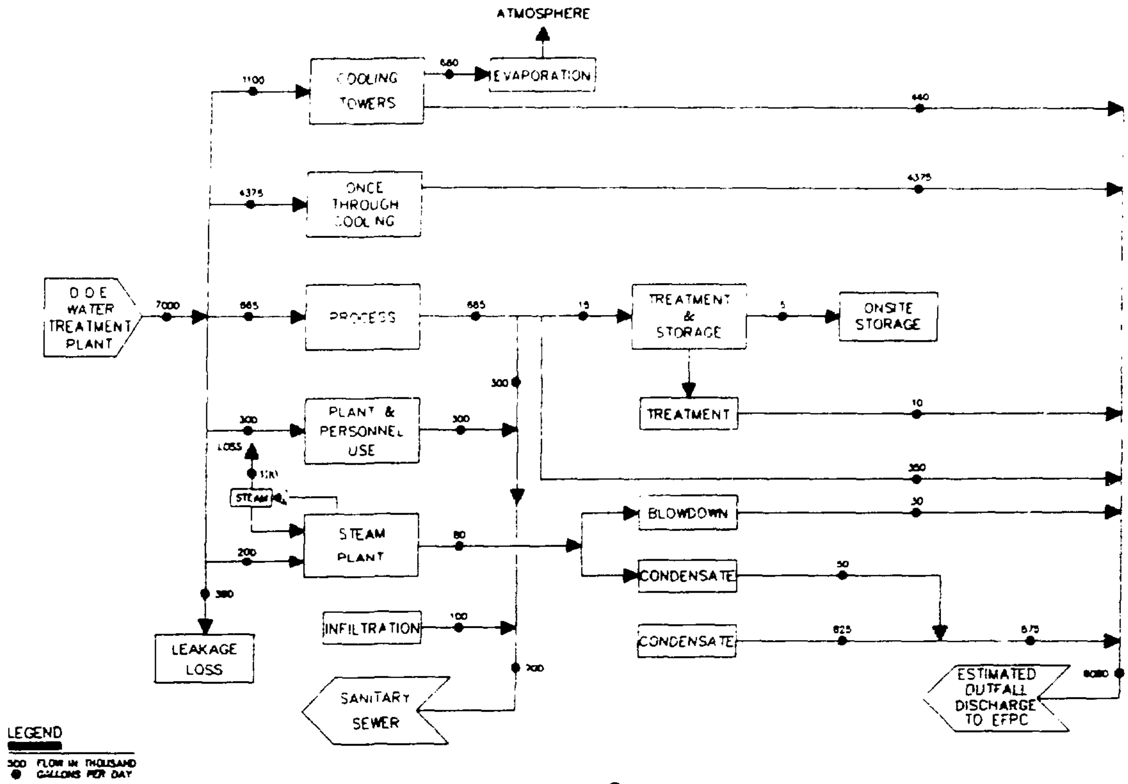

FIGURE 2
PRELIMINARY WATER BALANCE ANALYSIS FOR THE Y-12 PLANT

Table 1 were analyzed at each location on several occasions. Twenty-four hour composite and grab samples were obtained during both dry and wet weather at selected locations. The basic strategy of the sampling programs is to identify baseline pollutant loadings during dry weather and compare them to wet weather loadings. Specific areas of pollutant sources can then be identified using a mass balance approach. Additionally, the contribution of pollutants from groundwater infiltration and seepage must also be considered.

Data collected in the preliminary sampling program were compared to water quality criteria so that a more focused comprehensive sampling program could be developed. Water quality criteria for fish and aquatic life were exceeded at various locations for cadmium, mercury, copper, lead, and zinc. In addition, elevated levels of nitrate, sulfate, chloride, and dissolved and suspended solids were also observed during dry and wet weather.

TABLE 1
PARAMETERS ANALYZED

PARAMETER
1. Total Organic Compound (TOC)
2. Volatile Organic Compound (VOC)
3. Miscellaneous Parameters
3.1 Mercury, Total
3.2 Uranium, Total
3.3 Total Suspended Solids (TSS)
3.4 Total Kjeldahl Nitrogen (TKN)
3.5 Phosphorus, Total
3.6 Ammonia - Nitrogen
3.7 Nitrate - Nitrogen
3.8 ICP Metals
3.9 Arsenic
3.10 Lead
3.11 Sulfate
3.12 Nitrate - Nitrogen
3.13 Gross Alpha, Beta
3.14 Chemical Oxygen Demand (COD)
3.15 Total Residual Chlorine
3.16 Specific Conductance
3.17 Total Dissolved Solids (TDS)
3.18 pH
4. PCBs and Pesticides
5. Base Neutral/Acid Extractible
5.1 Base Neutral
5.2 Acid Extractables
6. Oil and Grease

During one storm event (approximately 2 inches in a 20-hour period), significant increases in pollutant loadings were measured as compared to pollutant loadings during dry weather. For example, wet weather loadings for heavy metals increased approximately 660 percent as a result of precipitation runoff. Kjeldahl nitrogen and phosphate increased by 330 percent, suspended solids increased by over 2000 percent, and total organic carbon increased by 150 percent. Preliminary findings are as follows:

1) Metals seem to be important area source pollutants. However, whether they are adversely affecting the receiving stream will be evaluated in the comprehensive sampling program.

2) The inorganic nonmetals show varied results. Of the five key inorganic nonmetals, only kjeldahl nitrogen and phosphate seem to be important sources from storm water runoff. Nitrate, sulfate, and chloride were found in base flow, therefore, storm water runoff is a less important source for these pollutants.

3) As expected, suspended solids is an important nonpoint source.

4) A substantial component of the base flow pollutant loading may be the result of groundwater infiltrating into the storm sewer system and stream channel. This component will be evaluated in later phases of this program.

3.0 RUNOFF MODEL

The RUNOFF model was used to analyze surface runoff and pollutant transport. The model has been extracted from the United States Environmental Protection Agency (USEPA) Storm Water Management Model (SWMM) and has been modified and enhanced by CDM. The RUNOFF model uses input rainfall hyetographs to simulate the surface runoff and storm water conveyance system for a watershed subjected to a specified rainfall event. The model produces a runoff hydrograph at selected watershed outlets.

The principal objectives of the model are:

- To estimate flows and pollutant loadings at different locations in the watershed.
- To identify general areas of concern and data gaps.
- To optimize the quantity of permanent monitoring sampling stations.
- To minimize sampling and analytical requirements.
- To simulate the impact of physical changes in the watershed.

The RUNOFF model requires data on the physical characteristics of the watershed and the network of channels, pipes, and/or lakes that drain the area. Rainfall hyetographs are applied to the watershed for calculations of overland flows and transport through the channel network. Printed or plotted output includes hydrographs for any channel within the network. The following discussion is divided into two parts pertaining to the major computational routines of the model: surface runoff and channel routing.

Surface Runoff

The watershed is first divided into smaller subbasins on the basis of drainage patterns and watershed characteristics such as infiltration parameters, slope, detention storage, and Manning's coefficients. Each land use has a characteristic percentage of its area which is impervious. Based upon input data for a subbasin, the model considers:

1. Impervious areas directly connected to the storm water drainage system without detention storage

2. Impervious areas directly connected to the storm water drainage system with detention storage

3. Pervious areas and impervious areas not directly connected to the storm water drainage system

The basic flow routing algorithm in RUNOFF is the kinematic wave approximation which assumes that the friction slope is equal to the slope of the overland flow plane or the channel. For this condition, the equations of continuity and uniform flow must be solved simultaneously to define the depth of flow and the outflow at each time step.

Channel Routing

A channel may be a pipe, trapezoidal channel, or double trapezoidal channel. Lakes, flooded channels, and overbank flows are also handled by the model. For each time step, outflow from every channel is determined, beginning with the most upstream channel and working downstream. The outflow from each channel serves as inflow to the next downstream channel.

The kinematic wave approximation is made and the equations of continuity and uniform flow are solved simultaneously at each time step.

4.0 MODEL SETUP

Two types of data are needed for RUNOFF: physical data representing the watershed that will not change from simulation to simulation, and run-specific data that depend on the rainfall event to be simulated. This section describes the data that have been compiled and reduced for the EFPC model.

Watershed Data

The EFPC 751-acre watershed was subdivided into 10 smaller watersheds ranging from 0.6 acre to 36.0 acres. These watersheds were numbered from 5,000 to 50,000 in increments of 5000. The subwatersheds were determined by the existing pipe network and outfalls to EFPC.

The subwatersheds were further broken down into subbasins with fairly homogeneous land use, soils, slopes, sewer characteristics, and impervious cover. The primary consideration distinguishing between subbasins were land use and drainage characteristics. One hundred six subbasins are delineated within the 10 subwatersheds. A typical group of subbasins is shown in **Figure 3**.

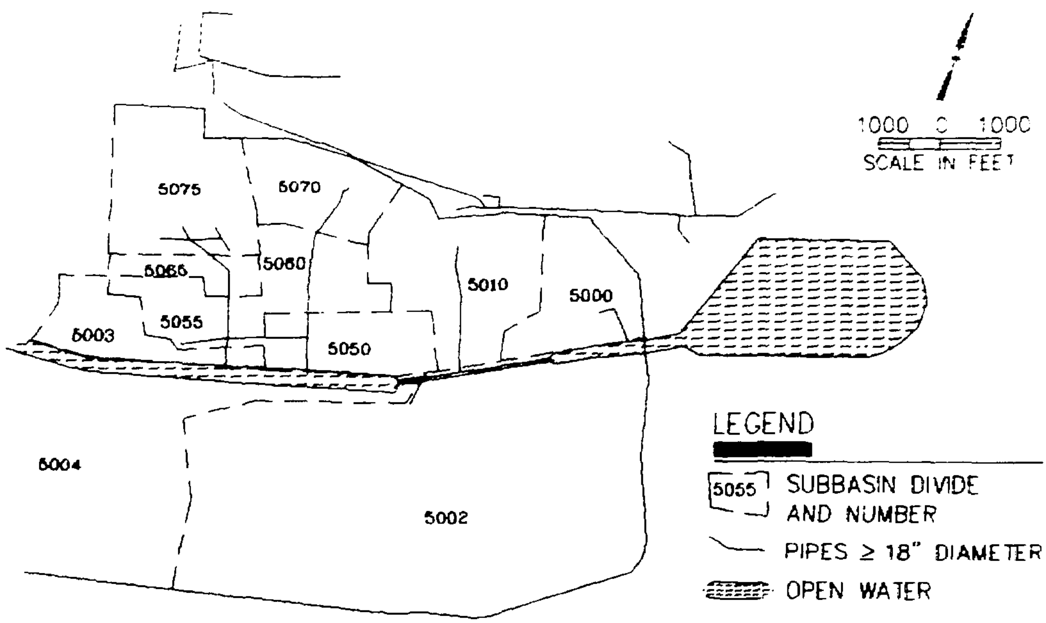

FIGURE 3
EXAMPLE OF PIPE NETWORK AND SUBBASINS

The land cover within each subbasin was subdivided by the following categories:

- o Metal rooftops
- o Gravel rooftops
- o Pavement (roads and parking areas)

- o Gravel (e.g., in the vicinity of the waste storage area)
- o Natural (grassed and forested areas)

The land uses within each subbasin were also identified as follows:

- o Research
- o Support
- o Administration
- o Production
- o Technical
- o Contractor
- o Waste
- o Parking
- o Natural

The predominant land use within each subbasin was characterized by overlaying the subbasin map on the Y-12 land use plan. As the comprehensive sampling data become available, the pollutant loading rates for each land use category can be factored into the analyses of pollutant washoff from specific watersheds.

The areas of the subbasins range from approximately 1 to 36 acres. Parameters describing the runoff characteristics for each subbasin were developed by areally weighting calibration parameters for each land cover category. The following sections describe how land cover parameters were determined.

Area - Subbasin acreage was determined by planimetering the EFPC base maps.

Average Overland Flow Path Length - The distance over which rainfall runoff must travel to reach a modeled pipe or channel was measured for several alternative overland flow paths through the subbasin. The length of lateral sewers and drains not included in the modeled portion of the system was added to the overland flow path length. The average subbasin overland flow path length is an areal average based on the size of the subbasin fraction drained by each path.

Average Slope - Topographic maps were used to estimate the average slope within each subbasin. Three slope measurements were made for most subbasins. These slopes were areally averaged to determine the average slope for each subarea.

Percent Impervious - Percent impervious is a calibration parameter that accounts for impervious areas which drain to pervious areas (e.g., roads which drain to grass swales or roof drains draining to lawn areas). Percent impervious factors were set as follows:

Metal Rooftops = 90%

Gravel Rooftops = 90%
Pavement/Roads = 70%
Gravel Surfaces = 0%
Natural Surfaces = 0%

Overall percent imperviousness for the EFPC basin was approximately 27%. Directly connected impervious areas with no detention storage were assumed equal to the fraction of each subbasin with metal roof land cover. Unlike the other land cover categories, metal roofs will tend to produce immediate runoff.

Depression Storage - Depression storage represents land surface features which must be filled with the initial stages of rainfall before runoff begins. Examples include surface storage in depressions and on tree cover. Values for depression storage were determined through calibration and are as follows:

Metal Rooftops = 0.00 inch
Gravel Rooftops = 0.20 inch
Pavement/Roads = 0.12 inch
Gravel Surfaces = 2.40 inch (equivalent to a six inch depth of gravel with a void ratio of about 0.4)
Natural Surfaces = 0.80 inch

Manning's n - Manning's n represents the roughness of the surface runoff plane. This is another calibration parameter which was determined to be as follows:

Metal Rooftops = 0.014
Gravel Rooftops = 0.100
Pavement/Roads = 0.014
Gravel Surfaces = 0.200
Natural Surfaces = 0.400

Infiltration Rates - The model assumes that no infiltration occurs on rooftop and pavement areas and that very little rainfall infiltrates into the soil below the gravel areas. Thus, a maximum infiltration volume of zero has been entered for gravel areas within each of the subbasins. The Anderson County Soil Survey was used to determine typical infiltration rates for soils along the natural areas in the EFPC basin.

Channel Characterization

The model simulates open channels and pipes flowing partly full. Channel lengths, side slopes, bottom widths, pipe diameters, average slopes, and roughness coefficients must be specified. A single idealized channel or pipe is used to drain each subbasin.

Data for the storm sewer network serving the Y-12 Plant were obtained from the Area Block Plan - Storm Sewer and other available drainage plans. The pipe lengths, diameters, and invert elevations were tabulated for all pipes with an 18-inch or greater diameter.

To reduce the large amount of pipe data generated and to simplify the modeling approach, while maintaining sufficient accuracy, many consecutive pipes with similar slopes and diameters were combined into an equivalent pipe and assigned a single pipe number and set of characteristics.

A total of 120 pipes and channels were delineated for the EFPC model to route flows through EFPC to the inlet of New Hope Pond. The pipes were numbered according to the watershed in which they were located. **Figure 4** shows a typical subbasin including the pipe numbers as well as the subbasin number(s) draining to each pipe. Pipe and channel data, including the pipe number, the downstream pipe number, the pipe diameter/channel bottom width, length, slope, channel bank slopes, Manning's n and overflow channel were summarized for all 120 pipes. All of the pipe data are stored in the EFPC model data base.

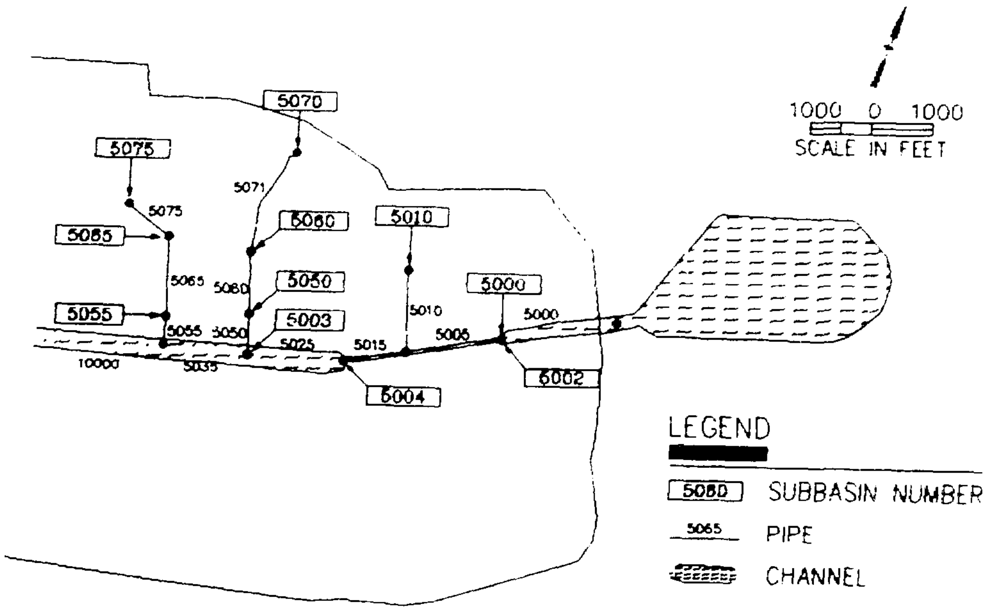

FIGURE 4
MODELING NETWORK

Rainfall Data

Strip charts from two recording rain gages located on the Y-12 Plant site have been digitized for rainfall events which occurred from September 23 through December 1986. The accumulated volume of rainfall measured at on-site gages was digitized every 5 minutes in increments of 0.01 inch. The rainfall hyetographs developed depicting rainfall intensity (inches per hour) versus time are stored in the model data base.

5.0 MODEL CALIBRATION

The general procedures for calibrating the EFPC model are described below:

1. Measured flow hydrographs are inspected for observable sharp-peaked runoff responses during rainfall events. Significant rainfall volumes (e.g., greater than 0.2 inches) and intensities (e.g., greater than 0.5 inches/hour) are required since runoff responses to light rainfall will be masked by the dry weather flow variations and infiltration of ground water. Calibration events are required for both smaller storms producing runoff from only the impervious areas (concrete, asphalt and rooftops), and larger events where graveled and natural areas also contribute runoff flows. Large rainfall events, which severely surcharge the system, cannot be accurately analyzed by the current EFPC model framework, therefore, the model should not be used for such analyses.

2. Dry weather flows must be derived from the total measured flow hydrograph to define the hydrograph for surface runoff conditions. Dry weather flow rates were defined by analyzing flow strip charts covering periods before and after the rainfall event.

3. Rainfall hyetographs must be constructed from the measured rainfall data. The accumulated volume of rainfall collected is recorded every 5 minutes in increments of 0.1 inch.

4. Comparative plots of simulated versus observed stormwater flow are generated. At this stage, model calibration is performed for the stormwater runoff parameters only, thus the dry weather flow (base flow) is subtracted from the two hydrographs. If the simulated and observed hydrographs match reasonably well, the model is considered calibrated. Typically, surface runoff parameters must be varied to achieve calibration. Depression storage is adjusted to match runoff volumes, and Manning's n is adjusted to match hydrograph shape.

5. Exact calibration of several events will often result in different sets of calibration parameters. An average of the parameters obtained for each calibration event is usually a good estimate of final calibration parameters unless the calibration parameters vary widely.

EFPC model calibration results (for the October 24, 1986 rainfall event) at Station 1 are presented in **Figure** 5.

The plots depict simulated versus observed flows at Station 1 during a significant rainfall event (2.04 inches). As may be seen, calibration results at Station 1 are quite good. Similar results were obtained from

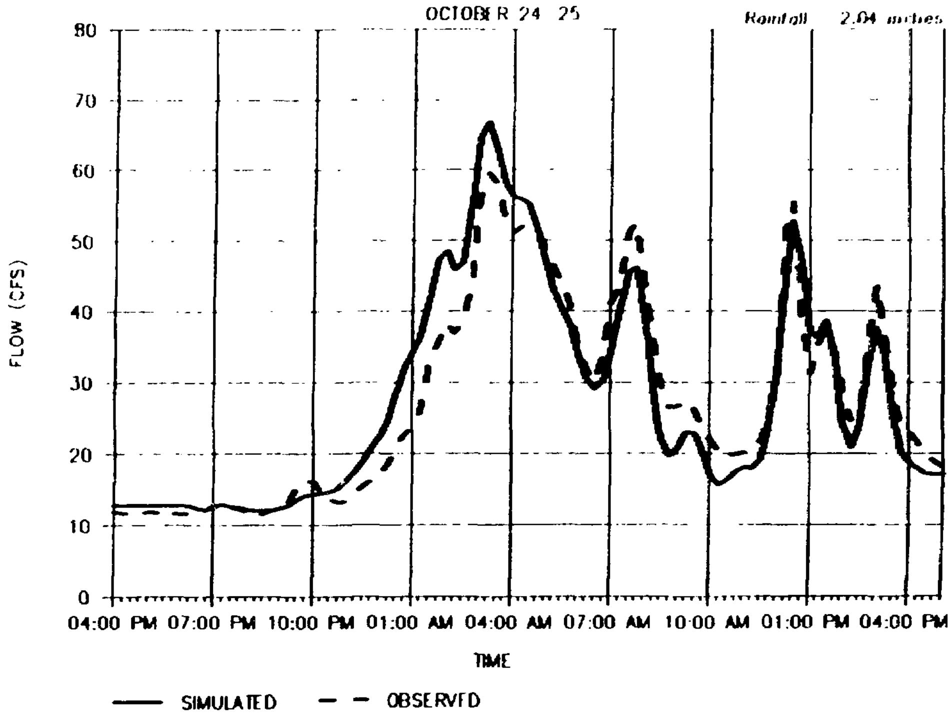

FIGURE 5
STATION 1 HYDROGRAPH

a wide range of storm events. Comparisons of simulated and observed peak flows and runoff volumes for other storm events are presented in **Table 2.** The storm events which occurred on October 12, October 13, and

TABLE 2

COMPARISON OF SIMULATED AND OBSERVED RUNOFF PEAK FLOWS AND VOLUMES

Date	Observed Peak Flow (cfs)	Simulated Peak Flow (cfs)	% Error	Observed Volume (cf)	Simulated Volume (cf)	% Error
OCT 12	71.6	70.0	-2.8	640,000	579,000	-9.6
OCT 13	74.8	69.6	-15.6	679,000	637,000	-6.2
OCT 24	59.5	67.0	12.5	2,470,000	2,443,000	-1.1
NOV 9	48.4	46.5	-4.8	412,000	366,000	-11.2
NOV 23	37.4	38.2	2.4	452,000	467,000	2.0
DEC 1	23.5	23.6	0.3	417,000	401,000	-3.8

November 9 were preceded by relatively wet periods which would tend to cause the model to undersimulate observed flows for the following reasons. The model assumes that all of the detention storage is available at the beginning of a storm event. If the antecedent period is wet, a portion of the detention storage may still be filled (e.g., puddles on pavement or ponding on roofs), therefore, observed runoff would tend to be greater than simulated.

6.0 COMPREHENSIVE SAMPLING PROGRAM

Information gathered in the preliminary sampling program and results from the model were used to design a representative sampling program that would efficiently characterize the area source pollution at the Y-12 Plant. The comprehensive sampling program will be used to identify, characterize, and quantify area source pollution at the Y-12 Plant. Three major objectives of the sampling program are (1) to characterize precipitation runoff with respect to pollutant yield, (2) to identify specific locations of area source discharges, and (3) to finalize the RUNOFF model calibration.

The comprehensive sampling program will consist of ten stations. All stations will monitor both flow and water quality and will be sampled during both wet and dry weather. The NPDES monitoring stations project is currently constructing permanent flow proportional sampling stations at several of the identified monitoring stations. Once constructed, these stations will be utilized in lieu of the temporary monitoring stations. There will probably be only two of these stations available when field sampling is initiated.

Equipment

Major equipment needed for the comprehensive sampling program includes 11 automatic samplers, 11 flow meters, 11 flow plotters, and two rain gages. Each monitoring station will have an automatic sampler, a flow meter, and a flow plotter. In addition, one set of monitoring equipment will be used for backup and for obtaining QA/QC samples.

Sampling Method and Frequency

Each station will be used to collect both water quality and flow data for both dry and wet weather events. The water quality samples will be collected by automatic, flow proportional samplers that have been set up for priority pollutant collection using Teflon suction lines, stainless steel strainers, and medical-grade silicone rubber pump tubing. The flow data will be measured on a continuous basis.

Sampling QA/QC Program

Energy Systems established procedures to assure the consistency, validity, and continuity of the data collected during the field investigation, especially that portion of the field work concerning the sample collection. The quality assurance/quality control (QA/QC) procedures outline the techniques for installation, calibration and maintenance of the sampling equipment;

guidelines for sample collection, handling, and preservation; and the requirements for the collection of QA/QC samples. Field QA/QC samples will consist of duplicates, sampler blanks and trip blanks. These procedures will be established in accordance with EPA guidelines and protocols. A Standard Operating Procedure (SOP) manual for the installation, maintenance, and calibration of field sampling equipment and guidelines for sample collection was prepared by CDM.

7.0 CONCLUSIONS

The Area Source Pollution Assessment and Control Plan for the Y-12 Plant drainage area is a comprehensive plan designed to develop management practices for the control of nonpoint pollution in the EFPC drainage area. One key element of the control plan is the development of the RUNOFF model. This model has been calibrated with existing information and with data collected in the preliminary program. The model was used to locate the permanent sampling stations in strategic locations so as to provide the maximum amount of useful data. The additional data will be used to fine-tune the model, to define the sources of the pollution, to predict the impact of source control, and to simulate extreme hydraulic and pollutant loading conditions in the drainage area.

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Real-Time Environmental Monitoring of Air, Water, and Stack Effluents

Presented by:

R. E. Pudelek, ORNL

Real-Time Environmental Monitoring of Air, Water, and Stack Effluents*

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ABSTRACT

The recently completed Environmental Monitoring System Upgrade Phase I at Oak Ridge National Laboratory provides new capabilities for monitoring both radiological and nonradiological parameters in real-time. This system includes a central computer system (Data Acquisition System, or DAS), the communication network, the data concentrators (DCs), and the instrumentation located at the monitoring sites. The DAS supports the automatic data collection, alarm processing, reporting functions, and operator interaction with field located DCs and instruments. The communications network consists of the telephone lines and associated modems that enable the DAS to communicate with the DCs. The DCs provide data acquisition, temporary data storage, alarm detection, and instrument control functions at each monitoring site. There are two primary stacks, 16 ambient air stations, and three water stations telemetering real-time data via one- or ten-minute polls by the DAS. The range of instrumentation contained at these sites include the following: particulate alpha/beta, iodine, noble gas, gross gamma, rain, pH, dissolved oxygen, conductivity, turbidity, and both water and air flow rates. In addition to the system description, this paper will discuss the data display capabilities of the system.

INTRODUCTION

Completion of the Environmental Monitoring System Upgrade Phase I (EMSU I) by Environmental Monitoring and Services, Inc. (a subsidiary of Combustion Engineering located in Chapel Hill, NC) has provided Oak Ridge National Laboratory with a unique system for monitoring/sampling various media at the Department of Energy Reservation in Oak Ridge. This system consists of a network of air, water, and stack monitoring sites linked via data communication lines to a central computer responsible for monitoring/sampling activities and data storage and reporting. An operator interface is provided to issue commands to specific stations and instruments, to review data, and to acknowledge alarms.

Communications software allows the DAS and DC to communicate a variety of data and command sequences. The database software organizes the historical data and systematically backs up the older data. Reporting and plotting software provides analyses of current and historical data trends. The system maintains a high degree of flexibility to change reports, plots, polling intervals, station configurations, and security privileges.

MONITORING SYSTEM DESIGN

The monitoring system consists of three components, the central computer system (Data Acquisition System, or DAS), see Figure 1, the communications network (telecommunications), and the instrumentation located at the monitoring sites. A brief description of each of these subsystems is provided in the following sections.

Data Acquisition System

The DAS consists of a Digital Equipment Corporation (DEC) VAX 11/750 with a total of 4M bytes of memory. The 11/750 is linked with two disk drives, an RA81 and RA60. The RA81 contains the system and applications software, software development work areas, and the buffer areas for data collected while the data disk is unavailable. The RA60 serves as the primary data archive disk. A magnetic tape drive is also linked to the 11/750 and serves to archive data and to back up the disks. The system is configured with communications ports distributed among dial-out lines with 2400 baud modems, dedicated lines with 2400 baud modems, dedicated lines to various destinations within ORNL (several of which utilize 9600 baud modems), and several spare ports.

The system also utilizes Tektronix 4109 multicolor graphics terminals as system operator consoles to control the DAS. Appropriate Ethernet hardware is used to link the new DAS to an existing VAX 11/750. DECnet is used as the software communication between the two VAX computers.

The operating system used for the system software is VAX/VMS. Numerous utility software that provide a variety of support functions like accounting, backup, etc. are also provided. The operator interface is provided for via Digital Command Language (DCL). The DCL allows an English language request/response interface to the DAS as well as to the VMS utilities and on-line diagnostics. DCL has many features that increase its beneficial application (i.e., on-line interactive assistance, abbreviated command specifications, and command line editing).

Telecommunications

The VAX 11/750 computer communicates with DCs located in the various monitoring stations. The communication is maintained through 2400-baud, asynchronous, 4-wire, leased-line modems in a multidrop configuration. Requirements for data transmissions and receipt is achieved by connecting each dedicated telephone line to three or fewer DCs. This configuration enables polling of the DCs in the one minute time increment necessary during emergency conditions. Modems are used by the VAX 11/750 to communicate with the Tektronix terminals and alarm printers located at both the offices of the Environmental Monitoring and Compliance Department and the Laboratory Emergency Response Center.

The DAS requests data, the contents of which depend on the mode of the sampling: normal, emergency, or bulk. Under normal operating conditions, the DAS provides automatic polling of DCs every ten minutes for ten minute averages and status. Ten minute data is validated and stored. Under emergency conditions, the DCs from one or more selected stations are polled every minute. The system as designed can support 10 DCs (and their respective data inputs from field instrumentation) on a one-minute polling interval at any one time and an average of four DCs in emergency mode for one month. The DAS software also provides for bulk polling for the recovery of data lost during an interruption in polling. Bulk polled data is stored by the database software in the same manner as normally polled data.

Instrumentation

The DC used by EMSU I to meet the data collection requirements in the field is a SumX 4500. The DC is equipped with battery-protected RAM for the applications memory and 24 hours of data storage if needed due to DAS or communications failures. At the end of the 24-hour period, the oldest data will be overwritten by current data.

The DC uses the data collected and checks it against alarm setpoints in RAM. It also compares with previous data for rate-of-change alarms. Ten minute averages are calculated from the one-minute averages and are stored. A minimum of 24 hours of 10 minute data are stored before being overwritten by new data.

An operator via the host computer or the DC (through an interface device) may initiate control functions; such as zero and span checks, check source actuation, etc., as required. Inputs to the DCs come from a variety of monitoring/sampling equipment. Tables 1 and 2 lists the monitoring equipment currently configured for the DAS. This equipment is located at three types of monitoring/sampling stations: ambient air (local and perimeter), stack, and water.

Table 1. Ambient Air and Stack Monitoring Equipment Collecting Real-Time Data

Particulate Alpha
Particulate Beta
Iodine
Noble Gas
Tritium[a]
Gross Gamma[b]
Rain[b]
Air Flow Rate

[a] Stack 3039 only
[b] Ambient Air Stations only

Table 2. Water Monitoring Equipment Collecting Real-Time Data

Temperature
Conductivity
Turbidity
pH
Dissolved Oxygen
Gross Beta
Total Gamma
Gamma Spectra
Water Flow Rate

DATA REVIEW

The DAS provides both fixed-format data displays and the capability for operator-tailored reports for selected reporting instruments at the monitoring sites. Fixed-format displays showing instrument response over time are available via the "TREND" command. These displays can be generated in either tabular or graphic format over a range of operator specific time intervals. Examples of fixed-format displays are shown in Figures 2 and 3. (To produce Figure 3 the operator enters the following command to graph particulate alpha data beginning at midnight of the current day.):

```
TREND/GRAPH LAM007 PA [CR]
```

If the operator needs to examine historical data this is accomplished by specifying the "From When" and "To When" dates.

```
TREND/GRAPH LAM007 PA 10-JUN-1987 15-JUN-1987 [CR]
```

Similar command strings are used to configure a monitoring/sampling station including alarm limits, communication type (dial-up or dedicated), instrumentation/sensor.

*Operated by Martin Marietta Energy Systems, Inc., for the U.S. Department of Energy under Contract No. DE-AC05-84OR21400

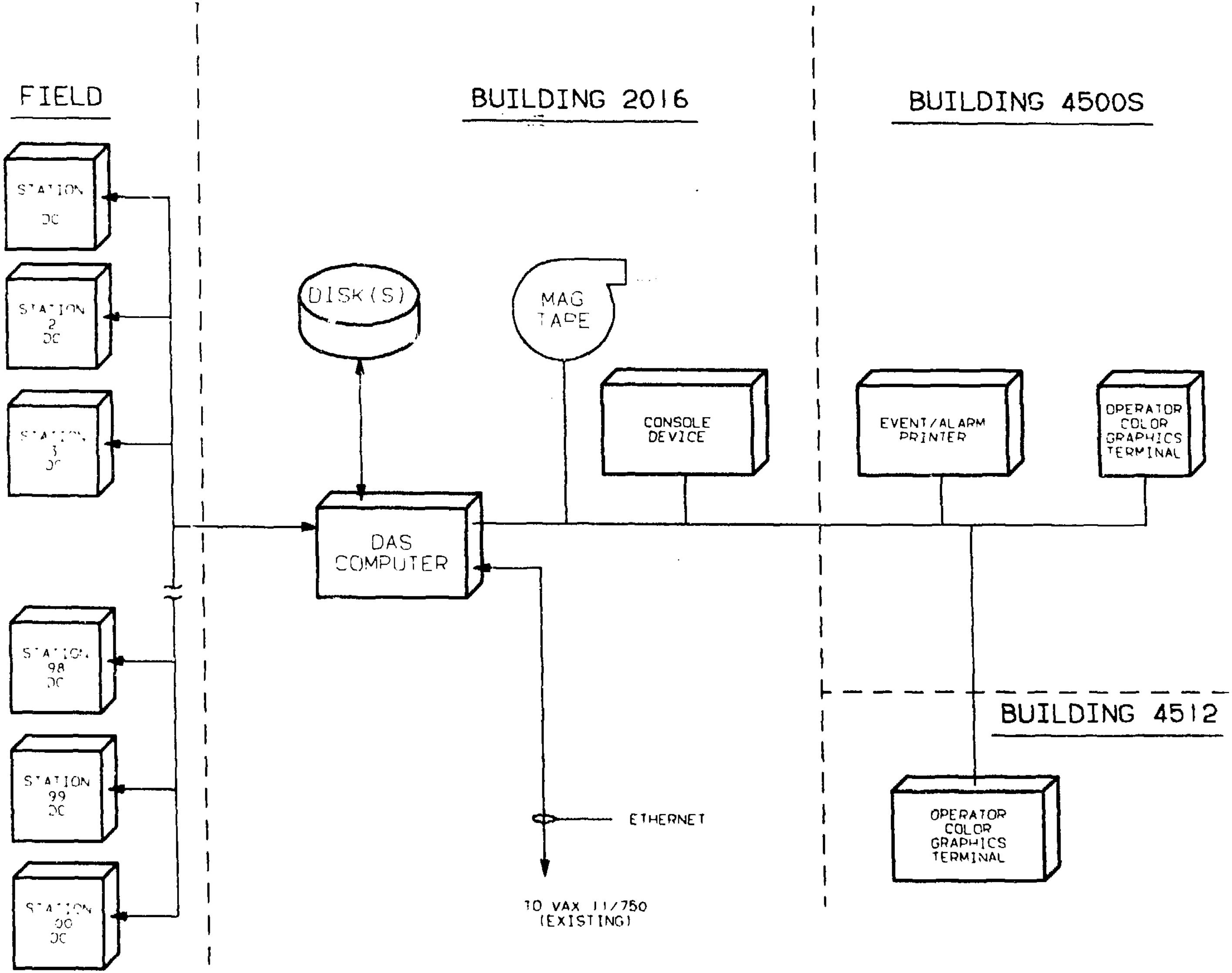

Figure 1. **Data Acquisition System Configuration**

Station: LAM007 Sensor: PA Created: 19-FEB-1987 17:32
From: 19-FEB-1987 00:10 To: 19-FEB-1987 17:32
TREND TABLE (TEN MINUTE)

DATE	TIME	VALUE(CPM)	VALID	FLAG
19-FEB-1987	00:10	3146.0	V	
19-FEB-1987	00:20	3146.0	V	
19-FEB-1987	00:30	3146.0	V	
19-FEB-1987	00:40	3146.0	V	
19-FEB-1987	00:50	3146.0	V	
19-FEB-1987	01:00	3146.0	V	
19-FEB-1987	01:10	3146.0	V	
19-FEB-1987	01:20	3146.0	V	
19-FEB-1987	01:30	3146.0	V	
19-FEB-1987	01:40	3146.0	V	
19-FEB-1987	01:50	3146.0	V	
19-FEB-1987	02:00	3146.0	V	
19-FEB-1987	02:10	3147.0	V	
19-FEB-1987	02:20	3146.0	V	
19-FEB-1987	02:30	3146.0	V	
19-FEB-1987	02:40	3146.0	V	

Press CTRL-Z to exit; RETURN to continue ...

Figure 2. **Tabular Data Display**

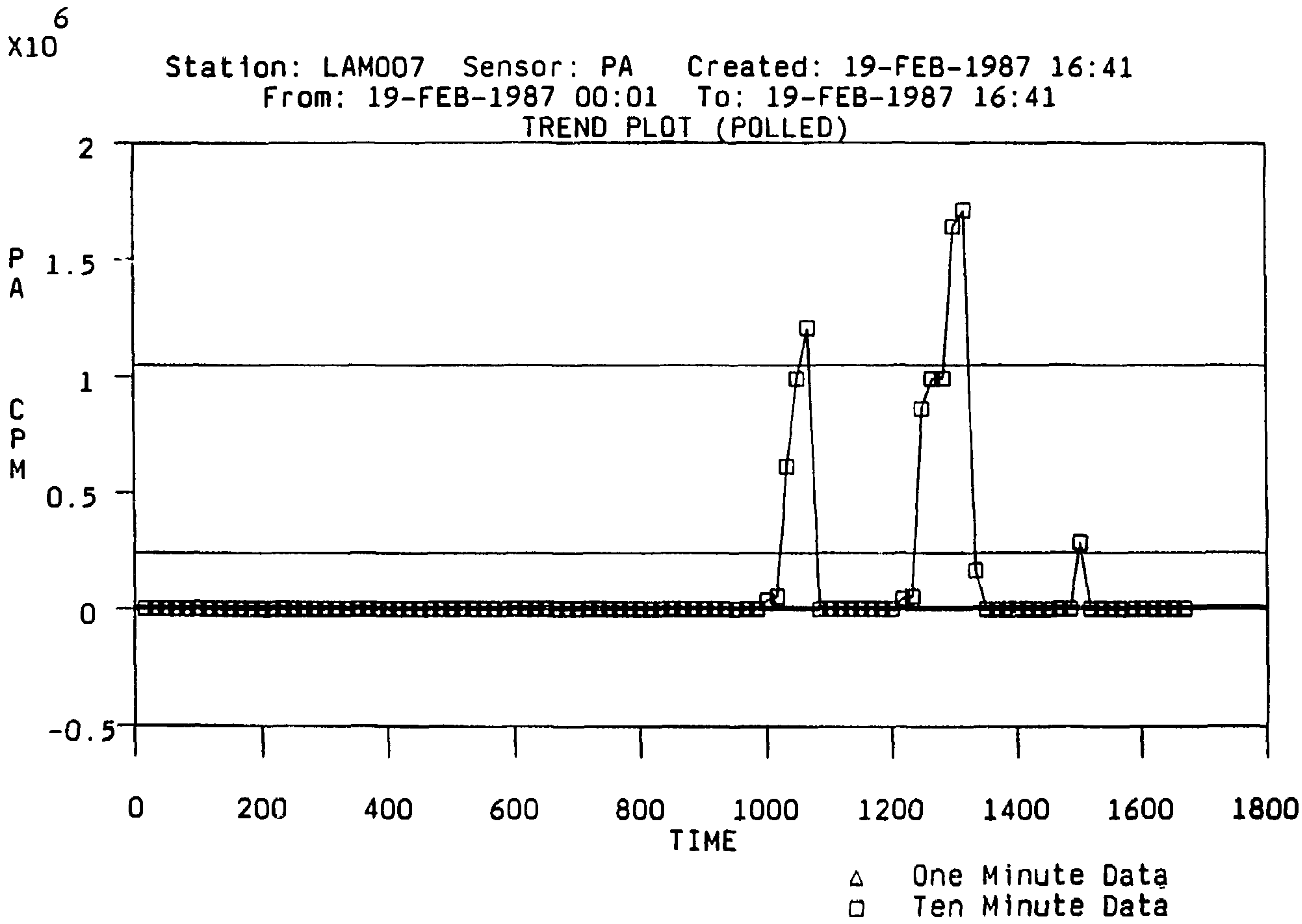

Figure 3. **Graphic Data Display**

Radiological Stack Monitoring at the Y-12 Plant

Presented by:

J. E. Powell, Y-12

RADIOLOGICAL STACK MONITORING AT THE Y-12 PLANT

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ABSTRACT

In February 1985, the Environmental Protection Agency (EPA) promulgated in the Federal Register final National Emission Standards for Hazardous Air Pollutants (NESHAP) regulations, standards for radionuclides. The EPA NESHAP regulations not only established maximum allowable dose limits for airborne radioactivity released from Department of Energy (DOE) facilities, but also set forth provisions requiring each facility to demonstrate its compliance status. Each DOE facility is now required to quantify and defend estimates of airborne radioactivity to regulatory agencies under Section 112 of the Clean Air Act.

The Oak Ridge Y-12 Plant, like many other DOE facilities, has several hundred point sources of exhaust air from production equipment and process areas within the plant. Many of these exhausts are potential sources of airborne radioactivity and are potentially regulated under provisions of the EPA NESHAP regulations. This presentation will define the program underway at the Y-12 Plant to quantify radiological air emissions for NESHAP compliance demonstration. The Y-12 Plant radiological stack monitoring program combines the use of periodic isokinetic stack sampling with the use of continuous stack sampling equipment and real-time radiation stack monitors with alarms. This compliance demonstration program has been presented to both state (Tennessee) and federal regulatory agencies and is currently operational at the Oak Ridge Y-12 Plant.

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*Operated for the U.S. Department of Energy by Martin Marietta Energy Systems, Inc., under contract DE-AC05-84OR21400.

Y-12

Y/TS-317

OAK RIDGE Y-12 PLANT

MARTIN MARIETTA

RADIOLOGICAL STACK MONITORING AT THE Y-12 PLANT

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Health, Safety, Environment, and
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October 15, 1987

Preprint for submission to:

Oak Ridge Model Conference
American Museum of Science and Energy

Thursday, October 15, 1987

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for the U.S. Department of Energy
under Contract No. DE-AC05-84OR21400

OPERATED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

RADIOLOGICAL STACK MONITORING AT THE Y-12 PLANT

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1.0 Introduction

The primary objective of this paper is to provide information on the Oak Ridge Y-12 Plant's Radiological Stack Monitoring Program to environmental managers of other Department of Energy (DOE) facilities and private industry. The Y-12 Plant Radiological Stack Monitoring Program has recently undergone significant change at considerable expense and effort. However, the final product of the one and one-half year long stack monitoring upgrade effort is now operational and producing high-quality, reliable results at the Oak Ridge Y-12 Plant. It is hoped that by understanding the comprehensive Y-12 Plant Radiological Stack Monitoring Program other environmental managers can assess their own program and identify potential solutions to complex challenges in the radiological stack monitoring arena.

2.0 Facility Description

The Oak Ridge Y-12 Plant was originally constructed for the U.S. Army Corps of Engineers in 1943 as part of the highly classified Manhattan Project. The original mission of the plant was to separate highly fissionable isotopes of uranium (U-235) by the electromagnetic process. Today, the plant is managed by Martin Marietta Energy Systems, Inc. (Energy Systems) under contract with the U.S. Department of Energy and has evolved into a highly complex and sophisticated weapons component manufacturing and development engineering organization. The single mission of the Y-12 Plant in 1943 has progressed into the four different principal missions of today.

The primary missions of the Oak Ridge Y-12 Plant are:

1. Production of nuclear weapons components and supporting DOE's weapons design laboratories.
2. Support for other Energy Systems installations.
3. Support and assistance to other government agencies, and
4. Processing of source and special nuclear materials.

The plant's primary mission of producing nuclear weapons components involves fabrication of various metals including uranium. The mission of processing special nuclear materials involves processing various forms of uranium solutions and oxides into uranium metal. Complex chemical processing operations involving the recovery and processing of uranium are commonplace throughout the Y-12 Plant site. In addition, uranium metal machine shops and component manufacturing areas are located throughout the plant and handle significant quantities of uranium and uranium alloys. The Y-12 Plant plays a major role in the overall DOE weapons complex and is a major manufacturing plant for both depleted and enriched uranium.

Exhaust ventilation systems are continuously operated on the majority of the operations that handle or process uranium or uranium-contaminated materials in order to maintain worker radiological exposure levels within DOE mandated As Low As Reasonably Achievable (ALARA) guidelines. These ventilation systems and their associated exhaust stacks are located throughout the 600-acre Y-12 Plant site in several of the 233 principal plant buildings. The majority of the Y-12 Plant production facilities were constructed in the late 1940's and early 1950's and have been remodeled and reworked numerous times in response to changes in plant operations and requirements. Exhaust ventilation systems were added, removed, and modified at hundreds of locations within the plant over the years to serve the dynamic plant operations.

Today, approximately 350 exhaust ventilation systems and stacks are operational at the Y-12 Plant and exhaust many million cubic feet of exhaust air per minute to the atmosphere. Many of these systems are equipped with state-of-the-art emission controls such as exhaust gas scrubbers and High Efficiency Particulate Air (HEPA) filters designed to remove greater than 99.9 percent of airborne contaminants. Some systems have emission controls of reduced removal efficiency or discharge directly to the atmosphere. All exhaust systems from production operations are permitted point sources with the Tennessee Department of Health and Environment (TDHE), Division of Air Pollution Control, and emissions are within the permitted standards of the TDHE.

3.0 Regulatory Requirements

In 1970, the U.S. Congress passed the Clean Air Act (CAA) which mandated the U.S. Environmental Protection Agency (EPA) to develop, implement, and periodically update a comprehensive regulatory program for the protection and maintenance of the nation's ambient air quality. On this far-reaching legislation, all U.S. air pollution regulations are based. Under Section 112 of the CAA, the Congress directed the EPA to develop and implement a scheme for the control of those air contaminants that are found to be hazardous to human health. It is under this authority that the EPA developed the National Emission Standards for Hazardous Air Pollutants (NESHAP) program. To date, only five substances have been listed as hazardous air pollutants regulated under the NESHAP program. These five substances are Asbestos, Beryllium, Mercury, Vinyl Chloride, and Airborne Radioactivity (radionuclides).

The addition of airborne radioactivity to the list of hazardous air pollutants was promulgated February 6, 1985, after a two-year public debate that ended in a U.S. District Court directive for EPA to publish the final rules. In response to the District Court decision the EPA published in the Federal Register (50 FR 5190) final NESHAP standards for radionuclides. These rules amended the EPA's Code of Federal

Regulations (Title 40, Chapter I, Part 61) by adding three additional subparts to the federal regulation of hazardous air pollution including Subpart H, National Emission Standard for Radionuclide Emissions from DOE facilities.

The final NESHAP standards for radionuclides set forth emission standards based upon the maximum radiological dose that any member of the public can receive from exposure to a DOE plant's emissions. The final NESHAP standards for airborne radioactivity limit emissions from DOE facilities to a level that will cause a dose equivalent not in excess of 25 millirem per year (mrem/yr) to the whole body or 75 mrem/yr to the maximum exposed critical organ of any member of the public. For a point of reference, it is estimated that the average citizen living in the East Tennessee area receives an annual dose equivalent of approximately 100-200 mrem from normal background radiation (primarily naturally occurring radon). The average chest x-ray results in a dose equivalent of approximately 20-50 mrem being received by the patient.

In addition to setting forth maximum allowable dose standards for DOE facilities, the 1985 NESHAP regulations set forth specific provisions for compliance demonstration. According to the final rules, compliance with the radionuclide emission dose limits must be calculated using approved atmospheric dispersion/radiological uptake models. Compliance demonstration is required at the point of maximum annual air concentration where any member of the public resides. Ambient air monitoring within the affected community can be used to support the dose model results, but can not be used to demonstrate compliance. Although the establishment of the actual dose standards was the most publicized part of the NESHAP ruling, the requirement that each facility must quantify its radiological dose for compliance demonstration purposes was a significant part of the ruling. This was the basis for the extensive Y-12 Plant radiological stack monitoring upgrade effort.

4.0. Y-12 Plant Radiological Stack Monitoring Upgrade Project

4.1 Compliance Demonstration Strategy

In response to compliance demonstration requirements of the EPA NESHAP regulations for radionuclides, the Y-12 Plant conducted an in-depth internal assessment of its airborne radiological monitoring program in early 1985. The purpose of this monitoring program assessment was to develop a NESHAP compliance demonstration strategy that was both reliable and cost effective for the Y-12 Plant. Deficiencies were identified in the existing Y-12 Plant airborne radiological monitoring program in areas where it was inconsistent with the new compliance demonstration strategy. This strategy outlined the following areas needed to accurately measure the plant's radiological emissions:

1. Continuous sampling of all process exhausts from enriched and depleted uranium handling areas in order to continuously measure uranium emissions,
2. Continuous, real-time radiation monitoring of major radiological exhausts to facilitate the existing emission control program and alarm plant operations of process upsets/emission control failure,
3. Periodic testing of major radiological exhausts using EPA protocol for particulate stack sampling in order to measure "baseline" stack emissions and document continuous stack sampling accuracy,
4. Continued analysis and expansion of ambient air monitoring program (both onsite and offsite) to support stack monitoring program and dose modeling results.

4.2 Project Description

The Y-12 Plant NESHAP compliance demonstration strategy for radionuclides was presented to DOE and Energy Systems management in September 1985. A comprehensive stack monitoring upgrade project proposal was presented at that time. This project proposal included the consolidation of 120 exhaust stacks into 85 new exhaust systems, the construction/modification of the 85 exhaust stacks to meet EPA protocol for particulate stack sampling (40 CFR Part 60, Appendix A, Method 1), the construction of permanent stack sampling access platforms on the new exhaust stacks, and the procurement and installation of continuous stack monitors and samplers for the exhausts. The total estimated cost of the stack monitoring upgrade project was $9.5 million. Expansion of the Y-12 Plant ambient air monitoring network was already underway with the construction of an additional station within the community of maximum theoretical uranium exposure and was not included in the project. The stack monitoring upgrade project was funded the next month, in October 1985, using a combination of available plant funds.

The project to carry out the improvements needed to the Y-12 Plant radiological stack monitoring program was not an easy one. Significant changes needed to be made to physical layout of over 100 exhaust systems in order to consolidate exhausts and meet EPA stack sampling protocol. New exhaust stacks had to be constructed at many locations and many others significantly modified. Permanent stack sampling access platforms had to be constructed at all 85 locations to facilitate emissions sampling. In some cases, modifications to the building structural steel were required to support the new exhaust systems and sampling platforms. In addition, new continuous stack sampling equipment and real-time radiation monitoring equipment had to be specified, procured, and installed. Due to the urgency of completing the monitoring improvements, a very ambitious project schedule was developed which called for project completion in February 1987, only 16 months after the project was initiated. In order to ensure project completion on schedule, monthly status reports were required to Energy Systems and DOE management and any problems which could delay project completion discussed.

4.3 Monitoring/Sampling Equipment Description

The Y-12 Plant NESHAP compliance demonstration strategy called for two types of stack emissions sampling/monitoring equipment to be procured. New continuous stack sampling capability was to be provided and installed on all 85 exhaust systems in order to continuously measure uranium emissions. In addition, new real-time stack radiation detection capability with alarms was to be installed on those major exhaust systems which had a potential for emitting a significant quantity of uranium in the event of a process upset or failure in emission control equipment. Engineering analysis identified 28 major exhaust systems for which real-time radiation detection was deemed feasible. On the remaining exhausts, engineering analysis determined that feasible emission excursions caused by process upsets and/or emission control device failures would still not emit enough uranium to exceed radiation detection sensitivity thresholds using off-the-shelf industrial equipment. Therefore, continuous stack sampling equipment without radiation detection was specified for installation on 57 minor exhaust systems while continuous stack sampling equipment with real-time radiation detectors and alarms were specified for the plant's 28 major exhaust systems.

The theory of operation for the Y-12 Plant continuous stack sampling equipment is relatively simple. A constant, rate-controlled sample of stack gas is drawn from the stack using a multi-point stack sampling probe which traverses the stack diameter. The orifice of the stack sample nozzles located on the probe are sized appropriately to provide approximate isokinetic sampling conditions at the normal stack flow rate. The probe nozzles are removable should operating conditions change or nozzle tips become damaged. The stack sample is then filtered to remove particulates (including uranium fines) and then routed through a sample mass-flow controller and returned to the stack. The sample flow controller ensures a constant sample flow rate as particulate buildup (and pressure drop increase) on the sample filter paper occurs. Sample filter papers are changed periodically and analyzed in the Y-12 Plant Laboratory to quantify uranium stack emissions. The overall design of the continuous stack sampler meets the intent and guidance found in the American National Standard Institute (ANSI) N 13.1 design guidance document.

The continuous stack samplers equipped with real-time radiation detection equipment and alarms are designed similar to the other stack sampling equipment except a localized two-inch radiation detector is located facing the sample filter paper. The radiation detector continuously monitors the activity level of the particulates accumulating on the filter. If a sudden increase in filter paper activity is detected, a high stack radiation alarm is generated. Such an increase in activity would most likely be associated with an uranium emission increase due to a process upset or failure in emission control equipment. The high-level alarm is designed to provide early notification of an emission excursion such that appropriate corrective actions can be taken to minimize the release of material to the environment.

Y-12 Plant exhaust ventilation systems that serve enriched uranium processing areas possess the greatest risk to the plant for uranium emission excursions. This is due to the relatively high specific activity of enriched uranium; Y-12 uranium enriched in the U-235 isotope has a specific activity approximately 150 times that of depleted uranium. For this reason, the majority of the Y-12 Plant stacks equipped with real-time radiation detection and alarm systems are located on exhaust systems from enriched uranium areas. Twenty-four of the 28 real-time stack monitors at the Y-12 Plant utilize a thallium activated sodium iodide radiation detector 0.06-inch thick to monitor for low energy x-rays like those emitted from U-235 present in enriched uranium. These detectors utilize a 0.005-inch thick beryllium window which transmits nearly all of the low energy x-rays to the photo-multiplier assembly while protecting the unit from the stack environment. Multi-channel energy analysis is then performed to algorithmically correct for background radiation and subtract out energy pulses generated from naturally occurring radon decay. Alarm generation is based upon a rate-of-rise calculation (counts per minute/minute) which corresponds to an accumulation rate of uranium on the sample filter (not a threshold).

The remaining Y-12 Plant real-time stack monitor systems utilize a premium grade plastic phosphor detector 0.0095 inches in thickness. The thin, low mass phosphor is highly efficient for the detection of beta radiation like that emitted from U-238 present in depleted uranium. An aluminum mylar window serves as the moisture and light barrier for the beta detector, admitting beta particles of approximately 50 kev and greater. Alarm generation with the beta detectors is also based upon a rate-of-rise equation, although no energy analysis or radon rejection is possible. Both types of radiation detectors are encased in a 3-inch lead shield to minimize background radiation. The localized radiation detectors do generate high-radiation alarms when uranium excursions are detected, but sample filter papers are charged routinely and analyzed in the Y-12 Plant laboratory to quantify uranium stack emissions.

5.0 Monitoring System Operating Experience

The completion of the Y-12 Plant radiological stack monitoring upgrade project was realized in late February 1987, in accordance with the original project schedule. The 57 new continuous stack samplers and 28 real-time monitors/samplers were declared operational March 1, 1987, after a short test-and-checkout period. To date, the performance of the units have been excellent and high quality, reliable emissions data have been obtained.

Within the first few months of operation, the new real-time radiation stack monitors generated a number of alarms due to a variety of conditions. Approximately 20 alarms were received within the first month of operation, mostly due to interference from background radiation or monitor malfunction. However, after only a few months the majority of these problems were corrected and very few "false" alarms are now received. In an average month of operation fewer than five stack alarms are now experienced.

Several stack alarms have been experienced over the past few months as a result of minor uranium emission excursions caused by process upsets. Although the actual quantity of radioactivity released in each case was quite small, the stack monitors did detect the emission rate change within a short time period and alert operations personnel of the problem. Follow-up activities by operations personnel resulted in the successful completion of corrective actions in each case which returned stack emissions to normal. These incidents have been realized on both enriched and depleted uranium operations which demonstrates the usefulness of the real-time radiation detection equipment for both types of operations.

Operation of continuous stack sampling equipment on the Y-12 Plant stacks also appears to be highly successful. High quality, reliable data generation has been realized since the startup of the new sampling equipment. The new monitoring/sampling equipment is being operated on a quarterly maintenance recall program to ensure the continued successful operation with minimal downtime. The development of accurate and useful operating and maintenance procedures is a task that required considerable attention and should not be underemphasized.

The periodic emission testing of the major radiological exhaust stacks has proved to be difficult, due primarily to the very low levels of radioactivity present within the exhaust stack. Very low emission levels must be measured which makes laboratory analysis difficult. The fact that the majority of the Y-12 Plant operations run in a batch-type mode also makes successful sampling difficult.

6.0 Conclusion

The Y-12 Plant Radiological Stack Monitoring Program is a multi-faceted monitoring program that utilizes state-of-the-art stack monitoring and sampling equipment as well as ambient air monitors to quantify radiological emission from the plant's many exhaust stacks. The use of real-time stack radiation monitors with alarms is an important part of this major monitoring effort and supplements the aggressive emission control program of the plant. Although the plant has had limited operating experience with the use of the newly upgraded stack monitoring system, it is believed that it will be a useful tool in maintaining radiological emissions within applicable guidelines and provide an effective means of quantifying emissions. The concepts applied at the Y-12 Plant could be easily utilized at other DOE facilities within the weapons complex and in private industry. It is hoped that by understanding the Y-12 Plant monitoring program other environmental managers can assess their own radiological monitoring program and plan and utilize the experience already learned at the Oak Ridge Y-12 Plant.

Gamma-Vent Monitors at Portsmouth Gaseous Diffusion Plant

Presented by:

S. A. Jones,
Portsmouth Gaseous Diffusion Plant

GAMMA-VENT MONITORS AT PORTSMOUTH GASEOUS DIFFUSION PLANT

By
S. A. Jones and M. J. Orlett

ABSTRACT

The scope of current development activities at Portsmouth regarding detection and quantification of gaseous radionuclide emissions of uranium-235 and technetium-99 in vent gases is described. This work results from the need to reduce radioactive discharges, quantify such discharges in real time and reduce the amount of solid waste resulting from the existing trapping system. The existing detection system, in particular the in-line ionization chambers and solution chemical analyzers, have limitations in their performance for meeting these goals.

Recent designs of NaF and Al_2O_3 sample traps result in the efficient collection of trace quantities of radionuclides which, in conjunction with either NAI(Tl) scintillation or HPGE detectors, can be analyzed by on-line computer-based multichannel analyzers. While data analysis follows conventional formats, a new method for generating alert and alarm warnings, based on Page's interval test, has been employed. Near real-time data with low false alarm rates are available to plant operations for the control of radioactive discharges. Details of the equipment and the analysis techniques chosen are presented, and proposed plant applications are discussed.

PROCEEDINGS PAPER NOT AVAILABLE
AT TIME OF PRINTING

A Plan for Continuous Sampling of Radioactive Gaseous Emissions at the Toxic Substances Control Act Incinerator

Presented by:

D. H. Bunch, ORGDP

365 | 366

K/QT-125A

A PLAN FOR CONTINUOUS SAMPLING OF RADIOACTIVE GASEOUS EMISSIONS AT THE TOXIC SUBSTANCES CONTROL ACT INCINERATOR

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Operated by Martin Marietta Energy Systems, Inc.
for the United States Department of Energy

ABSTRACT

As a permit condition for compliance with the National Emission Standard for Radionuclide Emissions from DOE Facilities, an off-gas sample must be withdrawn continuously during operation of the TSCA incinerator to determine the emission rates of uranium, technetium, radioactive iodine, and alpha and beta activity. Since some of these contaminants will be in particulate form, the sample must be removed from the stack isokinetically to get a representative portion of these contaminants in the sample gas. A sampling rate within 10% of the isokinetic rate is required to get a representative sample of the particulates. Obtaining a sample from the TSCA incinerator vent stack is particularly difficult because the flow rate will vary as different wastes are incinerated, and the off-gas is always saturated with water vapor. This presentation describes the equipment and procedures which were developed to meet these requirements.

K/QT-125

A PLAN FOR CONTINUOUS SAMPLING OF RADIOACTIVE GASEOUS EMISSIONS AT THE TOXIC SUBSTANCES CONTROL ACT INCINERATOR

D. H. Bunch

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Operated by Martin Marietta Energy Systems, Inc.
for the U.S. Department of Energy
under Contract No. DE-AC05-84OR21400

INTRODUCTION

The EPA requires that an off-gas sample be withdrawn continuously during the operation of the TSCA incinerator to determine the emission rates of uranium, technetium, radioactive iodine, and alpha and beta activity. Since some of these contaminants will be in particulate form, the off-gas sample must be removed from the stack isokineticly to get a representative portion of these contaminants in the sample gas. Isokinetic sampling means that the velocity of the sample gas is the same as the velocity of the off-gas in the stack. A sampling rate within 10 percent of the isokinetic rate is required to get a representative sample of the particulates.

EQUIPMENT

A sketch of the sampling train is shown in Figure 1. The sample will be pulled into a nozzle, probe, filter, condenser, and a series of impingers (bubblers), and drying tubes containing desiccant. The sample gas will then pass through a pump, a dry gas meter, and afterwards, discharged to the atmosphere.

The readings from a pitot tube and thermocouple will be used to determine the needed sampling rate. The sampling rate will be controlled by the valve on the by-pass line around the pump. The data needed to verify that isokinetic sampling rates are maintained will be recorded.

To insure that the equipment is operating correctly and is collecting the sample isokineticly, the system will be checked once during each shift, the desired sampling rate will be calculated, and any necessary adjustments will be made.

PITOT TUBE, NOZZLE, PROBE, AND FILTER

This portion of the sampling equipment will be located at a port at the level of the higher platform on the stack. This port is more than eight stack diameters past the last flow disturbance, and more than two stack diameters upstream from the stack exit.

A pitot tube, nozzle, and thermocouple assembly meeting the specifications of EPA Method 2 will be used. Because they will be swapped out each week to allow cleaning and sample recovery in the lab, two of these assemblies will be needed.

The probe will be heated to prevent condensation, and the filter will be heated to 223^{o} - $273^{o}F$. To reduce the impaction of particles on the tubing walls, there will be no bends in the tubing between the nozzle and the filter.

Each week, the entire pitot tube, thermocouple, and filter holder assembly will be replaced with a new assembly. The old assembly will be capped at each end to prevent particulate loss and taken to a laboratory for cleaning and sample recovery.

The entire sampling train will be leak checked before and after each weekly changeout. To leak check the train, the nozzle will be pulled from the stack and plugged. To allow the nozzle to be pulled for the leak check, the probe and the filter box will be mounted on a trolley and a section of the sample tubing will be flexible.

The nozzle will be located in the stack at a point where the off-gas velocity equals the average off-gas velocity for the stack cross-section.

CONDENSER

After the sample gas leaves the filter, a condenser will cool it to 70°F. The condensate will fall into a 30 gallon tank. The amount of water condensed will be measured weekly, and a representative sample of the condensate will be submitted to the lab weekly. The condensate will then be discharged to an existing sump treated and released.

IMPINGERS AND DRYING TUBES

The sample train will include at least nine impingers. The second impinger will be the Greenburg-Smith design, and the others the modified Greenburg-Smith type. All of the impingers will be in a refrigerated enclosure to condense the moisture in the sample gas. The first three impingers will contain six molar nitric acid which will absorb the nonparticulate uranium. The fourth, fifth, and sixth impingers will contain three molar sodium nydroxide which will absorb the molecular iodine and any nonparticulate technetium. The seventh impinger will be an empty entrainment separator. The eighth and ninth impingers will contain impregnated charcoal to absorb methyl iodine, any other organic iodine compounds, and any remaining molecular iodine.

After passing through the impingers, the sample gas will pass through a series of drying tubes to remove the remaining moisture.

The impingers and drying tubes will be cooled to maintain the sample gas leaving the last drying tube at less than 68°F.

DRY GAS METER

A dry gas meter capable of measuring the sample gas volume to within 2 percent will be used. The dry gas meter will be replaced each month, and the old dry gas meter will be calibrated.

LEAK TESTING

The sample train will be leak tested in the following manner before each weekly changeout:

1. The probe - filter box assembly will be pulled from the stack, and the end of the nozzle will be plugged.

2. A vacuum of 15" Hg will be pulled on the sampling train and held for two minutes.

If the leak rate exceeds 4 percent of the average sampling rate, a correction for the leak rate, as described in EPA Method 5, will be made in the emission rate calculations.

After the sampling train changeout, the sampling system will be leak checked again, and any necessary adjustments made to get a leak rate less than 4 percent of the average sampling rate before resuming sampling.

Environmental Auditing: Closing the Feedback Loop

Presented by:

C. P. East, Y-12

ENVIRONMENTAL AUDITING: CLOSING THE FEEDBACK LOOP

Stephanie Marcus

Health, Safety, Environment, and Accountability Division
Oak Ridge Y-12 Plant*
Martin Marietta Energy Systems, Inc.
Oak Ridge, Tennessee 37831

ABSTRACT

A principal element in the effective management of environmental programs is the assessment of actual conditions with respect to goals and requirements. Through such evaluations, the focus of a program is established. Program improvements can then be identified based upon the resources available.

Communication between facility managers, their staff, and regulatory agencies is the key to the success of this process, and it has become increasingly important considering the rate at which environmental regulations are promulgated and the complexity of the issues involved. While there is no substitute for direct communication, audits can and should be used as a management tool to supplement the existing communication chain. For example, selection of internal audit topics by line managers can be used to indicate the relative priorities of management interests. Interaction with auditors from regulatory agencies can result in the introduction of alternative regulatory interpretations and clarification of their expectations. In addition, the tracking of management commitments to compliance status improvements not only helps to assure implementation but can be used to demonstrate a good-faith effort to protect the environment. Used as such, environmental audits can be an effective means of closing the feedback loop.

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*Operated for the U.S. Department of Energy by Martin Marietta Energy Systems, Inc., under contract DE-AC05-84OR21400.

Y-12

Y/TS-318

OAK RIDGE
Y-12
PLANT

MARTIN MARIETTA

CLOSING THE FEEDBACK LOOP

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Environmental Management Department

Health, Safety, Environment, and
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October 16, 1987

Preprint for submission to:

Oak Ridge Model Conference
American Museum of Science and Energy

October 13-16, 1987

Prepared by the
Oak Ridge Y-12 Plant
Oak Ridge, Tennessee 37831
operated by
Martin Marietta Energy Systems, Inc.
for the U.S. Department of Energy
under Contract No. DE-AC05-84OR21400

OPERATED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

INTRODUCTION

- 0 ENVIRONMENTAL AUDITING PROVIDES AN ASSESSMENT OF ACTUAL CONDITIONS WITH RESPECT TO GOALS AND REQUIREMENTS

- 0 THIS ASSESSMENT CAN RESULT IN IMPROVEMENTS TO ENVIRONMENTAL PROGRAMS WHICH OTHERWISE MAY BE MISSED

- 0 FOLLOW-UP OF ASSESSMENT FINDINGS IS ESSENTIAL TO ENSURE DEFICIENCIES ARE APPROPRIATELY CORRECTED

AUDIT PURPOSE

- O TO PROVIDE A SYSTEMATIC AND DOCUMENTED IN-HOUSE REVIEW OF PLANT FACILITIES AND OPERATIONS FOR THE PURPOSE OF RISK ASSESSMENT AND DETERMINATION OF COMPLIANCE STATUS
- O TO FIND AND CORRECT DEFICIENCIES BEFORE AN EXTERNAL AUDIT
- O TO FAMILIARIZE PERSONNEL WITH ENVIRONMENTAL REGULATIONS PERTAINING TO THEIR OPERATIONAL RESPONSIBILITIES

AUDIT BENEFITS

- DOCUMENTATION OF PROGRESS TOWARD ACHIEVING REGULATORY COMPLIANCE
- DEMONSTRATED "GOOD FAITH" EFFORT TOWARD ACHIEVING REGULATORY COMPLIANCE
- UNDERSTANDING OF AN OVERALL COMPLIANCE STATUS FOR THE PLANT
- ENHANCED COMMUNICATION BETWEEN ENVIRONMENTAL AND PRODUCTION ORGANIZATIONS

CATEGORIES OF AUDITABLE TOPICS

- O FACILITY SPECIFIC
- O MATERIAL SPECIFIC
- O PROGRAM SPECIFIC

STEPS IN THE AUDIT PROCESS

- O PRE-AUDIT ACTIVITIES
- O CONDUCTING AUDIT
- O POST-AUDIT ACTIVITIES

PRE-AUDIT ACTIVITIES

- O REGULATORY OVERVIEW
- O PRE-AUDIT INTERVIEW
- O DRAFT CHECKLIST
- O SELECT AND IMPLEMENT AUDIT TEAM

CONDUCTING AUDIT

- O PAPER REVIEW
- O INTERVIEW
- O FACILITY WALK THROUGH

POST-AUDIT ACTIVITIES

- O POST-AUDIT MEETINGS
- O ISSUE FINDINGS REPORT
- O RESPONSES RECEIVED
- O PROGRESS TRACKED

CLOSURE OF LOOP OCCURS WHEN CORRECTIVE ACTIONS ARE TRACKED TO COMPLETION AND, WHEN COMPLETED, EVALUATED TO DETERMINE IF INTENT OF ORIGINAL FINDING IS SATISFIED.

RESULTS OF NOT CLOSING LOOP:

- HISTORICALLY A WEAK LINK

- CORRECTIONS NOT DOCUMENTED

- CORRECTIONS NOT IMPLEMENTED

CONSEQUENTLY THE ENVIRONMENTAL PROGRAM SUFFERS IN TERMS OF EFFECTIVENESS AND CREDIBILITY. NONCOMPLIANCE SITUATIONS CONTINUE WITH THE POTENTIAL FOR COMPLIANCE ORDERS/FINES FROM REGULATORS.

SUMMARY

- O ENVIRONMENTAL AUDITING PROVIDES AN ASSESSMENT OF ACTUAL CONDITIONS WITH RESPECT TO GOALS AND REQUIREMENTS

- O THIS ASSESSMENT CAN RESULT IN IMPROVEMENTS TO ENVIRONMENTAL PROGRAMS WHICH OTHERWISE MAY BE MISSED

- O TRACKING OF DEFICIENCIES AND RESULTING CORRECTIVE ACTIONS IS ESSENTIAL TO ENSURE THE DEFICIENCIES ARE APPROPRIATELY CORRECTED (CLOSING THE LOOP)

USDOE Headquarters Environmental Site Surveys: Operations Office Experience

Presented by:

Rebecca R. Hinton, DOE/ORO

USDOE HEADQUARTERS ENVIRONMENTAL SITE SURVEYS: OPERATIONS OFFICE EXPERIENCE

Rebecca R. Hinton, US DOE, Oak Ridge Operations, Oak Ridge, TN; Paul S. Rowher, Oak Ridge National Laboratory, Oak Ridge, TN; Dennis C. Parzyck, Oak Ridge National Laboratory, Oak Ridge, TN; and Frank J. Homan, Advanced Waste Management Systems Inc., Oak Ridge, TN.

The purpose of the US DOE Headquarters Environmental Site Survey is to provide a uniform basis for prioritization of remedial action within the agency. This goal is achieved by identifying, itemizing, and then prioritizing environmental risks and problems at forty DOE facilities. Four Environmental Site Surveys have been conducted at Oak Ridge Operations facilities. The purpose of this presentation is to summarize the experience gained to date at the operations office level. A general discussion of the background and structure of the environmental survey process is provided. The Oak Ridge National Laboratory Environmental Site Survey is used as a specific example to illustrate the types of findings and categories for classifying findings. Observations of operations office staff involved as survey team members are presented.

DOE HEADQUARTERS
ENVIRONMENTAL SITE SURVEYS

—

OPERATIONS OFFICE EXPERIENCE

R. R. HINTON, P. S. ROWHER,
D. C PARZYCK, AND F. HOMAN

HOW DID THE ENVIRONMENTAL SITE SURVEY DEVELOP?

- DOE SECRETARY HERRINGTON'S ENVIRONMENTAL INITIATIVES OF SEPTEMBER 1985
- REORGANIZED ES&H UNDER ONE ASSISTANT SECRETARY - MARY WALKER
- WALKER AND STAFF DEVELOPED SURVEY CONCEPT AS A MANAGEMENT TOOL FOR PLANNING AND ALLOCATING RESOURCES.
- FIRST SURVEY TEAM WAS AT FERNALD (OHIO) BY JUNE 1986

WHAT WILL THE ENVIRONMENTAL SITE SURVEY ACCOMPLISH?

- IDENTIFY ENVIRONMENTAL RISKS AND PROBLEMS
- INVENTORY TO SERVE AS A BASELINE AUDIT WITH FOLLOW-UP IN FY89
- PRIORITIZE USING THE SAME CRITERIA AT 40 DOE SITES

HOW LONG WILL THE SURVEY TAKE?

2 1/2 TO 3 YRS. (FY86 THROUGH FY89)

HOW MUCH WILL IT COST?

HEADQUARTERS: APPROXIMATELY $60M

EACH SITE: SIGNIFICANT UNDOCUMENTED AMOUNT

WHAT IS THE SCOPE OF THE SURVEY?

- AUDIT VS. SURVEY
  - FAULT/NO FAULT
  - MORE THAN COMPLIANCE
- ALL MEDIA
  - AIR, SURFACE WATER, GROUNDWATER, SOIL
- ALL ENVIRONMENTAL REGULATIONS
- ALL DOE ORDERS

HOW IS THE SURVEY CONDUCTED?

- A TOTAL OF 5 DOE TEAMS
  - 7 TO 10 MEMBERS, 2 DOE TEAM LEADERS, CONTRACTOR "EXPERTS"
- REVIEW DOCUMENTS
- PRE-SURVEY SITE VISITS
- ENVIRONMENTAL SITE SURVEY
  - TOURS, BRIEFINGS, SITE INSPECTION, TALK TO STAFF, REVIEW RECORDS
- SUPPLEMENTARY SAMPLING AND ANALYSIS

WHAT IS A FINDING?

- CATEGORY I - IMMEDIATE THREAT TO HUMAN LIFE
- CATEGORY II - REGULATORY NONCOMPLIANCE OR ADVERSE HEALTH EFFECTS NEEDING ATTENTION SOON
- CATEGORY III - NEEDS CORRECTION, GENERALLY NEED MORE INFORMATION TO PROCEED, REPRESENTS MAJORITY SURVEY FOCUS
- CATEGORY IV - ADMINISTRATIVE NONCOMPLIANCE, POOR OPERATIONAL PRACTICE, "HOUSEKEEPING"

TYPICAL ORNL SURVEY FINDINGS

CATEGORY II FINDING

THERE IS THE POTENTIAL THAT ADDITIONAL UNDERGROUND FUEL STORAGE TANKS EXIST THAT ARE NOT INCLUDED ON THE SITE INVENTORY. THESE TANKS COULD REPRESENT A POTENTIAL FOR UNDETECTED LEAKS TO SOILS AND GROUNDWATER.

ORNL RESPONSE

INITIAL QUESTIONNAIRE COMPLETED BY FACILITY ENGINEERS WILL BE SUPPLEMENTED BY EXAMINATION OF FACILITY DRAWINGS AND AN INTENSIFIED FOLLOW-UP OF QUESTIONNAIRE RESULTS. ANY ADDITIONAL TANKS LOCATED BY THIS EFFORT WILL BE REPORTED TO REGULATORY COMMUNITY AS REQUIRED.

TYPICAL ORNL SURVEY FINDINGS

Category III Finding

Discharges from the White Oak Creek, inflow from groundwater, and runoff from SWSA-6 have contributed to radionuclide and potentially organic and metal contamination of the White Oak Lake water and sediments.

ORNL Response

The White Oak Lake watershed is part of WAG 2 as reported to EPA under the requirements of RCRA 3004u. A remedial investigation plan is currently scheduled for delivery during 1988.

TYPICAL ORNL SURVEY FINDINGS

CATEGORY IV FINDING

INADEQUATE TANK LABELING HAS BEEN OBSERVED IN SEVERAL INSTANCES THROUGHOUT THE SITE.

ORNL RESPONSE

TANKS WITHOUT LABELS WERE APPROPRIATELY LABELED. FIELD INSPECTIONS WILL PERIODICALLY BE CONDUCTED TO ASSURE CONTINUED COMPLIANCE.

SUMMARY OF 47 ORNL FINDINGS

MEDIA	CATEGORY I	II	III	IV
Air				4
Soil/Radiation			2	4
Groundwater			4	1
Waste Management		1	1	2
Inactive site/releases			10	
Toxic/chemical materials		1	5	3
Surface water			7	1
QA/Qc				1

WHAT HAPPENS FOLLOWING THE SURVEY?

- CLOSE OUT BRIEFING WITH SITE
- SITE BRIEFING WITH REGULATORS
- EXECUTIVE SUMMARY
- PRELIMINARY REPORT
- SITE RESPONSE
- SAMPLING AND ANALYSIS DATA SUMMARY
- INTERIM REPORT
- FINAL SURVEY DOCUMENT

Environmental Audits of Federal and Industrial Facilities

Presented by:

Charles M. Mangan, Engineering-Science, Inc.

ENVIRONMENTAL AUDITS OF FEDERAL AND INDUSTRIAL FACILITIES

Charles M. Mangan, P.E.
Engineering-Science, Inc.
Atlanta, Georgia

and

Thomas N. Sargent, P.E.
Engineering-Science, Inc.
Atlanta, Georgia

As environmental regulations have become more complex and operating budgets reduced, it has become obvious that additional tools must be used to aid public and private sector management in risk analyses. One such tool, which has come to the forefront is the use of an environmental audit to verify compliance with environmental regulations, and internal policies and procedures. This presentation summarizes the experiences of Engineering-Science in conducting a wide variety of compliance audits at a large number of both federal and industrial facilities. Practical tips will be reviewed on addressing the following: audit team organization, audit areas of interest, obtaining pre-audit review information, on-site visit, and post-audit feedback. Specific suggestions will be made on streamlining information gathering during the on-site visit and monitoring the activities of the audit team. Similarities and differences in conducting environmental audits at federal and industrial facilities will also be summarized.

ENVIRONMENTAL AUDITS OF FEDERAL AND INDUSTRIAL FACILITIES

Charles M. Mangan, P.E.
Thomas N. Sargent, P.E.

Engineering-Science, Inc.
Atlanta, Georgia

OAK RIDGE MODEL CONFERENCE

OCTOBER 16, 1987

TYPES OF AUDITS

- o REGULATORY COMPLIANCE AUDIT
- o REAL ESTATE TRANSACTIONS

AUDIT AREAS

- AIR
- DRINKING WATER
- WASTEWATER
- HAZARDOUS WASTE
- HEALTH AND SAFETY

AUDIT TEAM ORGANIZATION

- TEAM LEADER
- TECHNICAL SPECIALISTS

AUDIT PROCEDURE

- o PRE-AUDIT INFORMATIONAL REVIEW
- o ON-SITE VISIT
- o POST AUDIT SUMMARY
- o AUDIT REPORT

ON-SITE AUDIT VISIT

- o ORGANIZATION
- o DAILY REVIEW

COMMON AUDITING PROBLEMS

- FACILITY COOPERATION
- CORPORATE MEMORY
- ON-SITE FEEDBACK
- CONFIDENTIALITY - RESTRICTED

FEDERAL/INDUSTRIAL AUDIT DIFFERENCES

- o REGULATORY JURISDICTION
- o ATTORNEY-CLIENT PRIVILEGE
- o FISCAL PROCESS FOR CORRECTIVE ACTION

415|-416

ORNL Environmental Review and Documentation Program

Presented by:

P. S. Rohwer, ORNL

ORNL ENVIRONMENTAL REVIEW AND DOCUMENTATION PROGRAM* - H. M. Braunstein and P. S. Rohwer, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831

The ORNL Environmental Review and Documentation Program (ERDP) is part of the Environmental Monitoring and Compliance Department (EMCD) in the ORNL Environmental Compliance and Health Protection (ECHP) Division. The program came into existence in 1985 in response to enhanced environmental awareness and the need for environmental review of all operations and activities at ORNL, including those conducted by construction subcontractors. The role of the ERDP is threefold: to ensure ORNL's compliance with all applicable environmental permits, rules regulations, and statutes; to promote environmental protection by implementation of ORNL's Environmental ALARA policy; and to maintain a high level of environmental quality throughout all phases of ORNL activities, operations and projects.

This presentation will address the Action Description Memorandum (ADM) and its function in complying with the National Environmental Policy Act (NEPA); Activities Description Memorandum (AcDM) and its function as an information bridge between ORNL Research/Engineering Divisions'

*Operated by Martin Marietta Energy Systems, Inc., for the U.S. Department of Energy under Contract No. DE-AC05-84OR21400

projects and the ORNL Operations Division's operations; the Environmental ALARA Memorandum (EAM) and Checklist and its contribution to ORNL's Environmental ALARA Program; the Environmental ALARA Review Letter (EARL) and its function as a means for extending, modifying, deactivating, or reactivating ADMs, AcDMs, or EAMs; and the Environmental Monitoring and Compliance Department's Site Inspection Program for following up on projects reviewed and documented under the ERDP.

The ERDP review fulfills three primary objectives: project assessment, permit compliance, and environmental protection. The assessment provides an evaluation of the potential environmental consequences of all phases of a proposed project or action, from the initial groundbreaking to the the final decommissioning. The compliance review ensures that a proposed action is carried out in full accord with all applicable rules, regulations, orders, statutes and permits, whereas environmental protection is achieved by specifying the measures that will be taken during both the construction and operational phases of a proposed action to ensure both protection of the environment and implementation of environmental ALARA.

The effectiveness of the ERDP depends primarily on commitment and support from Laboratory management, but several built-in mechanisms assist that pledge. The ERDP is facilitated by an ORNL environmental protection procedure, EPM-22, which requires that an environmental review be conducted and documented for each planned ORNL project or activity. The procedure, which calls for documentation of the review in the form of an Action Description Memorandum (ADM) or Activities Description Memorandum (AcDM), establishes guidelines, delineates responsibilities, and specifies the steps necessary for implementing the ERDP. One of these steps is official endorsement of the project ADM or AcDM by division management and the ORNL Environmental Coordinator as well as project management and operations personnel. This endorsement is a commitment from the signers to adhere to the provisions in the project ADM or AcDM. Also, no construction or operation can take place until an approved, signed ADM or AcDM is in place. A system for expediting the follow-up of a project after the ADM process has been completed is in place, and it consists of field inspections of the project site during construction activities accompanied with completion of a series of site inspection reports that document the environmental status of the project.

An Action Description Memorandum (ADM) is a written report documenting the environmental review of a planned project. The word "planned" is a key word. An ADM is prepared very early in the planning stages of a project to ensure that project decisions include environmental considerations. The ADM, which must provide sufficient information to assist the decision-making process, is a DOE-specific instrument for fulfilling the agency's NEPA obligations. It contains an assessment of alternatives to a proposed action and it records the measures to be taken to protect the environment. ADMs are transmitted to DOE-ORO, where the project descriptions are reviewed for potential environmental impacts. If a decision is made that the action described will have no significant impact, a "concurrence" letter is drafted, which documents DOE's concurrence that no higher level of NEPA documentation is necessary. ADMs are retained in a computerized auditable file as a permanent record of the commitment to minimize risks to the environment during operations.

An Activities Description Memorandum (AcDM) is an internal assessment document with the same objectives as an ADM. However, it differs from an ADM in that (1) the action it describes usually does not involve construction, (2) alternatives are not addressed, (3) it is not a NEPA-compliance instrument, and (4) it is not transmitted to DOE. Internally, the AcDM functions as a formal agreement, it provides risk identification and assessment, and it becomes part of the permanent computerized environmental record at ORNL.

A relatively recent addition to the ERDP is the Environmental ALARA Memorandum (EAM). It functions like the ADM and AcDM in that it documents an ERDP project review. However, the EAM utilizes a check-list of computer-merged data and this significantly reduces document preparation time. Use of the EAM is generally reserved for select projects where determination is made after environmental review that full documentation as an ADM or AcDM is not warranted. The EAM, like the ADM and AcDM, provides a brief project description, an environmental assessment of the proposed action, and a permit compliance review.

The most recent addition to the ERDP is the Environmental ALARA Review Letter (EARL). This is an instrument for modifying, extending, or changing an ADM, AcDM, or EAM. The EARL can be used to halt operations, alter operations, and/or introduce new environmental data into operations. This is a highly flexible, 1-2 page document that enhances the application of ADMs, AcDMs, or EAMs. Because ERDP reviews are conducted very early in the planning phase of a project, there is a potential for missing project information developed after completion of the documentation. The EARL provides a very effective means for revisiting a project under the ERDP and documenting the findings.

The ERDP is responsible for reviewing and documenting more than 100 ORNL projects per year (120 assessments were issued during the last fiscal year and approximately 150 are typically in the program at any one time). In order to meet engineering construction schedules and program operating dates, ERDP work must be completed in a timely manner. Therefore, the personal computer (PC) has become the tool of choice for both program management and document preparation or editing, as well as for document formatting and final printing. A PC-computerized project tracking system has been developed to manage the control of operations such as project log in, assignment, monitoring, and tracking. Status reports (biweekly, monthly, and quarterly) are prepared and issued directly from the tracking system. All documents are prepared, edited, and printed on/from the PC. In addition a secondary file of significant compliance and protection information is generated with each project and this secondary file is computer-merged into a set of primary files, including all subsequent distribution letters. All of this is done prior to the internal review stage of the program and the materials are used as needed as the project documentation moves through the various reviews to endorsement and finalization.

Full benefit of the ERDP program is realized and assured by the followup and field oversight procedures. Followup begins with participation of EMCD representatives in a preconstruction meeting with contractor personnel, the construction engineer, and training personnel. During the preconstruction meeting, the contents of the ADM are discussed, the protective measures are outlined, and company policy regarding the environment is reviewed. Followup continues when construction is initiated. An EMCD site inspector who is acquainted with the project ADM inspects the project regularly and inspection reports are generated and distributed to document the environmental status of the project. This field inspection portion of the project oversight has proved to be most beneficial in ensuring that the measures in the ADMs are followed.

In summary, ORNL has developed and implemented an effective Environmental Review and Documentation Program. The approach and the objectives of the program have been summarized. The program initially focused on the ADMs required by DOE for major construction projects. As the program evolved and matured, additional less complex forms of documentation (i.e., AcDMs, EAMs, and EARLs) were added to expand the spectrum of activities covered and enhance the flexibility of the program. A strong documented field oversight and inspection effort is also pointed out as being equally important in assuring successful implementation of the ERDP program. With additional experience, the ERDP is expected to further mature with additions and refinements being considered as needed to fully compliment other ES&H programs and guard against important items being missed in the numerous areas of disciplinary interface and overlap.

Hazardous Waste Incinerator Contractor Audits

Presented by:

John T. Lawton,
Tennessee Valley Authority

HAZARDOUS WASTE INCINERATOR CONTRACTOR AUDITS

Under Federal regulations, hazardous waste generators have cradle-to-grave responsibility for their wastes. Because of this the Tennessee Valley Authority (TVA) has a policy of contracting only with environmentally responsible and financially sound hazardous waste contractors. TVA conducts environmental audits to ensure that their contractors are in substantial compliance with environmental regulations and to make subjective evaluations of (1) their disposal contractor's internal management controls; (2) public and regulatory perceptions of the contractor's operation; (3) the contractor's equipment design, maintenance, and operation; and (4) future contractor viability.

Although TVA's hazardous waste contractor audits are multidisciplined--that is, they address air, water, and solid/hazardous waste issues, this paper will primarily address the air issues associated with hazardous waste and PCB incineration.

HAZARDOUS WASTE INCINERATOR CONTRACTOR AUDITS

Introduction

It is well publicized that, under Federal regulations, hazardous waste generators have cradle-to-grave responsibility for their wastes. Because of this and other reasons, the Tennessee Valley Authority (TVA) has a policy of contracting only with environmentally responsible and financially sound hazardous waste contractors.

To implement this policy, an interdisciplinary team screens potential contractors. The team consists of engineers, an attorney, environmental specialists, production personnel, and a purchasing agent. Those firms judged to meet TVA policy criteria are recommended to the General Manager and Board of Directors. If approved, they are placed on a restricted award list. Only firms from this list are allowed to bid on TVA hazardous waste disposal contracts.

In 1985, TVA began conducting environmental audits to ensure the proper handling of its hazardous wastes by their selected disposal contractors. In addition to determining the contractors' compliance status with the environmental regulations and the contract terms, TVA wanted to (1) assess future viability of the contractor; (2) evaluate the effectiveness of the contractor's environmental program; (3) assess TVA liability risks relative to other contractors; (4) evaluate the adequacy of the contractor's equipment design, operation, and maintenance.

Although TVA's contractor audits evaluate several disposal methods and are multidisciplined--that is, they address air, water and solid/hazardous waste issues, this talk will primarily address the air issues associated with hazardous waste and PCB incineration.

Audit Design

Each contractor audit is divided into three phases--(1) preaudit or preparation phase; (2) the field inspection phase; and (3) reporting phase. During the preparation, the contractor is given four- to six-weeks advance notice to ensure their process is scheduled to operate and key site personnel will be available for the entrance meeting and site interviews. During notification the following information is requested from the contractor: (1) company history, (2) facility layout, (3) process flow diagram, (4) contractor's Security Exchange Commission 10-K report, if applicable, and (5) copies of facility insurance coverage. At the same time, arrangements are made with the EPA regional office, the State regulators, and local regulators to interview inspectors assigned to the contractor's operation.

Typically, the audit team consists of three people. After the lead auditor assembles the audit team, the TVA contract agreement, and hazardous waste manifests are reviewed to determine precisely the types of waste shipped to the audited contractor. TVA personnel responsible for storing and shipping hazardous waste and for administering the contract are asked to identify problems with the manifests or the certificates of destruction, which we require prior to payment.

An audit checklist is prepared or updated with portions devoted to specific disciplines. The checklist is completed as much as possible from published information gathered during the preparation or at the regulators' offices. During the field portion of the audit, information is verified and the balance of the checklist is completed.

Conducting the Audit

The field portion of the audit begins with a half day at the EPA Regional Office to review their risk assessment reports, inspection reports, and a copy of the RCRA Part B Application. This allows the audit team to become more familiar with the contractor's process. Interviews with the EPA inspectors help define the operation, previous compliance problems, and concerns or potential problems. Since the State regulators are more involved on a regular basis and have primacy in most areas, a full day is allowed at the State offices. Interviews are also held with the State inspectors and the following file material is reviewed: (1) trial burn data; (2) routine inspection reports; (3) operating permits; (4) permit applications; (5) citizen complaints; (6) enforcement actions; (7) special reports; (8) risk assessment studies; (9) public hearing information; (10) monitoring data; and (11) other relevant nonproprietary information. Where a local control authority exists, they too will be contacted to interview their inspectors and look at their file material. In addition to providing valuable compliance information, the time with the regulators defines the <u>perception</u> the regulators, citizens, and local officials have towards the audited disposal firm. Overwhelming adverse perceptions could endanger the future viability of a contractor.

Typically, site inspections are arranged through the Customer Service or Sales Department who allow a half-day or less to tour the facilities. With the amount of information accumulated during the preparation phase and at the regulators' offices, this time may be more efficiently spent focusing on specific compliance issues.

The following summarizes what is known about the contractor at this point in the audit:

- o The contract review and interviews with TVA personnel have identified special problems in the contract administration, the manifests, or with obtaining the Certifications of Destruction.

- o The manifest review has provided knowledge of the waste sent to the audited contractor and enables the auditor to compare these waste compounds to the destruction removal efficiency (DRE) of the principal organic hydrocarbons (POHC) used in the trial burns.

- o The office review of their SEC 10-K report has brought to light any litigation or environmental liabilities. It also has provided insight into the contractor's financial strength and insurability.

- o The RCRA Part B Application review has provided detailed descriptions of the site layout, process flow diagrams, material feed system, incinerator design, air pollution control equipment design, unit capacities, material handling processes, ash disposal methods, emission monitoring equipment, electrical interlocks and so on. The Part B review has also enabled us to complete the preaudit portion of the checklist and identify major compliance issues to be investigated at the site.

- o The review of the inspection reports and interviews with regulators provided a history of compliance problems, solutions, and trends. It also has revealed the level of regulatory oversight.

At the contractor's site, the checklist will be completed concerning unpermitted sources, wastes currently received, visual emissions, fugitive dust or odors, and descriptions of proposed new sources. The monitoring and operating data gathered from the trial burn test information and from the the permit applications are verified through direct observation and interviews with site personnel. Physical inspection of the process equipment while in operation is a must. Particular attention should be given to the material feeding operation and ash removal to ensure that the primary combustion chamber, usually a rotary kiln, is maintained under negative pressure and that there are no fugitive emissions of odors, dust, or products of incomplete combustion (PICs), which could be hazardous. Kiln rotation speed and waste material flow through the kiln should be observed to ensure adequate time for destruction. Evaluate general housekeeping and look for oil piping leaks, especially where waste fuels are used.

Interview plant operators about their daily checks and how leaks are handled. The incinerator availability and scheduled maintenance program can be indicators of the general condition of the equipment and the level of management commitment to its proper operation. Look closely at ash handling, sampling, and analysis. Determine if the ash is reinjected when the analysis indicates insufficient destruction. Determine also whether ash is treated or disposed onsite. Characterize the future capacity of the onsite landfill. If ash is shipped offsite, determine the final disposal site, distance to the site, method of shipment, facility owner, and remaining capacity. Offsite ash disposal at third-party facilities may increase risks to the generator.

The afterburner should be inspected for evidence of upset conditions and leaky fuel piping. Look at monitor locations, documentation of daily calibrations, and backup systems. Determine monitor availability, reasonableness of output, whether they are periodically certified, and how they are maintained during night shifts and weekends. Record the retention time, O_2, CO, CO_2, air flow, kiln temperature, afterburner temperature, and static pressures for comparison to the permit limits and trial burn data operating conditions. In interviews with operating personnel, determine how they define "stable operations" and at what point waste streams are fed to the incinerator. If the afterburner outlet is equipped with an emergency bypass, observe it for leakage and determine how frequently it is used. The newer, more efficient, incinerator systems will have heat recovery equipment and its operation should be evaluated.

Air pollution control equipment design varies greatly, but will have particulate control equipment, and a gas absorber, a demister, and a stack. Particulate control is done with cyclones, for high loadings or coarse particles. This is followed by either a venturi, electrostatic precipitator, baghouse or ionizer-wet scrubber for the remaining fine particulates. An auditor should be familiar with the operating parameters for each type of equipment and how they affect system performance. For example, throat pressure drop is the primary indicator of performance for a venturi. Particulate removal efficiency improves with increased pressure differential; however, higher pressure drop could also indicate increased air flow. For a variable throat venturi, confirm that the pressure drop for a given air flow has not been reduced. Liquor distribution is also important. Some venturi designs rely on nucleation to "grow" particles so that they may be removed at lower pressure drop and therefore at lower energy costs. <u>All operating parameters should compare to the trial burn or compliance test conditions</u>.

Electrostatic precipitators are sensitive to face velocity, inlet air distribution, and power levels. Other operational areas to be observed are rapper operation, rapper timing, and the ash removal system. Ambient air infiltration through corroded housings, bad seals, or poor ductwork can cause corrosion and warpage of the internals, which will reduce collection efficiency. Increased spark rate could indicate a broken wire, hopper bridging, excessive power levels, plate warpage, or other internal problems. The ionizing section of an ionizer-wet scrubber is similar to an ESP, but with a higher face velocity. Only 40-60 percent of the particulate is collected in the ionizer while the balance is collected in the absorber section. However, during the deluge wash cycles, power to the ionizer section is interrupted which temporarily reduces its control capability. Frequency and duration of the wash cycle should be noted as well as any increase in visible emissions.

Baghouse pressure drop can indicate problems with ruptured or loose bags; bag blinding; excessive air flow; caking due to moisture infiltration; shaker problems; or problems with the reverse air pulse system. Physical inspection of the housing, ducting, hoppers, and ash removal system can indicate operational problems or poor maintenance.

Gas absorption is typically done by a packed scrubber or spray dryer. Often the scrubber is preceded by a quench tower to protect the packing and absorber shell from excessive heat and a condenser to lower the saturation temperature for greater absorption or nuclear fine particles. Heat may be rejected from the recirculation liquor through cooling ponds or cooling towers. Cross-flow packed absorbers can bypass a portion of the gas if the packing settles below the air baffles. This is indicated by a lower system pressure drop at a given air flow. Recirculation liquor and air distribution are critical to absorber performance. Plugged nozzles are indicated by high nozzle pressure while abnormally low pressure would indicate worn, broken, or missing nozzles. Makeup water, chemical makeup, recirculation liquor temperature, recirculation rate, inlet air temperature, and air flow all affect the absorption equilibrium. These data should be recorded and compared to the compliance or design data.

Demisters prevent liquid carryover from the quench chambers, condenser, and wet scrubber. Operational problems can occur from particulate buildup at the wet/dry interface of the demister or from water carryover during the wash cycles.

After the process evaluation, subjective judgments can be made regarding system reliability, incinerator performance, control system performance, operating procedures, and maintenance practices. Interviews with site personnel should characterize the methods and effectiveness of their corporate environmental program. (1) Dedicated, professional, environmental staff; (2) management pay incentives for environmental performance; (3) onsite presence of independent corporate environmental personnel; and (4) a formal corporate environmental audit program are indications of a well-managed program. Some companies additionally provide employees a toll-free hotline for anonymous disclosure of environmental problems.

<u>Audit Reporting and Followup</u>

At the conclusion of the audit, the findings and observations are discussed with site personnel and a formal report is issued to TVA management. If major problems are identified, TVA's existing contract language allows for termination of the disposal agreement. Audit findings that increase risks are tracked by TVA personnel. The report may recommend a preference of waste types to be shipped to the audited contractor. Under separate cover the contractors may be ranked by the auditors for each category of waste on the basis of their environmental program.

Conclusion

Environmental audits are an effective tool to help ensure that hazardous wastes are properly transported, stored, and disposed. The audits also help TVA maintain a list of viable contractors for future wastes and minimize risks associated with the disposal of hazardous wastes.

Establishing and Operating a Corporate Environmental Audit Program

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ESTABLISHING AND OPERATING A CORPORATE ENVIRONMENTAL AUDIT PROGRAM

More and more companies are establishing internal environmental auditing programs as a safeguard against nonconformances with Federal, State, and local environmental regulations and corporate policies and procedures. Environmental audits evaluate the status of facility and activity compliance and recommend corrective actions to management. Audits can provide a valuable service to the entire corporation--both management and employees. To be effective, an environmental audit program should be established based on modern internal auditing standards. Independence from audited facilities and activities and a high degree of professionalism are extremely important. It is also critical that there be support from the very top of the corporation. Properly executed, an environmental audit program can help companies by reducing risks and saving the company loss of favor with both regulators and the public.

ESTABLISHING AND OPERATING A CORPORATE ENVIRONMENTAL AUDIT PROGRAM

INTRODUCTION

Why discuss environmental auditing at this conference on hazardous wastes? The answer to this question is probably obvious to most people--or at least it should be. In recent years EPA and the States have levied substantial civil and criminal penalties against corporations for noncompliance with hazardous waste regulations and for falsification of documents and records. The trend is toward even more rigorous enforcement with steeper fines and incarceration of high-level corporate managers. We have all seen recent examples of this in the media. The penalties and adverse publicity that can result from noncompliance have proven to be an incentive for more and more companies to look at environmental auditing as a tool to help reduce risks and improve overall corporate performance.

The purpose of this paper is to point out and discuss some of the very important and fundamental milestones and prerequisites that, in the opinion of the author, are necessary for the establishment and operation of an effective environmental auditing program.

WHAT IS ENVIRONMENTAL AUDITING?

Auditing has been defined as "work done not only by accountants and auditors in examining financial statements but also work done in reviewing (a) compliance with applicable laws and regulations, (b) economy and efficiency of operations, and (c) effectiveness in achieving program results."(1) As you can see, this is a rather broad definition and I believe that it appropriately describes the state of modern, enlightened auditing.

There are basically two types of auditing, financial auditing and operational auditing. Environmental auditing is one type of operational auditing. At TVA, we define environmental auditing as the verification and evaluation of the compliance status of facilities and activities with State, Federal, and local regulations and TVA environmental policies and procedures. Audits identify deficiencies and nonconformances and point out the need for corrective action. Environmental auditing serves the entire corporate organization by providing information on compliance status to the Board of Directors, the General Manager (Chief Executive Officer), and line management. It also helps facility operations and production level personnel understand compliance requirements and correct nonconformances and deficiencies. A well managed environmental auditing program provides a very valuable management and employee information system.

WHAT ARE THE BENEFITS OF AN ENVIRONMENTAL PROGRAM?

With the implementation of so many new environmental regulations and the concomitant enforcement activities of both Federal and State regulatory authorities, particularly in regard to hazardous waste management, managers in many corporations have made the decision to establish environmental auditing programs. These companies have decided that it makes good business sense to attempt to gain an added measure of risk protection against both financial penalties and poor public relations associated with being cited for violations of environmental regulations. There is widespread consensus among corporations which have established environmental audit programs that environmental auditing has been a wise investment of resources and that it has brought considerable benefits to the company. Environmental audits can help a company maintain an exemplary compliance record which can result in (1) an improved public image; (2) a good reputation with the regulators; (3) cost savings through fewer fines, and elimination of inefficiencies; and (4) improved transfer of environmental compliance information among employees throughout the corporation.

Audit programs do cost money, however, and may be beyond the available resources of many mid-sized and smaller companies. The large Fortune 500 level companies and utilities are typical of the corporations that have established ongoing internal environmental audit programs. There are consulting firms that provide audit services and many companies may find this an attractive alternative to establishing their own program. This paper is primarily aimed at those companies that wish to establish their own program.

WHAT IS NEEDED TO SET UP AN EFFECTIVE ENVIRONMENTAL AUDIT PROGRAM?

Sawyer (2) in his book on internal auditing states that successful internal auditing is constructed on a foundation of technical excellence--butressed on one side by demonstrated acceptance and support at the highest levels in the corporation; on the other side by continued, professional, imaginative service by the audit program to the corporation. I could not agree with this more and cannot overemphasize the importance of these three elements: strong support from the top, strong audit program technical ability, and a creative, imaginative approach by the program--not only to management, but to the entire organization. It is very important when establishing an audit program to aim the program not just toward service to management but to the entire organization.

Furthermore, I believe that it is of vital importance that an environmental audit program be established on a foundation or framework based on the principles and standards of the internal auditing profession. These are set forth in the Institute of Internal Auditors Standards for the Professional Practice of Internal Auditing (3) and are as follows:

1. Internal auditors should be independent of activities audited.

2. Internal audits should be proficient and professional.

3. The internal audit should encompass the evaluation of the adequacy and effectiveness of the organizations' system of internal control and quality of performance.

4. Audit work should include proper planning; examination of information; communication of results; and follow-up.

5. The director of internal auditing should properly manage the internal auditing department.

These standards should be used to form the cornerstone of any auditing program if it is to be effective. The Environmental Protection Agency's Environmental Auditing Policy Statement includes seven elements of an effective environmental auditing program.(4) While organized differently, the EPA elements communicate the same principals as the above standards. It may not be possible to fully meet each of these standards depending upon how a particular corporation's management sets up its audit program, but the personnel managing the program and corporate management should strive to meet as many of these as is possible.

Regarding the first standard, independence, any environmental auditing group should be independent of the activities it audits. Total and complete independence within any corporation is probably not possible, but the audit program must endeavor to achieve an acceptable level of independence so that it can be objective and unbiased. To achieve the necessary degree of independence and objectivity, it is critical that the program be mandated and established by the Board of Directors, and that the responsibilities and role of the audit function be communicated to all employees in writing. The ideal way to accomplish this is to have this delegation set forth in a written, formal corporate policy document and to have a written charter or organizational statement which details in writing the program purpose, objectives, responsibility, and scope. A set of corporate audit procedures rounds out the list of basic organizational tools that provide the needed foundation. Explicit top management support and a corporate commitment to followup on audit findings is essential if the program is to be successful.

Regarding the second standard, if audits are not performed with due professional care by auditors who are proficient (i.e., have good auditing skills and the necessary technical and organizational background and experience to understand and know the facilities they are auditing), the effectiveness of the program will be severely limited. It is essential that auditors be knowledgeable about the facilities they are auditing. Auditees are usually very skeptical and wary of auditors who they know or suspect do not have any background or experience or general understanding of the facility being audited.

Strong communication, both oral and written, and interpersonal skills are also of paramount importance. No matter how great the auditor's technical skills and understanding of the facility being audited, the auditor will only be effective if he/she has the ability to effectively communicate and work with the personnel at the audited facility. Unfortunately, it is not easy to find people who have that valuable combination of technical, analytical and communication skills.

Standard number three is also very important. Too frequently audits, whether operational or financial, focus on the symptoms of a problem and never attempt to define and advise management about the cause of the problem. Most environmental auditors I know can without too much difficulty visit a facility, review records and permits, tour and inspect the facility and identify and write up nonconformances and deficiencies. The real challenge is to determine if these nonconformances are evidence of a larger, more pervasive problem such as lack of training or proper management controls. For instance, are the lack of PCB labels on doors to a room containing PCB transformers and improperly documented PCB inspection records indicators of a poorly managed and administered PCB inspection and compliance program? Or is the PCB program in excellent shape and these nonconformances simply isolated instances attributed to the ever present pest of random human error? The challenge for the audit program is to always be asking these kinds of questions and to be alert and searching for the real problems.

Regarding the fourth standard, audits must be carefully planned and organized so that the best information can be collected and properly evaluated. Planning the audit is very time consuming and frequently takes more time than is spent at the facility. Findings must be written so that they can be easily understood and transmitted efficiently to management. A system of tracking and closing findings must also be established so that proper corrective action can be taken in a timely manner.

Regarding the final standard, the success of an auditing program depends upon the quality of the product it is providing the corporation. It is the responsibility of the manager to continually stand back and look at the overall program to ensure that it is meeting its purpose and objectives and producing the best possible product. The auditors must conduct themselves in a thoroughly professional manner displaying the highest level of objectivity and integrity and they must show the auditee that they are skilled and knowledgeable. The manager must constantly remind the auditors to spend enough time asking the right questions and looking at enough records and equipment to have a reasonably accurate picture of the environmental compliance status of the particular facility. Auditors must always be looking at the evidence and ask questions such as whether an identified problem is a symptom of some larger management problem. The manager's job is to help ensure that this happens. If the audit program is consistently doing this, then the program is more than likely providing a good product to the corporation.

WHAT IS NEEDED TO MAINTAIN AN EFFECTIVE ENVIRONMENTAL AUDIT PROGRAM?

An established audit program like any other group or organization should always be searching for new ideas, new approaches and always be ready and willing to change. Growth and improvement stop when an organization loses sight of this important need. To best serve the corporation and provide the best product requires effort and a systematic, carefully thought out game plan.

As stated above, the manager of the audit program is responsible for the effective operation of the program. He/she must ensure that the program operates over time in a highly professional manner and meets the conditions set forth in its charter. A number of tools are available which can be used to achieve this desired end. Having each member of the audit program interface during the year with his or her counterparts from other companies is a very effective training tool. This can be done by visiting other companies and by attending auditing courses and workshops such as those offered by the Institute of Internal Auditors. Time spent outside the confines of one's own corporation exchanging thoughts and ideas is necessary.

Another helpful tool is having an external audit of the audit program. Every few years an audit program should have an outside party, e.g., an experienced consulting firm or members from another company conduct a quality assurance review of its performance. This is a healthy and needed exercise. It not only helps keep the program "on its toes," but it also adds an important measure of fairness and credibility as others in the corporation see that the auditors also get audited. The Standards for the Professional Practice of Internal Auditing(3) call for this external review to be accomplished at least once every three years, and it must be done by qualified persons independent of the audit program. It is also imperative for auditors to attend technical courses and seminars aimed at particular regulations or pollution control technologies. Auditors must keep current with regulatory changes, and new audit techniques, to ensure the continued success of the program. In short, auditors with a positive attitude and "fresh" outlook are the best assurance for producing the best product possible for the corporation.

Finally, annual planning meetings for audit schedule development, goal setting and preparation of an annual report are important elements in maintaining an ongoing, effective audit program. The number of facilities audited each year will depend upon resources available to the program and the desires and needs of management.

CONCLUSION

For those of you who have been thinking about establishing an environmental auditing program in your company and for those of you who may already be doing it, I hope these remarks have been helpful. For environmental auditing to be successful there must be a clear endorsement and firm support from the highest levels of the corporation. There must also be recurring evidence that this support is real. Auditors must be knowledgeable of the facilities and activities they audit, know the regulations and company policies, and have good auditing skills, namely, strong communicative and interpersonal skills. Auditors must also display a high degree of professionalism and objectivity. As has been shown in many corporations in the last few years, environmental auditing can be a very positive tool in helping a company more effectively conduct its business. However, establishing the program on the foundation of modern internal auditing standards assures the best opportunity for the program to be successful.

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☆ U.S. GOVERNMENT PRINTING OFFICE 1988—548-118/60139