

Originally Processed With FOIA(s):  
2025-0373-S

FOIA Number:  
2025-0373-S

# FOIA MARKER

**This is not a textual record. This is used as an  
administrative marker by the George Bush Presidential  
Library Staff.**

---

**Record Group/Collection:** George H.W. Bush Presidential Records  
**Collection/Office of Origin:** Chief of Staff, White House Office of  
**Series:** Card, Andrew, Files  
**Subseries:**

---

**OA/ID Number:** 05215  
**Folder ID Number:** 05215-002b

---

**Folder Title:**  
Background Material from Andrew Card and Beatrice Taggart [2]

---

| Stack: | Row: | Section: | Shelf: | Position: |
|--------|------|----------|--------|-----------|
| G      | 15   | 22       | 1      |           |

---

THE PETITION OF CITIZENS OPPOSED TO  
POLLUTING THE ENVIRONMENT OF THE SOUTH SHORE  
TO USE INNOVATIVE TECHNOLOGIES IN THE HAZARDOUS  
WASTE REMEDIATION AT THE BAIRD AND MCGUIRE SITE,  
HOLBROOK, MASSACHUSETTS

Submitted by Citizens  
Opposed to Polluting the  
Environment of the South Shore

by its attorneys,

Mark W. Roberts  
BARRON & STADFELD, P.C.  
Two Center Plaza  
Third Floor  
Boston, MA 02108  
(617) 723-9800



I. COPE CALLS ON THE EPA TO UTILIZE  
INNOVATIVE TECHNOLOGIES

Citizens Opposed to Polluting the Environment of the South Shore ("COPE") hereby petition the United States Environmental Protection Agency ("EPA") to utilize innovative remediation technologies other than hazardous waste incineration at the Baird and McGuire Site. COPE specifically requests that the EPA reopen the Records of Decision which were issued on September 30, 1986 and September 14, 1989 ("ROD I" and "ROD II"), respectively, to consider the use of innovative technologies rather than incineration to remediate the Site. COPE submits this Petition in accordance with the National Contingency Plan (NCP), 40 C.F.R. §300.1 et seq. and the Interim of Final Guidance on Preparing Superfund Decision Documents, OSWER directive 9355.3-02 as they pertain to amendments of records of decisions.

Viable new technologies for hazardous waste remediation have been developed since the EPA originally chose to utilize an incinerator at the Baird and McGuire Site in September of 1986. The implementation of these innovative technologies could effectuate a permanent remedy while substantially reducing the health risk to the residents of the cities and towns of Holbrook, Randolph, Braintree, Whitman, Avon, Brockton and Abington. An amendment of ROD I and ROD II to adopt a more environmentally sound remedy before the

incineration option is implemented is consistent with the intent and purpose of the Comprehensive Environmental Response, Compensation and Liability Act of 1980, 42 U.S.C. §9601, et seq. (CERCLA).

Nationally, the EPA is actively evaluating innovative hazardous waste treatment technologies under the Superfund Innovative Technology Evaluation (SITE) Program. The goal of the SITE Program is to ensure that innovative technologies are developed, demonstrated and made commercially available for permanent cleanup of superfund sites. The EPA wants to replace reliance on land disposal and removal option wherever this is technically feasible. This Program was authorized under the Superfund Amendments and Reauthorization Act of 1988.

Since the cleanup at Baird and McGuire is being undertaken by the EPA and the Commonwealth of Massachusetts, the remedial strategy which is finally implemented should meet both the letter and the spirit of CERCLA to permanently cleanup the hazardous waste on the Site. The mixture of organic and inorganic contaminants makes it an ideal site to demonstrate that innovative technologies can be used, individually or in combination, to permanently clean up a major superfund site. When the EPA began work at Baird and McGuire, technologies were not available to do this. However, innovative technologies are available and have been proven to be effective in permanently remediating all

components of the contamination found at Baird and McGuire. The EPA should not be caught by the inertia of its past decision to utilize incineration but, rather, it should seize the opportunity to demonstrate that soil and groundwater contamination can be permanently cleaned up without creating contamination in the atmosphere.

#### 1.1 Site History

The Baird and McGuire Site is located on South Street, Holbrook, Massachusetts, approximately 14 miles south of Boston. For over seventy years, Baird and McGuire, Inc. operated a chemical manufacturing and batching facility on the property. Later activities at Baird & McGuire included mixing, packaging, storing and distributing various products, including pesticides, herbicides, disinfectants, soaps, floor waxes and solvents. Waste disposal methods at the Site included direct discharge into the soil, nearby brook and wetlands and a former gravel pit in the eastern portion of the Site. Underground disposal systems were also used to dispose of waste.

In December, 1982, the Baird and McGuire Site was placed on EPA's Proposed National Priorities List (NPL). The Baird and McGuire Site is now ranked as the fourteenth worst hazardous waste site in the country.

#### 1.2 RESPONSE HISTORY

In 1983, the EPA conducted a removal action at the Site after a waste lagoon overflowed near the Cochato River and



spread contaminants into the river. The emergency activities included removing approximately 1000 cubic yards of heavily contaminated soils, construction of a ground water interception/recirculation system to limit contaminated groundwater from migrating into the river, regrading the contaminated waste disposal area and covering it with a temporary cap. In response to the lagoon overflow, the Tri-Town Water Board, (Holbrook, Randolph and Braintree) closed the sluice gate that diverted water to the Richardi Reservoir for domestic use. To date, the sluice gate has remained closed.

A second removal action at the Site was initiated in 1985 following the discovery of dioxin in soils at the Site. The EPA conducted additional sampling of air, soils and water, and installed an additional 5,600 feet of fence.

The EPA implemented an initial remedial measure ("IRM") during the period 1985 through 1987. The IRM consisted of constructing a new water main along South Street to replace an existing main that past through the Baird and McGuire Site. Additionally, the Baird and McGuire laboratory, mixing buildings, and tank farm were demolished and removed as part of the IRM. Once these structures were removed, a temporary synthetic cap was installed over that portion of the Site.

The Remedial Investigation (RI) revealed a "chemical soup" of organic chemicals including volatiles, base/neutrals, acid extractables, pesticides, herbicides and



dioxin, and inorganic chemicals including arsenic, barium, lead and zinc. Summaries of the RI analytical data for critical contaminants are attached hereto in Appendix A.

A second phase of the RI attempted to resolve some questions left by the initial investigation, and additionally studied contamination in the Cochato River and surrounding wetlands. The predominant contaminants detected in the river sediments were base/neutral organics, predominantly polynuclear aromatic hydrocarbons (PAHs); pesticides; volatile organic compounds (VOCs); and arsenic.

Clean-up of a site of this magnitude, with the complexity of contaminants present, had never been effectively undertaken as of 1986. Cleanup technology was in its infancy and the EPA attempted to develop a remediation plan which would address all 102 chemicals on site as simply as possible. In 1986, ROD I was issued which divided cleanup of the Baird and McGuire Site into operable units. The ROD I established two major remedial components: extraction and on-site treatment of groundwater, and extraction and on-site incineration of contaminated soil. In addition, the demolition materials which remain from the original Baird and McGuire buildings were to be incinerated on-site when the soil incineration portion of the long-term remedial action program was initiated.

In 1986, when the EPA decided to incinerate the soil to remove hazardous substances, incineration was an unproven

technology for the destruction of dioxin contaminated soils, (other than in short duration, ideal condition test-burns). Final Feasibility Study Report Baird and McGuire Site, Holbrook, Massachusetts p. 5-34. However, the EPA was looking for technologies that would destroy hazardous wastes rather than only capping or relocating the problem. Incineration was the only alternative considered in 1986, which actually would destroy hazardous materials. Innovative technologies such as chemical treatments, biological treatments, and in-situ treatments were not considered. One primary reason that these technologies were not considered in the 1986 Feasibility Study was that the development of hazardous waste remediation technologies was in its infancy, many of the above-described technologies either had not been developed or had not been proven at that time.

On September 14, 1989, the EPA issued ROD II which addressed remediation of sediment contamination in the Cochato River attributable to the Baird and McGuire Site. The assessment of remedial alternatives again failed to consider most available innovative remedial strategies. Solvent extraction was considered as an alternative to incineration, however, the analysis was biased in favor incineration due to the decision to utilize incineration in ROD I. When the remedial alternatives were compared, the cost of installing the incinerator was not considered in ROD



II because the incinerator was already pre-approved in ROD I. If these costs had been included, solvent extraction would have been more cost-effective than incineration.

II. INCINERATION IS NOT THE MOST EFFECTIVE  
WAY OF PROTECTING PUBLIC HEALTH AND THE ENVIRONMENT  
WHILE CLEANING UP THE BAIRD AND MCGUIRE SITE

Incineration takes the problem of soil contamination at Baird and McGuire and creates a problem of the emission of air toxics over a much larger area. These public health and environmental risks were recognized and addressed in the Final Feasibility Study Report, dated July 18, 1986. The section entitled "Public Health Evaluation of Alternative No.3B" contains the following passage:

The incineration phase of Alternative No. 3B, however, raises public health concerns both positive and negative in nature. On the positive side, the complete and permanent destruction of the contaminants at the Site in the soils will permanently eliminate the threat of the public posed by this material. On the other hand, the incineration process proposes additional health risks. For this reason, the Environmental Protection Agency and incinerator equipment manufacturers are in the process of testing the efficiencies of the various equipment with test burning programs. No incineration can take place at this site or any other site contaminated with dioxin until this testing program is completed and the EPA issues pre-approval for the process. Public health concerns will always be considered in these cases.

Therefore, Alternative No. 3(b) will only be considered if the testing programs now being studies (sic) show a net increase in public health protection with incineration-based technologies for hazardous waste site remediation.

Final Feasibility Study Report Baird & McGuire Site, Holbrook, MA, July 18, 1986 at p. 5-36-7. (Emphasis added).



Innovative technologies hold the potential for providing greater protection to public health and the environment than incineration. Alternatively, implementation of certain innovative technologies to the hazardous waste at Baird and McGuire prior to incineration may substantially reduce the volume of contaminants contained in emissions. Therefore, since incineration may not show a "net increase in public health protection," it should not be implemented until the alternatives are fully explored.

III. INCINERATION POSES SUFFICIENT  
RISKS TO WARRANT EXAMINATION OF INNOVATIVE  
TECHNOLOGIES FOR A SAFER SOLUTION

During the development and utilization of hazardous waste incinerators, numerous problems associated with their use have been discovered. Those problems include the following:

1. Operational experience has demonstrated that human error can render the incinerators theoretical burn efficiencies meaningless. Even relatively short-term operation of incinerators under improper conditions can greatly increase the total amount of contaminants released to the environment. Affixed hereto Attachment B are excerpts from a document entitled "The Track Record of the Hazardous Waste Incineration Industry" prepared by Citizens Clearing House for Hazardous Waste, Inc.

2. Once the incinerator is fully licensed, many emission components are not monitored on an ongoing basis.

Therefore, operation of the incinerator with destruction efficiencies of some substances of less than 99.9999% can occur without detection.

3. Analytical methods for monitoring emissions utilize the concept of destruction efficiency to determine whether the incineration has destroyed all components of the hazardous waste. This approach emphasizes the identification of several preselected compounds in the waste and does not fully address either partial oxidation or chemical recombinations which may create new toxic compounds.

4. Recent studies have determined that chemical recombination may occur outside of the stack itself after emissions from the stack cool. By the process of chemical recombination, many hazardous chemicals, including dioxin may be created. (A copy of the Human Health Effects Associated with Exposure to Herbicides and/or their Associated Contaminants (including Dioxin), Richard Clapp, M.P.H., Sc.D. et al. is affixed hereto as Attachment C.)

5. Heavy metals, such as arsenic and lead contained in the soils to be burned can pass through the incinerator and filters and be emitted in substantial quantities. It is our understanding that even after all of the studies that have been conducted to date at Baird and McGuire Site, the EPA is not able to predict with any certainty how much arsenic and other heavy metals will be emitted when the incineration occurs.

6. Potentially, the largest short-term exposure to hazardous materials related to incineration may occur during the removal and transportation of the contaminated soils to the incinerator itself. Such "fugitive emissions" of hazardous contaminants can be substantial, and can not be effectively prevented.

IV. INNOVATIVE REMEDIATION TECHNOLOGIES  
HAVE BEEN PROVEN WHICH CAN BE USED TO  
REMEDiate THE HAZARDOUS WASTE  
AT THE BAIRD AND MCGUIRE SITE

Since ROD I and ROD II were issued, numerous alternative technologies have been developed. Additionally, as hazardous waste sites are being cleaned up across the country, these alternatives are being proven to be effective. At the Union Chemical Co., Inc. Site, which has similar organic and inorganic contamination to that at Baird and McGuire, a compendium of potential applicable or remedial technologies was compiled. A copy of that compendium is affixed hereto as Appendix D. It is the petitioners' contention that a similar analysis should be conducted of remedial alternatives for the Baird and McGuire Site to determine whether individually or in combination such technologies can be utilized to remediate some or all of the site, while reducing the risk to public health and the environment.

Over 140 sites across the country are considering, planning or implementing bioremediation technologies. Over 80 sites are applying in-situ treatments, while over 60 other



sites have chosen land treatment or treatment in a bioreactor. Affixed hereto as Attachment E is a list of CERCLA, RCRA and UST sites considering, planning or operating full-scale bioremediation systems which was produced by the EPA, March 1991 in a publication entitled "Bioremediation in the Field". The petitioners were interested to note that the Baird and McGuire Site is the first site listed on the table. It is the petitioners contention that if bioremediation is being considered for a portion of the cleanup at the Baird and McGuire Site, the entire cleanup should be analyzed to determine whether other aspects would benefit from the use of innovative technologies.

Dioxin wastes have been pointed to as one of the key hazardous components which are driving the need for incineration. However, numerous treatment alternatives for dioxin waste exist which do not cause the air emissions associated with incineration. See, A Review of Treatment Alternatives for Dioxin Waste, Harry M. Friedman and Robert A. Olexsey affixed hereto as Attachment F. Additionally, in a document produced by the EPA entitled "Innovative Treatment Technologies, Semi-Annual Status Report, January, 1991, (1991 Report) 5th innovative treatment technologies, other than incineration, are being implemented at four superfund sites to remove dioxin. A copy of the "1991 Report" is affixed hereto as Attachment G.

The "1991 Report" only contains information contained in records of decision from superfund sites issued between 1982-1989 but reveals that innovative technologies are being implemented at 93 superfund sites across the country. Thirty-one sites are implementing bioremediation; 22 are employing in-situ soil flushing; thermal desorption is being used at 10 sites; soil washing is being used at 10 additional sites; 6 sites are using chemical extraction; 4 sites are using chemical treatment; and 2 sites are utilizing in situ vitrification.

The emission of arsenic and heavy metals may pose the most serious long term health threat of incineration at the Baird and McGuire Site. Therefore, if incineration is the only feasible remedy specific consideration should be given to the use of innovative technologies to remove heavy metals before incineration of the Baird and McGuire waste laden soils. A number of the innovative treatment technologies listed in the "1991 Report" specifically deal with remediating arsenic and lead.

The petitioners are in the process of assembling additional information on the health effects of incineration and the development and proven use of innovative treatment technologies to remediate the types of wastes present at Baird and McGuire. Attached hereto as Attachment F are a limited number of additional references and articles describing relevant innovative treatment technologies.

The Petitioners respectfully request that they be able to submit a supplemental filing on or before May 15, 1991.

#### CONCLUSION

The incineration of hazardous waste laden in soils, by necessity creates the emission of air toxics. Human error, or mechanical malfunction can cause even greater emissions. One rationale for the original selection of incineration was that it insured the complete and permanent destruction of the contaminants rather than capping or relocating the problem. Since the decision was made to utilize incineration at Baird McGuire, other innovative technologies have been developed and proven which also completely and permanently destroy hazardous materials, without, however creating hazardous emissions. Before the EPA irretrievably commits itself to incineration, COPE requests that the EPA reopen ROD I and ROD II in order that these innovative technologies may be fully analyzed. COPE urges that these innovative technologies be analyzed first to determine whether they individually or in combination provide an alternative to incineration, and second if replacement of incineration is not possible, determine whether individually or in combination innovative technologies can be used to reduce or remove any class of contaminants from the emissions from an incinerator.

The EPA has a unique opportunity at the Baird and McGuire Site since the cleanup is being devised, implemented and paid for by the Governments to demonstrate that



innovative technologies can be utilized to remedy complex hazardous at one facility by shifting the contamination to another site or into the atmosphere. COPE urges the EPA to seize the opportunity and implement innovative technologies that will permanently and completely clean up the Baird and McGuire Site.

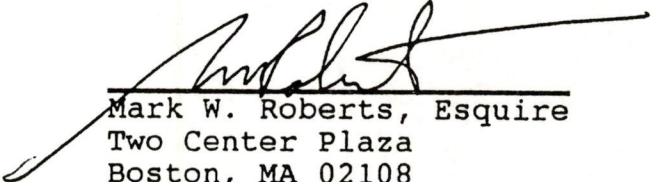
Dated at Boston, Massachusetts this 1st day of May, 1991.

Respectfully submitted,

CITIZENS OPPOSED TO POLLUTING  
THE ENVIRONMENT OF THE SOUTH SHORE

by their attorneys,

BARRON & STADFELD, P.C.



Mark W. Roberts, Esquire  
Two Center Plaza  
Boston, MA 02108  
(617) 723-9800

00012665

To date, volatile organics have not been detected above background levels at the Site. Additional air monitoring for semi-volatile organics, pesticides, herbicides, and arsenic is being conducted as part of the Phase II Remedial Investigation (RI) and results will be released by EPA when they become available.

#### 1.25 Summary Tables for Designated Zones (Areas) of the Site

For the presentation and analysis of the data generated during the RI/FS, the Baird & McGuire Site and study area has been divided into a set of Zones based on physical features and contaminant distribution. A description of the designated Zones is provided later in Section 2.22, and the Zones are shown graphically in Figure 2-1 therein.

Tables 1-1 through 1-11 below provide tabular summaries of the concentrations of 39 critical contaminants at the Site selected for use in the public health risk assessment (Section 2.00 herein). Each Table summarizes the data for each Zone and environmental media according to:

1. Frequency of detection of each contaminants (equals number of samples in which the compound was found divided by the number of samples analyzed);
2. Maximum concentration reported; and,
3. Average of concentrations reported.

In these Summary Tables, surface soils data are for samples collected at depths of from 0 to 4 feet, and deep soils data are for samples collected at depths greater than 4 feet. Some environmental media, e.g., surface water and sediments, are not present in all the Zones and some were not sampled in every Zone. Notations on the Tables indicate where there are no data for a particular media in each Zone.

Table 1-12 provides a summary of soil testing results for samples collected beneath the Baird & McGuire buildings during the Phase II RI.

TABLE 1-1

## SUMMARY OF RI ANALYTICAL DATA FOR CRITICAL CONTAMINANTS IN ZONE 1

| Compound                    | G Sup | (-- Surface Soils (to 4 feet) --) |                    |                    | (-- Deep Soils (below 4 feet) --) |                    |                    | (- Ground Water -) |                    |                    | (- Surface Water -)          |                    |                    | (- Sediments -)              |                    |                    |
|-----------------------------|-------|-----------------------------------|--------------------|--------------------|-----------------------------------|--------------------|--------------------|--------------------|--------------------|--------------------|------------------------------|--------------------|--------------------|------------------------------|--------------------|--------------------|
|                             |       | Frequency                         | Maximum Conc (ppb) | Average Conc (ppb) | Frequency                         | Maximum Conc (ppb) | Average Conc (ppb) | Frequency          | Maximum Conc (ppb) | Average Conc (ppb) | Frequency                    | Maximum Conc (ppb) | Average Conc (ppb) | Frequency                    | Maximum Conc (ppb) | Average Conc (ppb) |
| 1,1-Dichloroethylene        | C     | 0 / 46                            |                    |                    | 0 / 37                            |                    |                    | 0 / 3              |                    |                    |                              |                    |                    |                              |                    |                    |
| 1,2-Dichloroethane          | C     | 0 / 46                            |                    |                    | 0 / 37                            |                    |                    | 0 / 3              |                    |                    |                              |                    |                    |                              |                    |                    |
| 2,3,7,8-TCDD                | C     | 11 / 28                           | 11.3               | 2.6                | 0 / 0                             |                    |                    | 0 / 0              |                    |                    |                              |                    |                    |                              |                    |                    |
| 4,4'-DDD                    | C     | 34 / 46                           | 1300000.0          | 129067.7           | 28 / 37                           | 280000.0           | 33956.8            | 1 / 3              | 0.2                | 0.2                |                              |                    |                    |                              |                    |                    |
| 4,4'-DDE                    | C     | 33 / 46                           | 420000.0           | 43693.0            | 15 / 37                           | 1142000.0          | 77344.8            | 0 / 3              |                    |                    |                              |                    |                    |                              |                    |                    |
| 4,4'-DDT                    | C     | 37 / 46                           | 2600000.0          | 166098.1           | 20 / 37                           | 268000.0           | 21766.1            | 1 / 3              | 0.4                | 0.4                | Not Applicable for this zone |                    |                    | Not Applicable for this zone |                    |                    |
| Aldrin                      | C     | 0 / 46                            |                    |                    | 0 / 37                            |                    |                    | 1 / 3              | 0.1                | 0.1                |                              |                    |                    |                              |                    |                    |
| Arsenic                     | C     | 26 / 27                           | 380000000.0        | 22071773.1         | 25 / 37                           | 1800000.0          | 151620.0           | 0 / 3              |                    |                    |                              |                    |                    |                              |                    |                    |
| Benzene                     | C     | 3 / 46                            | 125.0              | 51.3               | 0 / 37                            |                    |                    | 0 / 3              |                    |                    |                              |                    |                    |                              |                    |                    |
| Benzidine                   | C     | 0 / 46                            |                    |                    | 0 / 37                            |                    |                    | 0 / 3              |                    |                    |                              |                    |                    |                              |                    |                    |
| Benzo(a)pyrene              | C     | 6 / 46                            | 9000.0             | 2876.7             | 1 / 37                            | 1900.0             | 1900.0             | 0 / 3              |                    |                    |                              |                    |                    |                              |                    |                    |
| Beryllium                   | C     | 22 / 27                           | 1700.0             | 660.5              | 35 / 37                           | 2400.0             | 857.4              | 0 / 3              |                    |                    |                              |                    |                    |                              |                    |                    |
| BHC-alpha                   | C     | 8 / 46                            | 9000.0             | 4617.1             | 3 / 37                            | 1900.0             | 646.5              | 0 / 3              |                    |                    |                              |                    |                    |                              |                    |                    |
| BHC-beta                    | C     | 0 / 46                            |                    |                    | 1 / 37                            | 3.1                | 3.1                | 0 / 3              |                    |                    |                              |                    |                    |                              |                    |                    |
| BHC-delta                   | C     | 1 / 46                            | 8.0                | 8.0                | 3 / 37                            | 152.8              | 77.9               | 0 / 3              |                    |                    |                              |                    |                    |                              |                    |                    |
| BHC-gamma (Lindane)         | C     | 19 / 46                           | 31000.0            | 7572.3             | 15 / 37                           | 16000.0            | 2903.3             | 0 / 3              |                    |                    |                              |                    |                    |                              |                    |                    |
| Cadmium                     | C     | 10 / 27                           | 10000.0            | 1977.5             | 7 / 37                            | 3700.0             | 1251.4             | 0 / 3              |                    |                    |                              |                    |                    |                              |                    |                    |
| Chlordane                   | C     | 36 / 46                           | 138000000.0        | 4182607.3          | 19 / 37                           | 410000.0           | 51306.2            | 0 / 3              |                    |                    |                              |                    |                    |                              |                    |                    |
| Chloroform                  | C     | 1 / 46                            | 6.3                | 6.3                | 0 / 37                            |                    |                    | 0 / 3              |                    |                    |                              |                    |                    |                              |                    |                    |
| Dieldrin                    | C     | 21 / 46                           | 52000.0            | 11366.7            | 21 / 37                           | 26000.0            | 5531.5             | 0 / 3              |                    |                    |                              |                    |                    |                              |                    |                    |
| Heptachlor                  | C     | 2 / 46                            | 3400.0             | 3400.0             | 1 / 37                            | 0.5                | 0.5                | 0 / 3              |                    |                    |                              |                    |                    |                              |                    |                    |
| Heptachlor Epoxide          | C     | 1 / 46                            | 28.0               | 28.0               | 3 / 37                            | 2190.0             | 822.8              | 0 / 3              |                    |                    |                              |                    |                    |                              |                    |                    |
| Nickel                      | C     | 25 / 27                           | 54000.0            | 9624.0             | 33 / 37                           | 16000.0            | 6903.0             | 2 / 3              | 19.0               | 16.0               |                              |                    |                    |                              |                    |                    |
| Tetrachloroethylene         | C     | 24 / 46                           | 62645.0            | 5796.8             | 10 / 37                           | 8900.0             | 1488.3             | 0 / 3              |                    |                    |                              |                    |                    |                              |                    |                    |
| Trichloroethylene           | C     | 7 / 46                            | 4800.0             | 710.7              | 1 / 37                            | 770.0              | 770.0              | 0 / 3              |                    |                    |                              |                    |                    |                              |                    |                    |
| Vinyl chloride              | C     | 0 / 46                            |                    |                    | 0 / 37                            |                    |                    | 0 / 3              |                    |                    |                              |                    |                    |                              |                    |                    |
| 1,2-trans-Dichloroethylene  | NC    | 2 / 46                            | 19.0               | 17.0               | 0 / 37                            |                    |                    | 0 / 3              |                    |                    |                              |                    |                    |                              |                    |                    |
| 1,3-trans-Dichloropropylene | NC    | 0 / 46                            |                    |                    | 0 / 37                            |                    |                    | 0 / 3              |                    |                    |                              |                    |                    |                              |                    |                    |
| 2-Butanone                  | NC    | 6 / 46                            | 113208.0           | 58394.2            | 8 / 37                            | 7200.0             | 4688.5             | 3 / 3              | 10.0               | 10.0               |                              |                    |                    |                              |                    |                    |
| Barium                      | NC    | 26 / 27                           | 59000.0            | 29961.5            | 37 / 37                           | 71000.0            | 22078.4            | 3 / 3              | 364.0              | 173.3              |                              |                    |                    |                              |                    |                    |
| Ethylbenzene                | NC    | 15 / 46                           | 29613.0            | 6753.9             | 15 / 37                           | 52000.0            | 13746.3            | 0 / 3              |                    |                    |                              |                    |                    |                              |                    |                    |
| Fluoranthene                | NC    | 32 / 46                           | 34169.0            | 7280.8             | 7 / 37                            | 23000.0            | 3841.4             | 0 / 3              |                    |                    |                              |                    |                    |                              |                    |                    |
| Lead                        | NC    | 27 / 27                           | 87000.0            | 35318.5            | 37 / 37                           | 38000.0            | 9845.9             | 0 / 3              |                    |                    |                              |                    |                    |                              |                    |                    |
| Silver                      | NC    | 8 / 27                            | 7500.0             | 2312.5             | 6 / 37                            | 2100.0             | 1066.7             | 0 / 3              |                    |                    |                              |                    |                    |                              |                    |                    |
| Toluene                     | NC    | 19 / 46                           | 8469.0             | 1771.4             | 16 / 37                           | 7400.0             | 2134.1             | 0 / 3              |                    |                    |                              |                    |                    |                              |                    |                    |
| Ylenes (Tot) (tech)         | NC    | 21 / 46                           | 300000.0           | 54410.2            | 18 / 37                           | 330000.0           | 80401.9            | 0 / 3              |                    |                    |                              |                    |                    |                              |                    |                    |
| Zinc                        | NC    | 27 / 27                           | 179000.0           | 62518.5            | 37 / 37                           | 226000.0           | 56243.2            | 2 / 3              | 32.0               | 18.4               |                              |                    |                    |                              |                    |                    |
| Total Other PAHs            | SC    | 38 / 46                           | 12860000.0         | 785508.9           | 29 / 37                           | 5590000.0          | 740436.2           | 1 / 3              | 120.0              | 120.0              |                              |                    |                    |                              |                    |                    |
| Dibenzofuran                | SC1   | 17 / 46                           | 850000.0           | 74371.3            | 18 / 37                           | 190000.0           | 42576.1            | 0 / 3              |                    |                    |                              |                    |                    |                              |                    |                    |



TABLE 1-2

## SUMMARY OF RI ANALYTICAL DATA FOR CRITICAL CONTAMINANTS IN ZONE 2

| Compound                    | Group | (-- Surface Soils (to 4 feet) --) |                    |                    | (-- Deep Soils (below 4 feet) --) |                    |                    | Ground Water |                    |                    | Surface Water                |                    |                    | Sediments |                    |                    |
|-----------------------------|-------|-----------------------------------|--------------------|--------------------|-----------------------------------|--------------------|--------------------|--------------|--------------------|--------------------|------------------------------|--------------------|--------------------|-----------|--------------------|--------------------|
|                             |       | Frequency                         | Maximum Conc (ppb) | Average Conc (ppb) | Frequency                         | Maximum Conc (ppb) | Average Conc (ppb) | Frequency    | Maximum Conc (ppb) | Average Conc (ppb) | Frequency                    | Maximum Conc (ppb) | Average Conc (ppb) | Frequency | Maximum Conc (ppb) | Average Conc (ppb) |
| 1,1-Dichloroethylene        | C     | 0 / 10                            |                    |                    | 0 / 33                            |                    |                    | 1 / 16       | 120.0              | 120.0              |                              |                    |                    | 0 / 2     |                    |                    |
| 1,2-Dichloroethane          | C     | 0 / 10                            |                    |                    | 0 / 33                            |                    |                    | 0 / 16       |                    |                    |                              |                    |                    | 0 / 2     |                    |                    |
| 2,3,7,8-TCDD                | C     | 1 / 7                             | 0.4                | 0.4                | 0 / 0                             |                    |                    | 0 / 0        |                    |                    |                              |                    |                    | 0 / 2     |                    |                    |
| 4,4'-DDD                    | C     | 10 / 14                           | 330000.0           | 63229.6            | 28 / 33                           | 170000.0           | 13806.2            | 5 / 16       | 1.1                | 0.5                |                              |                    |                    | 0 / 2     |                    |                    |
| 4,4'-DDE                    | C     | 6 / 14                            | 10816.0            | 1814.9             | 13 / 33                           | 15000.0            | 1873.3             | 2 / 16       | 0.1                | 0.1                |                              |                    |                    | 1 / 2     | 1.8                | 1.8                |
| 4,4'-DDT                    | C     | 8 / 14                            | 2900000.0          | 380166.7           | 10 / 33                           | 62000.0            | 9864.5             | 4 / 16       | 0.2                | 0.1                | Not Applicable for this zone |                    |                    | 0 / 2     |                    |                    |
| Aldrin                      | C     | 1 / 10                            | 8.7                | 8.7                | 1 / 33                            | 4.2                | 4.2                | 0 / 16       |                    |                    |                              |                    |                    | 0 / 2     |                    |                    |
| Arsenic                     | C     | 10 / 10                           | 60000.0            | 12880.0            | 25 / 33                           | 433000.0           | 53473.6            | 12 / 16      | 3850.0             | 1435.0             |                              |                    |                    | 2 / 2     | 2500.0             | 2050.0             |
| Benzene                     | C     | 0 / 10                            |                    |                    | 0 / 33                            |                    |                    | 7 / 16       | 290.0              | 149.9              |                              |                    |                    | 0 / 2     |                    |                    |
| Benzidine                   | C     | 0 / 10                            |                    |                    | 0 / 33                            |                    |                    | 1 / 16       | 1000.0             | 1000.0             |                              |                    |                    | 0 / 2     |                    |                    |
| Benzo(a)pyrene              | C     | 0 / 10                            |                    |                    | 0 / 33                            |                    |                    | 0 / 16       |                    |                    |                              |                    |                    | 0 / 2     |                    |                    |
| Beryllium                   | C     | 10 / 10                           | 410.0              | 195.0              | 22 / 33                           | 370.0              | 201.4              | 1 / 16       | 0.3                | 0.3                |                              |                    |                    | 0 / 2     |                    |                    |
| BHC-alpha                   | C     | 2 / 10                            | 261.0              | 131.6              | 0 / 33                            |                    |                    | 2 / 16       | 0.8                | 0.5                |                              |                    |                    | 0 / 2     |                    |                    |
| BHC-beta                    | C     | 1 / 10                            | 95.7               | 95.7               | 0 / 33                            |                    |                    | 3 / 16       | 0.4                | 0.3                |                              |                    |                    | 1 / 2     | 5.3                | 5.3                |
| BHC-delta                   | C     | 1 / 10                            | 95.7               | 95.7               | 1 / 33                            | 79.3               | 79.3               | 4 / 16       | 0.1                | 0.1                |                              |                    |                    | 2 / 2     | 65.0               | 39.2               |
| BHC-gamma (Lindane)         | C     | 0 / 10                            |                    |                    | 9 / 33                            | 2300.0             | 658.5              | 3 / 16       | 0.5                | 0.3                |                              |                    |                    | 0 / 2     |                    |                    |
| Cadmium                     | C     | 8 / 10                            | 130.0              | 77.0               | 13 / 33                           | 3400.0             | 879.4              | 6 / 16       | 23.0               | 9.3                |                              |                    |                    | 2 / 2     | 560.0              | 375.0              |
| Chlordane                   | C     | 7 / 14                            | 170000.0           | 30131.2            | 18 / 33                           | 1200000.0          | 75337.0            | 4 / 16       | 0.5                | 0.5                |                              |                    |                    | 0 / 2     |                    |                    |
| Chloroform                  | C     | 0 / 10                            |                    |                    | 1 / 33                            | 150.0              | 150.0              | 1 / 16       | 5.0                | 5.0                |                              |                    |                    | 0 / 2     |                    |                    |
| Dieldrin                    | C     | 11 / 14                           | 36000.0            | 3978.6             | 17 / 33                           | 8600.0             | 1540.4             | 4 / 16       | 1.8                | 0.6                |                              |                    |                    | 0 / 2     |                    |                    |
| Heptachlor                  | C     | 0 / 10                            |                    |                    | 1 / 33                            | 5.5                | 5.5                | 0 / 16       |                    |                    |                              |                    |                    | 0 / 2     |                    |                    |
| Heptachlor Epoxide          | C     | 0 / 10                            |                    |                    | 2 / 33                            | 7200.0             | 6400.0             | 1 / 16       | 0.0                | 0.0                |                              |                    |                    | 0 / 2     |                    |                    |
| Nickel                      | C     | 10 / 10                           | 25000.0            | 4575.0             | 32 / 33                           | 38000.0            | 5875.0             | 3 / 16       | 27.0               | 24.3               |                              |                    |                    | 1 / 2     | 2300.0             | 2300.0             |
| Tetrachloroethylene         | C     | 0 / 10                            |                    |                    | 3 / 33                            | 11000.0            | 4010.0             | 1 / 16       | 14.0               | 14.0               |                              |                    |                    | 0 / 2     |                    |                    |
| Trichloroethylene           | C     | 1 / 10                            | 17.0               | 17.0               | 0 / 33                            |                    |                    | 2 / 16       | 54.0               | 31.3               |                              |                    |                    | 0 / 2     |                    |                    |
| Vinyl chloride              | C     | 0 / 10                            |                    |                    | 0 / 33                            |                    |                    | 4 / 16       | 160.0              | 104.8              |                              |                    |                    | 0 / 2     |                    |                    |
| 1,2-trans-Dichloroethylene  | NC    | 0 / 10                            |                    |                    | 0 / 33                            |                    |                    | 5 / 16       | 1800.0             | 603.2              |                              |                    |                    | 0 / 2     |                    |                    |
| 1,3-trans-Dichloropropylene | NC    | 0 / 10                            |                    |                    | 0 / 33                            |                    |                    | 0 / 16       |                    |                    |                              |                    |                    | 0 / 2     |                    |                    |
| 2-Butanone                  | NC    | 0 / 10                            |                    |                    | 10 / 33                           | 37000.0            | 7644.6             | 4 / 16       | 200.0              | 102.5              |                              |                    |                    | 0 / 2     |                    |                    |
| Barium                      | NC    | 10 / 10                           | 64000.0            | 16060.0            | 33 / 33                           | 36000.0            | 18034.8            | 6 / 16       | 165.0              | 91.2               |                              |                    |                    | 2 / 2     | 7400.0             | 6950.0             |
| Ethylbenzene                | NC    | 2 / 10                            | 35.0               | 20.0               | 8 / 33                            | 160000.0           | 26275.6            | 8 / 16       | 1100.0             | 503.4              |                              |                    |                    | 0 / 2     |                    |                    |
| Fluoranthene                | NC    | 1 / 10                            | 10.0               | 10.0               | 7 / 33                            | 14000.0            | 4317.1             | 0 / 16       |                    |                    |                              |                    |                    | 0 / 2     |                    |                    |
| Lead                        | NC    | 10 / 10                           | 14400.0            | 7360.0             | 33 / 33                           | 48000.0            | 8557.3             | 9 / 16       | 74.0               | 26.0               |                              |                    |                    | 2 / 2     | 9200.0             | 6300.0             |
| Silver                      | NC    | 5 / 10                            | 3000.0             | 780.0              | 5 / 33                            | 2300.0             | 1860.0             | 2 / 16       | 3.1                | 3.1                |                              |                    |                    | 0 / 2     |                    |                    |
| Toluene                     | NC    | 3 / 10                            | 7.0                | 5.7                | 11 / 33                           | 8400.0             | 1714.2             | 7 / 16       | 1500.0             | 617.3              |                              |                    |                    | 0 / 2     |                    |                    |
| Xylenes (Tot) (tech)        | NC    | 3 / 10                            | 20.0               | 17.0               | 14 / 33                           | 750000.0           | 75597.4            | 7 / 16       | 4700.0             | 1986.4             |                              |                    |                    | 0 / 2     |                    |                    |
| Zinc                        | NC    | 10 / 10                           | 63000.0            | 18600.0            | 26 / 33                           | 71000.0            | 29592.3            | 12 / 16      | 230.0              | 67.4               |                              |                    |                    | 2 / 2     | 14000.0            | 14000.0            |
| Total Other PAHs            | SC    | 6 / 10                            | 27976.0            | 6334.3             | 19 / 33                           | 1654000.0          | 332951.4           | 10 / 16      | 10900.0            | 4793.5             |                              |                    |                    | 2 / 2     | 96210.0            | 52329.0            |
| Dibenzofuran                | SC1   | 3 / 10                            | 400.0              | 270.0              | 14 / 33                           | 57000.0            | 22347.1            | 4 / 16       | 1000.0             | 338.3              |                              |                    |                    | 1 / 2     | 10.0               | 10.0               |

TABLE 1-3

## SUMMARY OF RI ANALYTICAL DATA FOR CRITICAL CONTAMINANTS IN ZONE 3

| Compound                    | Group | (-- Surface Soils (to 4 feet) --) |                    |                    | (-- Deep Soils (below 4 feet) --) |                    |                    | (----- Ground Water -----) |                    |                    | (----- Surface Water -----) |                    |                    | (----- Sediments -----) |                    |                    |
|-----------------------------|-------|-----------------------------------|--------------------|--------------------|-----------------------------------|--------------------|--------------------|----------------------------|--------------------|--------------------|-----------------------------|--------------------|--------------------|-------------------------|--------------------|--------------------|
|                             |       | Frequency                         | Maximum Conc (ppb) | Average Conc (ppb) | Frequency                         | Maximum Conc (ppb) | Average Conc (ppb) | Frequency                  | Maximum Conc (ppb) | Average Conc (ppb) | Frequency                   | Maximum Conc (ppb) | Average Conc (ppb) | Frequency               | Maximum Conc (ppb) | Average Conc (ppb) |
| 1,1-Dichloroethylene        | C     | 0 / 23                            |                    |                    | 0 / 33                            |                    |                    | 0 / 11                     |                    |                    | 0 / 2                       |                    |                    | 0 / 4                   |                    |                    |
| 1,2-Dichloroethane          | C     | 0 / 23                            |                    |                    | 0 / 33                            |                    |                    | 0 / 11                     |                    |                    | 0 / 2                       |                    |                    | 0 / 4                   |                    |                    |
| 2,3,7,8-TCDD                | C     | 13 / 26                           | 27.8               | 4.8                | 0 / 0                             |                    |                    | 0 / 0                      |                    |                    | 0 / 0                       |                    |                    | 0 / 4                   |                    |                    |
| 4,4'-DDD                    | C     | 28 / 39                           | 490000.0           | 54535.2            | 21 / 33                           | 28000.0            | 1542.9             | 8 / 11                     | 120.0              | 16.6               | 0 / 2                       |                    |                    | 2 / 4                   | 110000.0           | 55019.7            |
| 4,4'-DDE                    | C     | 21 / 39                           | 38000.0            | 6408.4             | 11 / 33                           | 1600.0             | 238.9              | 4 / 11                     | 9.8                | 2.9                | 0 / 2                       |                    |                    | 1 / 4                   | 8180.0             | 8180.0             |
| 4,4'-DDT                    | C     | 30 / 39                           | 630000.0           | 67629.8            | 18 / 33                           | 16000.0            | 1715.5             | 5 / 11                     | 10.0               | 4.4                | 0 / 2                       |                    |                    | 3 / 4                   | 183000.0           | 61017.9            |
| Aldrin                      | C     | 0 / 23                            |                    |                    | 0 / 33                            |                    |                    | 0 / 11                     |                    |                    | 0 / 2                       |                    |                    | 0 / 4                   |                    |                    |
| Arsenic                     | C     | 21 / 23                           | 5700000.0          | 438057.1           | 17 / 33                           | 32000.0            | 10005.3            | 6 / 11                     | 3700.0             | 919.3              | 1 / 2                       | 87.0               | 87.0               | 3 / 4                   | 40000.0            | 14533.3            |
| Benzene                     | C     | 0 / 23                            |                    |                    | 0 / 33                            |                    |                    | 4 / 11                     | 12.0               | 5.3                | 0 / 2                       |                    |                    | 0 / 4                   |                    |                    |
| Benidine                    | C     | 0 / 23                            |                    |                    | 0 / 33                            |                    |                    | 0 / 11                     |                    |                    | 0 / 2                       |                    |                    | 0 / 4                   |                    |                    |
| Benzo(a)pyrene              | C     | 6 / 23                            | 4000.0             | 1473.3             | 1 / 33                            | 1140.0             | 1140.0             | 1 / 11                     | 27.0               | 27.0               | 0 / 2                       |                    |                    | 1 / 4                   | 2160.0             | 2160.0             |
| Beryllium                   | C     | 14 / 23                           | 1400.0             | 588.6              | 27 / 33                           | 840.0              | 401.1              | 1 / 11                     | 0.3                | 0.3                | 0 / 2                       |                    |                    | 3 / 4                   | 470.0              | 393.3              |
| BHC-alpha                   | C     | 0 / 23                            |                    |                    | 0 / 33                            |                    |                    | 2 / 11                     | 0.4                | 0.2                | 0 / 2                       |                    |                    | 0 / 4                   |                    |                    |
| BHC-beta                    | C     | 1 / 23                            | 167.0              | 167.0              | 0 / 33                            |                    |                    | 3 / 11                     | 4.3                | 2.4                | 0 / 2                       |                    |                    | 0 / 4                   |                    |                    |
| BHC-delta                   | C     | 0 / 23                            |                    |                    | 1 / 33                            | 15.7               | 15.7               | 3 / 11                     | 2.4                | 1.3                | 0 / 2                       |                    |                    | 0 / 4                   |                    |                    |
| BHC-gamma (Lindane)         | C     | 3 / 23                            | 13.0               | 7.2                | 0 / 33                            |                    |                    | 3 / 11                     | 0.8                | 0.3                | 0 / 2                       |                    |                    | 0 / 4                   |                    |                    |
| Cadeiaa                     | C     | 14 / 23                           | 45000.0            | 5480.9             | 3 / 33                            | 28000.0            | 9412.3             | 3 / 11                     | 140.0              | 51.4               | 0 / 2                       |                    |                    | 3 / 4                   | 750.0              | 346.7              |
| Chlordane                   | C     | 28 / 39                           | 730000.0           | 116810.4           | 17 / 33                           | 49000.0            | 3417.9             | 8 / 11                     | 48.0               | 11.3               | 0 / 2                       |                    |                    | 1 / 4                   | 44600.0            | 44600.0            |
| Chlorofora                  | C     | 0 / 23                            |                    |                    | 0 / 33                            |                    |                    | 0 / 11                     |                    |                    | 0 / 2                       |                    |                    | 0 / 4                   |                    |                    |
| Dieldrin                    | C     | 24 / 39                           | 26184.0            | 4109.7             | 10 / 33                           | 1600.0             | 173.5              | 4 / 11                     | 2.4                | 1.4                | 0 / 2                       |                    |                    | 0 / 4                   |                    |                    |
| Heptachlor                  | C     | 0 / 23                            |                    |                    | 0 / 33                            |                    |                    | 1 / 11                     | 0.0                | 0.0                | 0 / 2                       |                    |                    | 0 / 4                   |                    |                    |
| Heptachlor Epoxide          | C     | 1 / 23                            | 12.0               | 12.0               | 0 / 33                            |                    |                    | 2 / 11                     | 2.8                | 1.8                | 0 / 2                       |                    |                    | 0 / 4                   |                    |                    |
| Nickel                      | C     | 21 / 23                           | 38000.0            | 11852.4            | 31 / 33                           | 54000.0            | 9145.2             | 3 / 11                     | 27.0               | 22.0               | 0 / 2                       |                    |                    | 3 / 4                   | 17000.0            | 10066.7            |
| Tetrachloroethylene         | C     | 1 / 23                            | 5.0                | 5.0                | 0 / 33                            |                    |                    | 0 / 11                     |                    |                    | 0 / 2                       |                    |                    | 0 / 4                   |                    |                    |
| Trichloroethylene           | C     | 1 / 23                            | 10.0               | 10.0               | 0 / 33                            |                    |                    | 2 / 11                     | 2.0                | 2.0                | 0 / 2                       |                    |                    | 0 / 4                   |                    |                    |
| Vinyl chloride              | C     | 0 / 23                            |                    |                    | 0 / 33                            |                    |                    | 1 / 11                     | 15.0               | 15.0               | 0 / 2                       |                    |                    | 0 / 4                   |                    |                    |
| 1,2-trans-Dichloroethylene  | NC    | 0 / 23                            |                    |                    | 0 / 33                            |                    |                    | 4 / 11                     | 14.0               | 7.5                | 0 / 2                       |                    |                    | 0 / 4                   |                    |                    |
| 1,3-trans-Dichloropropylene | NC    | 0 / 23                            |                    |                    | 0 / 33                            |                    |                    | 0 / 11                     |                    |                    | 0 / 2                       |                    |                    | 0 / 4                   |                    |                    |
| 2-Butanone                  | NC    | 0 / 23                            |                    |                    | 0 / 33                            |                    |                    | 5 / 11                     | 20.0               | 12.2               | 0 / 2                       |                    |                    | 1 / 4                   | 19.0               | 19.0               |
| Barium                      | NC    | 23 / 23                           | 403000.0           | 72608.7            | 32 / 33                           | 68000.0            | 21368.8            | 5 / 11                     | 230.0              | 71.2               | 0 / 2                       |                    |                    | 4 / 4                   | 64000.0            | 41500.0            |
| Ethylbenzene                | NC    | 2 / 23                            | 19.0               | 12.0               | 2 / 33                            | 3915.0             | 2497.5             | 2 / 11                     | 32.0               | 17.5               | 0 / 2                       |                    |                    | 0 / 4                   |                    |                    |
| Fluoranthene                | NC    | 14 / 23                           | 169606.0           | 20738.3            | 2 / 33                            | 1580.0             | 1485.0             | 1 / 11                     | 172.0              | 172.0              | 0 / 2                       |                    |                    | 1 / 4                   | 1080.0             | 1080.0             |
| Lead                        | NC    | 23 / 23                           | 3710000.0          | 268617.4           | 31 / 33                           | 42000.0            | 8129.0             | 4 / 11                     | 37.0               | 21.2               | 0 / 2                       |                    |                    | 4 / 4                   | 20000.0            | 9600.0             |
| Silver                      | NC    | 5 / 23                            | 35000.0            | 8260.0             | 3 / 33                            | 2000.0             | 1560.0             | 0 / 11                     |                    |                    | 0 / 2                       |                    |                    | 1 / 4                   | 50.0               | 50.0               |
| Toluene                     | NC    | 2 / 23                            | 10.0               | 7.5                | 0 / 33                            |                    |                    | 3 / 11                     | 5.0                | 4.0                | 0 / 2                       |                    |                    | 0 / 4                   |                    |                    |
| Xylenes (Tot) (tech)        | NC    | 0 / 23                            |                    |                    | 2 / 33                            | 38366.0            | 23805.5            | 2 / 11                     | 16.0               | 11.0               | 0 / 2                       |                    |                    | 1 / 4                   | 6.0                | 6.0                |
| Zinc                        | NC    | 23 / 23                           | 54000000.0         | 2507695.7          | 33 / 33                           | 120000.0           | 40030.3            | 9 / 11                     | 210.0              | 53.6               | 0 / 2                       |                    |                    | 4 / 4                   | 200000.0           | 86500.0            |
| Total Other PAHs            | SC    | 14 / 23                           | 49300.0            | 11364.4            | 5 / 33                            | 12991.0            | 3840.2             | 2 / 11                     | 752.0              | 381.0              | 0 / 2                       |                    |                    | 1 / 4                   | 19440.0            | 19440.0            |
| Dibenzofuran                | SCI   | 3 / 23                            | 1200.0             | 443.3              | 0 / 33                            |                    |                    | 1 / 11                     | 27.0               | 27.0               | 0 / 2                       |                    |                    | 0 / 4                   |                    |                    |

TABLE 1-4

## SUMMARY OF RI ANALYTICAL DATA FOR CRITICAL CONTAMINANTS IN ZONE 4 NORTH

| Compound                    | Group | (-- Surface Soils (to 4 feet) --) |                    |                    | (-- Deep Soils (below 4 feet) --) |                    |                    | Ground Water |                    |                    | Surface Water                |                    |                    | Sediments                    |                    |                    |
|-----------------------------|-------|-----------------------------------|--------------------|--------------------|-----------------------------------|--------------------|--------------------|--------------|--------------------|--------------------|------------------------------|--------------------|--------------------|------------------------------|--------------------|--------------------|
|                             |       | Frequency                         | Maximum Conc (ppb) | Average Conc (ppb) | Frequency                         | Maximum Conc (ppb) | Average Conc (ppb) | Frequency    | Maximum Conc (ppb) | Average Conc (ppb) | Frequency                    | Maximum Conc (ppb) | Average Conc (ppb) | Frequency                    | Maximum Conc (ppb) | Average Conc (ppb) |
| 1,1-Dichloroethylene        | C     | 0 / 7                             |                    |                    | 0 / 16                            |                    |                    | 0 / 6        |                    |                    |                              |                    |                    |                              |                    |                    |
| 1,2-Dichloroethane          | C     | 0 / 7                             |                    |                    | 0 / 16                            |                    |                    | 0 / 6        |                    |                    |                              |                    |                    |                              |                    |                    |
| 2,3,7,8-TCDD                | C     | 11 / 27                           | 48.0               | 6.9                | 0 / 0                             |                    |                    | 0 / 0        |                    |                    |                              |                    |                    |                              |                    |                    |
| 4,4'-DDD                    | C     | 22 / 28                           | 1100000.0          | 70496.7            | 12 / 16                           | 5600.0             | 766.2              | 2 / 6        |                    | 0.3                |                              | 0.2                |                    |                              |                    |                    |
| 4,4'-DDE                    | C     | 16 / 28                           | 47000.0            | 6307.8             | 9 / 16                            | 540.0              | 68.9               | 1 / 6        |                    | 0.2                |                              | 0.2                |                    |                              |                    |                    |
| 4,4'-DDT                    | C     | 12 / 28                           | 22000.0            | 5895.2             | 9 / 16                            | 2900.0             | 379.6              | 2 / 6        |                    | 1.1                |                              | 0.6                |                    |                              |                    |                    |
| Aldrin                      | C     | 0 / 7                             |                    |                    | 0 / 16                            |                    |                    | 0 / 6        |                    |                    | Not Applicable for this zone |                    |                    | Not Applicable for this zone |                    |                    |
| Arsenic                     | C     | 7 / 7                             | 1000000.0          | 190557.1           | 15 / 16                           | 32000.0            | 11160.0            | 0 / 6        |                    |                    |                              |                    |                    |                              |                    |                    |
| Benzene                     | C     | 0 / 7                             |                    |                    | 0 / 16                            |                    |                    | 0 / 6        |                    |                    |                              |                    |                    |                              |                    |                    |
| Benzidine                   | C     | 0 / 7                             |                    |                    | 0 / 16                            |                    |                    | 0 / 6        |                    |                    |                              |                    |                    |                              |                    |                    |
| Benzo(a)pyrene              | C     | 0 / 7                             |                    |                    | 0 / 16                            |                    |                    | 0 / 6        |                    |                    |                              |                    |                    |                              |                    |                    |
| Beryllium                   | C     | 7 / 7                             | 2000.0             | 932.9              | 16 / 16                           | 590.0              | 415.0              | 0 / 6        |                    |                    |                              |                    |                    |                              |                    |                    |
| BHC-alpha                   | C     | 0 / 7                             |                    |                    | 0 / 16                            |                    |                    | 1 / 6        |                    | 1.8                |                              | 1.8                |                    |                              |                    |                    |
| BHC-beta                    | C     | 0 / 7                             |                    |                    | 0 / 16                            |                    |                    | 1 / 6        |                    | 1.8                |                              | 1.8                |                    |                              |                    |                    |
| BHC-delta                   | C     | 0 / 7                             |                    |                    | 0 / 16                            |                    |                    | 0 / 6        |                    |                    |                              |                    |                    |                              |                    |                    |
| BHC-gamma (Lindane)         | C     | 0 / 7                             |                    |                    | 0 / 16                            |                    |                    | 1 / 6        |                    | 4.2                |                              | 4.2                |                    |                              |                    |                    |
| Cadmium                     | C     | 3 / 7                             | 13000.0            | 5316.7             | 3 / 16                            | 2600.0             | 916.0              | 0 / 6        |                    |                    |                              |                    |                    |                              |                    |                    |
| Chlordane                   | C     | 15 / 28                           | 1700000.0          | 229438.9           | 12 / 16                           | 8800.0             | 1199.8             | 1 / 6        |                    | 0.1                |                              | 0.1                |                    |                              |                    |                    |
| Chloroform                  | C     | 0 / 7                             |                    |                    | 0 / 16                            |                    |                    | 0 / 6        |                    |                    |                              |                    |                    |                              |                    |                    |
| Dieldrin                    | C     | 16 / 28                           | 32000.0            | 3483.1             | 9 / 16                            | 360.0              | 44.2               | 1 / 6        |                    | 0.0                |                              | 0.0                |                    |                              |                    |                    |
| Heptachlor                  | C     | 0 / 7                             |                    |                    | 0 / 16                            |                    |                    | 0 / 6        |                    |                    |                              |                    |                    |                              |                    |                    |
| Heptachlor Epoxide          | C     | 0 / 7                             |                    |                    | 0 / 16                            |                    |                    | 0 / 6        |                    |                    |                              |                    |                    |                              |                    |                    |
| Nickel                      | C     | 7 / 7                             | 25000.0            | 12157.1            | 15 / 16                           | 14000.0            | 7066.7             | 2 / 6        |                    | 18.0               |                              | 17.0               |                    |                              |                    |                    |
| Tetrachloroethylene         | C     | 0 / 7                             |                    |                    | 0 / 16                            |                    |                    | 0 / 6        |                    |                    |                              |                    |                    |                              |                    |                    |
| Trichloroethylene           | C     | 0 / 7                             |                    |                    | 0 / 16                            |                    |                    | 2 / 6        |                    | 5.0                |                              | 5.0                |                    |                              |                    |                    |
| Vinyl chloride              | C     | 0 / 7                             |                    |                    | 0 / 16                            |                    |                    | 1 / 6        |                    | 10.0               |                              | 10.0               |                    |                              |                    |                    |
| 1,2-trans-Dichloroethylene  | NC    | 0 / 7                             |                    |                    | 0 / 16                            |                    |                    | 1 / 6        |                    | 50.0               |                              | 50.0               |                    |                              |                    |                    |
| 1,3-trans-Dichloropropylene | NC    | 0 / 7                             |                    |                    | 0 / 16                            |                    |                    | 0 / 6        |                    |                    |                              |                    |                    |                              |                    |                    |
| 2-Butanone                  | NC    | 0 / 7                             |                    |                    | 0 / 16                            |                    |                    | 1 / 6        |                    | 100.0              |                              | 100.0              |                    |                              |                    |                    |
| Barium                      | NC    | 7 / 7                             | 498000.0           | 137142.9           | 16 / 16                           | 37000.0            | 21000.0            | 5 / 6        |                    | 57.0               |                              | 36.6               |                    |                              |                    |                    |
| Ethylbenzene                | NC    | 0 / 7                             |                    |                    | 0 / 16                            |                    |                    | 1 / 6        |                    | 110.0              |                              | 110.0              |                    |                              |                    |                    |
| Fluoranthene                | NC    | 2 / 7                             | 4500.0             | 2255.0             | 0 / 16                            |                    |                    | 0 / 6        |                    |                    |                              |                    |                    |                              |                    |                    |
| Lead                        | NC    | 7 / 7                             | 721000.0           | 174428.6           | 16 / 16                           | 24000.0            | 6906.3             | 2 / 6        |                    | 27800.0            |                              | 13902.1            |                    |                              |                    |                    |
| Silver                      | NC    | 1 / 7                             | 200.0              | 200.0              | 0 / 16                            |                    |                    | 0 / 6        |                    |                    |                              |                    |                    |                              |                    |                    |
| Toluene                     | NC    | 0 / 7                             |                    |                    | 0 / 16                            |                    |                    | 1 / 6        |                    | 8.7                |                              | 8.7                |                    |                              |                    |                    |
| Xylenes (Tot) (tech)        | NC    | 0 / 7                             |                    |                    | 0 / 16                            |                    |                    | 1 / 6        |                    | 5.0                |                              | 5.0                |                    |                              |                    |                    |
| Zinc                        | NC    | 7 / 7                             | 354000.0           | 115000.0           | 16 / 16                           | 55000.0            | 36125.0            | 5 / 6        |                    | 103.0              |                              | 36.1               |                    |                              |                    |                    |
| Total Other PAHs            | SC    | 2 / 7                             | 21900.0            | 10965.0            | 1 / 16                            | 200.0              | 200.0              | 1 / 6        |                    | 20.0               |                              | 20.0               |                    |                              |                    |                    |
| Dibenzofuran                | SCI   | 0 / 7                             |                    |                    | 0 / 16                            |                    |                    | 0 / 6        |                    |                    |                              |                    |                    |                              |                    |                    |



TABLE 1-5

## SUMMARY OF ANALYTICAL DATA FOR CRITICAL CONTAMINANTS IN ZONE 4 SOUTH

| Compound                    | Group | (-- Surface Soils (to 4 feet) --) |                    |                    | (-- Deep Soils (below 4 feet) --) |                    |                    | Ground Water |                    |                    | Surface Water                |                    |                    | Sediments                    |                    |                    |
|-----------------------------|-------|-----------------------------------|--------------------|--------------------|-----------------------------------|--------------------|--------------------|--------------|--------------------|--------------------|------------------------------|--------------------|--------------------|------------------------------|--------------------|--------------------|
|                             |       | Frequency                         | Maximum Conc (ppb) | Average Conc (ppb) | Frequency                         | Maximum Conc (ppb) | Average Conc (ppb) | Frequency    | Maximum Conc (ppb) | Average Conc (ppb) | Frequency                    | Maximum Conc (ppb) | Average Conc (ppb) | Frequency                    | Maximum Conc (ppb) | Average Conc (ppb) |
| 1,1-Dichloroethylene        | C     | 0 / 15                            |                    |                    | 0 / 28                            |                    |                    | 1 / 8        | 5.0                | 5.0                |                              |                    |                    |                              |                    |                    |
| 1,2-Dichloroethane          | C     | 0 / 15                            |                    |                    | 0 / 28                            |                    |                    | 1 / 8        | 5.0                | 5.0                |                              |                    |                    |                              |                    |                    |
| 2,3,7,8-TCDD                | C     | 0 / 9                             |                    |                    | 0 / 0                             |                    |                    | 0 / 0        |                    |                    |                              |                    |                    |                              |                    |                    |
| 4,4'-DDD                    | C     | 12 / 15                           | 13000.0            | 16984.6            | 14 / 28                           | 4100.0             | 624.0              | 3 / 8        | 0.7                | 0.3                |                              |                    |                    |                              |                    |                    |
| 4,4'-DDE                    | C     | 12 / 15                           | 11000.0            | 2072.6             | 8 / 28                            | 500.0              | 144.8              | 1 / 8        | 0.1                | 0.1                |                              |                    |                    |                              |                    |                    |
| 4,4'-DDT                    | C     | 15 / 15                           | 260000.0           | 27031.8            | 9 / 28                            | 22000.0            | 2713.7             | 2 / 8        | 0.1                | 0.1                |                              |                    |                    |                              |                    |                    |
| Aldrin                      | C     | 0 / 15                            |                    |                    | 0 / 28                            |                    |                    | 0 / 8        |                    |                    | Not Applicable for this zone |                    |                    | Not Applicable for this zone |                    |                    |
| Arsenic                     | C     | 14 / 15                           | 70000.0            | 24950.0            | 9 / 28                            | 37000.0            | 12400.0            | 1 / 8        | 4.4                | 4.4                |                              |                    |                    |                              |                    |                    |
| Benzene                     | C     | 0 / 15                            |                    |                    | 0 / 28                            |                    |                    | 2 / 8        | 1.0                | 1.0                |                              |                    |                    |                              |                    |                    |
| Benidine                    | C     | 0 / 15                            |                    |                    | 0 / 28                            |                    |                    | 0 / 8        |                    |                    |                              |                    |                    |                              |                    |                    |
| Benz(a)pyrene               | C     | 1 / 15                            | 18000.0            | 18000.0            | 0 / 28                            |                    |                    | 0 / 8        |                    |                    |                              |                    |                    |                              |                    |                    |
| Beryllium                   | C     | 13 / 15                           | 2300.0             | 1142.3             | 20 / 28                           | 750.0              | 386.5              | 0 / 8        |                    |                    |                              |                    |                    |                              |                    |                    |
| BHC-alpha                   | C     | 0 / 15                            |                    |                    | 0 / 28                            |                    |                    | 1 / 8        | 0.0                | 0.0                |                              |                    |                    |                              |                    |                    |
| BHC-beta                    | C     | 1 / 15                            | 0.0                | 0.0                | 0 / 28                            |                    |                    | 0 / 8        |                    |                    |                              |                    |                    |                              |                    |                    |
| BHC-delta                   | C     | 0 / 15                            |                    |                    | 0 / 28                            |                    |                    | 0 / 8        |                    |                    |                              |                    |                    |                              |                    |                    |
| BHC-gamma (Lindane)         | C     | 0 / 15                            |                    |                    | 0 / 28                            |                    |                    | 0 / 8        |                    |                    |                              |                    |                    |                              |                    |                    |
| Cadeina                     | C     | 2 / 15                            | 120.0              | 95.0               | 1 / 28                            | 620.0              | 620.0              | 4 / 8        | 28.0               | 15.3               |                              |                    |                    |                              |                    |                    |
| Chlordane                   | C     | 6 / 15                            | 17000.0            | 3889.3             | 7 / 28                            | 1800.0             | 339.3              | 1 / 8        | 0.6                | 0.6                |                              |                    |                    |                              |                    |                    |
| Chloroform                  | C     | 0 / 15                            |                    |                    | 0 / 28                            |                    |                    | 0 / 8        |                    |                    |                              |                    |                    |                              |                    |                    |
| Dieldrin                    | C     | 4 / 15                            | 1200.0             | 303.0              | 0 / 28                            |                    |                    | 0 / 8        |                    |                    |                              |                    |                    |                              |                    |                    |
| Heptachlor                  | C     | 0 / 15                            |                    |                    | 0 / 28                            |                    |                    | 0 / 8        |                    |                    |                              |                    |                    |                              |                    |                    |
| Heptachlor Epoxide          | C     | 1 / 15                            | 0.0                | 0.0                | 0 / 28                            |                    |                    | 0 / 8        |                    |                    |                              |                    |                    |                              |                    |                    |
| Nickel                      | C     | 10 / 15                           | 113000.0           | 19765.0            | 20 / 28                           | 9500.0             | 5865.0             | 0 / 8        |                    |                    |                              |                    |                    |                              |                    |                    |
| Tetrachloroethylene         | C     | 0 / 15                            |                    |                    | 0 / 28                            |                    |                    | 0 / 8        |                    |                    |                              |                    |                    |                              |                    |                    |
| Trichloroethylene           | C     | 0 / 15                            |                    |                    | 0 / 28                            |                    |                    | 3 / 8        | 5.0                | 4.7                |                              |                    |                    |                              |                    |                    |
| Vinyl chloride              | C     | 0 / 15                            |                    |                    | 0 / 28                            |                    |                    | 2 / 8        | 4.0                | 4.0                |                              |                    |                    |                              |                    |                    |
| 1,2-trans-Dichloroethylene  | NC    | 1 / 15                            | 46.0               | 46.0               | 0 / 28                            |                    |                    | 7 / 8        | 14.0               | 6.3                |                              |                    |                    |                              |                    |                    |
| 1,3-trans-Dichloropropylene | NC    | 0 / 15                            |                    |                    | 0 / 28                            |                    |                    | 0 / 8        |                    |                    |                              |                    |                    |                              |                    |                    |
| 2-Butanone                  | NC    | 0 / 15                            |                    |                    | 0 / 28                            |                    |                    | 1 / 8        | 10.0               | 10.0               |                              |                    |                    |                              |                    |                    |
| Barium                      | NC    | 15 / 15                           | 175000.0           | 58813.3            | 27 / 28                           | 48000.0            | 14640.7            | 1 / 8        | 36.0               | 36.0               |                              |                    |                    |                              |                    |                    |
| Ethylbenzene                | NC    | 0 / 15                            |                    |                    | 0 / 28                            |                    |                    | 0 / 8        |                    |                    |                              |                    |                    |                              |                    |                    |
| Fluoranthene                | NC    | 3 / 15                            | 1400.0             | 1070.0             | 0 / 28                            |                    |                    | 0 / 8        |                    |                    |                              |                    |                    |                              |                    |                    |
| Lead                        | NC    | 15 / 15                           | 249000.0           | 85132.7            | 27 / 28                           | 78000.0            | 9481.5             | 3 / 8        | 20.0               | 16.5               |                              |                    |                    |                              |                    |                    |
| Silver                      | NC    | 2 / 15                            | 350.0              | 325.0              | 1 / 28                            | 2000.0             | 2000.0             | 1 / 8        | 14.0               | 14.0               |                              |                    |                    |                              |                    |                    |
| Toluene                     | NC    | 1 / 15                            | 92.0               | 92.0               | 0 / 28                            |                    |                    | 2 / 8        | 35.0               | 34.5               |                              |                    |                    |                              |                    |                    |
| Xylenes (Tot) (tech)        | NC    | 2 / 15                            | 33.0               | 22.5               | 0 / 28                            |                    |                    | 0 / 8        |                    |                    |                              |                    |                    |                              |                    |                    |
| Zinc                        | NC    | 15 / 15                           | 159000.0           | 59783.3            | 28 / 28                           | 53000.0            | 34750.0            | 8 / 8        | 72.0               | 47.1               |                              |                    |                    |                              |                    |                    |
| Total Other PAHs            | SC    | 4 / 15                            | 8820.0             | 4477.5             | 2 / 28                            | 2860.0             | 1430.0             | 0 / 8        |                    |                    |                              |                    |                    |                              |                    |                    |
| Dibenzofuran                | SC1   | 1 / 15                            | 1400.0             | 1400.0             | 1 / 28                            | 270.0              | 270.0              | 0 / 8        |                    |                    |                              |                    |                    |                              |                    |                    |

TABLE 1-6

## SUMMARY OF ANALYTICAL DATA FOR CRITICAL CONTAMINANTS IN ZONE 5

| Compound                    | Group | (-- Surface Soils (to 4 feet) --) |                    |                    | (-- Deep Soils (below 4 feet) --) |                    |                    | Ground Water |                    |                    | Surface Water |                    |                    | Sediments                    |                    |                              |
|-----------------------------|-------|-----------------------------------|--------------------|--------------------|-----------------------------------|--------------------|--------------------|--------------|--------------------|--------------------|---------------|--------------------|--------------------|------------------------------|--------------------|------------------------------|
|                             |       | Frequency                         | Maximum Conc (ppb) | Average Conc (ppb) | Frequency                         | Maximum Conc (ppb) | Average Conc (ppb) | Frequency    | Maximum Conc (ppb) | Average Conc (ppb) | Frequency     | Maximum Conc (ppb) | Average Conc (ppb) | Frequency                    | Maximum Conc (ppb) | Average Conc (ppb)           |
| 1,1-Dichloroethylene        | C     | 0 / 7                             |                    |                    | 0 / 10                            |                    |                    | 0 / 4        |                    |                    |               |                    |                    |                              |                    |                              |
| 1,2-Dichloroethane          | C     | 0 / 7                             |                    |                    | 0 / 10                            |                    |                    | 0 / 4        |                    |                    |               |                    |                    |                              |                    |                              |
| 2,3,7,8-TCDD                | C     | 1 / 2                             | 0.7                | 0.7                | 0 / 0                             |                    |                    | 0 / 0        |                    |                    |               |                    |                    |                              |                    |                              |
| 4,4'-DDD                    | C     | 4 / 7                             | 678.0              | 351.3              | 5 / 10                            | 3200.0             | 1381.9             | 1 / 4        | 12.0               | 12.0               |               |                    |                    |                              |                    |                              |
| 4,4'-DDE                    | C     | 4 / 7                             | 1900.0             | 537.9              | 5 / 10                            | 370.0              | 160.9              | 1 / 4        | 0.5                | 0.5                |               |                    |                    |                              |                    |                              |
| 4,4'-DDT                    | C     | 4 / 7                             | 1200.0             | 371.3              | 5 / 10                            | 500.0              | 207.3              | 1 / 4        | 1.0                | 1.0                |               |                    |                    |                              |                    |                              |
| Aldrin                      | C     | 1 / 7                             | 878.0              | 878.0              | 0 / 10                            |                    |                    | 0 / 4        |                    |                    |               |                    |                    | Not Applicable for this zone |                    | Not Applicable for this zone |
| Arsenic                     | C     | 7 / 7                             | 155000.0           | 33881.4            | 9 / 10                            | 155000.0           | 28855.6            | 0 / 4        |                    |                    |               |                    |                    |                              |                    |                              |
| Benzene                     | C     | 0 / 7                             |                    |                    | 0 / 10                            |                    |                    | 1 / 4        | 16.0               | 16.0               |               |                    |                    |                              |                    |                              |
| Benidine                    | C     | 0 / 7                             |                    |                    | 0 / 10                            |                    |                    | 0 / 4        |                    |                    |               |                    |                    |                              |                    |                              |
| Benzo(a)pyrene              | C     | 1 / 7                             | 260.0              | 260.0              | 0 / 10                            |                    |                    | 0 / 4        |                    |                    |               |                    |                    |                              |                    |                              |
| Beryllium                   | C     | 7 / 7                             | 750.0              | 422.9              | 4 / 10                            | 600.0              | 405.0              | 0 / 4        |                    |                    |               |                    |                    |                              |                    |                              |
| BHC-alpha                   | C     | 0 / 7                             |                    |                    | 0 / 10                            |                    |                    | 0 / 4        |                    |                    |               |                    |                    |                              |                    |                              |
| BHC-beta                    | C     | 1 / 7                             | 707.0              | 707.0              | 0 / 10                            |                    |                    | 1 / 4        | 0.1                | 0.1                |               |                    |                    |                              |                    |                              |
| BHC-delta                   | C     | 1 / 7                             | 598.0              | 598.0              | 0 / 10                            |                    |                    | 1 / 4        | 0.1                | 0.1                |               |                    |                    |                              |                    |                              |
| BHC-gamma (Lindane)         | C     | 0 / 7                             |                    |                    | 2 / 10                            | 11.0               | 5.9                | 1 / 4        | 0.1                | 0.1                |               |                    |                    |                              |                    |                              |
| Cadmium                     | C     | 2 / 7                             | 190.0              | 150.0              | 4 / 10                            | 2800.0             | 1010.7             | 2 / 4        | 28.0               | 18.1               |               |                    |                    |                              |                    |                              |
| Chlordane                   | C     | 3 / 7                             | 12000.0            | 4121.7             | 3 / 10                            | 980.0              | 462.7              | 1 / 4        | 0.6                | 0.6                |               |                    |                    |                              |                    |                              |
| Chloroform                  | C     | 0 / 7                             |                    |                    | 0 / 10                            |                    |                    | 1 / 4        | 5.0                | 5.0                |               |                    |                    |                              |                    |                              |
| Dieldrin                    | C     | 1 / 7                             | 116.0              | 116.0              | 1 / 10                            | 80.0               | 80.0               | 2 / 4        | 0.9                | 0.7                |               |                    |                    |                              |                    |                              |
| Heptachlor                  | C     | 0 / 7                             |                    |                    | 0 / 10                            |                    |                    | 0 / 4        |                    |                    |               |                    |                    |                              |                    |                              |
| Heptachlor Epoxide          | C     | 0 / 7                             |                    |                    | 0 / 10                            |                    |                    | 0 / 4        |                    |                    |               |                    |                    |                              |                    |                              |
| Nickel                      | C     | 7 / 7                             | 9100.0             | 6242.9             | 8 / 10                            | 8100.0             | 5325.0             | 0 / 4        |                    |                    |               |                    |                    |                              |                    |                              |
| Tetrachloroethylene         | C     | 0 / 7                             |                    |                    | 0 / 10                            |                    |                    | 0 / 4        |                    |                    |               |                    |                    |                              |                    |                              |
| Trichloroethylene           | C     | 0 / 7                             |                    |                    | 0 / 10                            |                    |                    | 1 / 4        | 5.0                | 5.0                |               |                    |                    |                              |                    |                              |
| Vinyl chloride              | C     | 0 / 7                             |                    |                    | 0 / 10                            |                    |                    | 0 / 4        |                    |                    |               |                    |                    |                              |                    |                              |
| 1,2-trans-Dichloroethylene  | NC    | 0 / 7                             |                    |                    | 0 / 10                            |                    |                    | 0 / 4        |                    |                    |               |                    |                    |                              |                    |                              |
| 1,3-trans-Dichloropropylene | NC    | 0 / 7                             |                    |                    | 0 / 10                            |                    |                    | 0 / 4        |                    |                    |               |                    |                    |                              |                    |                              |
| 2-Butanone                  | NC    | 0 / 7                             |                    |                    | 1 / 10                            | 8.0                | 8.0                | 1 / 4        | 10.0               | 10.0               |               |                    |                    |                              |                    |                              |
| Barium                      | NC    | 7 / 7                             | 87000.0            | 28614.3            | 9 / 10                            | 39000.0            | 18277.8            | 2 / 4        | 310.0              | 170.5              |               |                    |                    |                              |                    |                              |
| Ethylbenzene                | NC    | 0 / 7                             |                    |                    | 0 / 10                            |                    |                    | 0 / 4        |                    |                    |               |                    |                    |                              |                    |                              |
| Fluoranthene                | NC    | 2 / 7                             | 6000000.0          | 3000550.0          | 0 / 10                            |                    |                    | 0 / 4        |                    |                    |               |                    |                    |                              |                    |                              |
| Lead                        | NC    | 7 / 7                             | 24000.0            | 12885.7            | 9 / 10                            | 52000.0            | 10088.9            | 0 / 4        |                    |                    |               |                    |                    |                              |                    |                              |
| Silver                      | NC    | 1 / 7                             | 400.0              | 400.0              | 2 / 10                            | 1700.0             | 975.0              | 0 / 4        |                    |                    |               |                    |                    |                              |                    |                              |
| Toluene                     | NC    | 0 / 7                             |                    |                    | 1 / 10                            | 5.0                | 5.0                | 1 / 4        | 7.9                | 7.9                |               |                    |                    |                              |                    |                              |
| Xylenes (Tot) (tech)        | NC    | 0 / 7                             |                    |                    | 0 / 10                            |                    |                    | 0 / 4        |                    |                    |               |                    |                    |                              |                    |                              |
| Zinc                        | NC    | 7 / 7                             | 47000.0            | 35485.7            | 10 / 10                           | 50000.0            | 30100.0            | 4 / 4        | 110.0              | 66.3               |               |                    |                    |                              |                    |                              |
| Total Other PAHs            | SC    | 3 / 7                             | 12800000.0         | 4267860.0          | 1 / 10                            | 1330.0             | 1330.0             | 0 / 4        |                    |                    |               |                    |                    |                              |                    |                              |
| Dibenzofuran                | SCI   | 1 / 7                             | 10.0               | 10.0               | 0 / 10                            |                    |                    | 0 / 4        |                    |                    |               |                    |                    |                              |                    |                              |

ZONE 1-7

SUMMARY OF RI ANALYTICAL DATA FOR CRITICAL CONTAMINANTS IN ZONE 6

| Compound                    | Group | (-- Surface Soils (to 4 feet) --) |                    |                    | (-- Deep Soils (below 4 feet) --) |                    |                    | (----- Ground Water -----)      |                    |                       | (----- Surface Water -----) |                    |                    | (----- Sediments -----) |                    |                    |
|-----------------------------|-------|-----------------------------------|--------------------|--------------------|-----------------------------------|--------------------|--------------------|---------------------------------|--------------------|-----------------------|-----------------------------|--------------------|--------------------|-------------------------|--------------------|--------------------|
|                             |       | Frequency                         | Maximum Conc (ppb) | Average Conc (ppb) | Frequency                         | Maximum Conc (ppb) | Average Conc (ppb) | Frequency                       | Maximum Conc (ppb) | Average Det Lim (ppb) | Frequency                   | Maximum Conc (ppb) | Average Conc (ppb) | Frequency               | Maximum Conc (ppb) | Average Conc (ppb) |
| 1,1-Dichloroethylene        | C     | 0 / 2                             |                    |                    |                                   |                    |                    |                                 |                    |                       | 0 / 8                       |                    |                    | 0 / 18                  |                    |                    |
| 1,2-Dichloroethane          | C     | 0 / 2                             |                    |                    |                                   |                    |                    |                                 |                    |                       | 0 / 8                       |                    |                    | 0 / 18                  |                    |                    |
| 2,3,7,8-TCDD                | C     | 0 / 8                             |                    |                    |                                   |                    |                    |                                 |                    |                       | 0 / 8                       |                    |                    | 0 / 18                  |                    |                    |
| 4,4'-DDD                    | C     | 3 / 4                             | 350.0              | 306.0              |                                   |                    |                    |                                 |                    |                       | 0 / 8                       |                    |                    | 12 / 18                 | 190000.0           | 17450.2            |
| 4,4'-DDE                    | C     | 3 / 4                             | 280.0              | 107.3              |                                   |                    |                    |                                 |                    |                       | 0 / 8                       |                    |                    | 9 / 18                  | 56000.0            | 6349.5             |
| 4,4'-DDT                    | C     | 2 / 4                             | 4900.0             | 2838.0             |                                   |                    |                    |                                 |                    |                       | 0 / 8                       |                    |                    | 6 / 18                  | 1600.0             | 798.8              |
| Aldrin                      | C     | 0 / 2                             |                    |                    | There are no data for this zone   |                    |                    | There are no data for this zone |                    |                       | 0 / 8                       |                    |                    | 0 / 18                  |                    |                    |
| Arsenic                     | C     | 2 / 2                             | 3500.0             | 3250.0             |                                   |                    |                    |                                 |                    |                       | 2 / 8                       | 16.0               | 13.5               | 15 / 18                 | 1290000.0          | 155193.3           |
| Benzene                     | C     | 0 / 2                             |                    |                    |                                   |                    |                    |                                 |                    |                       | 0 / 8                       |                    |                    | 1 / 18                  | 49.0               | 49.0               |
| Benzidine                   | C     | 0 / 2                             |                    |                    |                                   |                    |                    |                                 |                    |                       | 0 / 8                       |                    |                    | 0 / 18                  |                    |                    |
| Benzofluorene               | C     | 0 / 2                             |                    |                    |                                   |                    |                    |                                 |                    |                       | 0 / 8                       |                    |                    | 4 / 18                  | 3300.0             | 1107.5             |
| Beryllium                   | C     | 2 / 2                             | 150.0              | 150.0              |                                   |                    |                    |                                 |                    |                       | 0 / 8                       |                    |                    | 12 / 18                 | 2600.0             | 1027.5             |
| BHC-alpha                   | C     | 0 / 2                             |                    |                    |                                   |                    |                    |                                 |                    |                       | 0 / 8                       |                    |                    | 0 / 18                  |                    |                    |
| BHC-beta                    | C     | 0 / 2                             |                    |                    |                                   |                    |                    |                                 |                    |                       | 0 / 8                       |                    |                    | 2 / 18                  | 172.0              | 89.5               |
| BHC-delta                   | C     | 0 / 2                             |                    |                    |                                   |                    |                    |                                 |                    |                       | 0 / 8                       |                    |                    | 5 / 18                  | 300.0              | 110.9              |
| BHC-gamma (Lindane)         | C     | 0 / 2                             |                    |                    |                                   |                    |                    |                                 |                    |                       | 0 / 8                       |                    |                    | 1 / 18                  | 27.0               | 27.0               |
| Cadmium                     | C     | 2 / 2                             | 124.0              | 119.5              |                                   |                    |                    |                                 |                    |                       | 0 / 8                       |                    |                    | 11 / 18                 | 10000.0            | 1575.5             |
| Chlordane                   | C     | 1 / 4                             | 202.0              | 202.0              |                                   |                    |                    |                                 |                    |                       | 0 / 8                       |                    |                    | 5 / 18                  | 76000.0            | 17155.2            |
| Chloroform                  | C     | 0 / 2                             |                    |                    |                                   |                    |                    |                                 |                    |                       | 0 / 8                       |                    |                    | 0 / 18                  |                    |                    |
| Dieldrin                    | C     | 3 / 4                             | 42.0               | 32.7               |                                   |                    |                    |                                 |                    |                       | 0 / 8                       |                    |                    | 4 / 18                  | 12000.0            | 3042.3             |
| Heptachlor                  | C     | 0 / 2                             |                    |                    |                                   |                    |                    |                                 |                    |                       | 0 / 8                       |                    |                    | 0 / 18                  |                    |                    |
| Heptachlor Epoxide          | C     | 0 / 2                             |                    |                    |                                   |                    |                    |                                 |                    |                       | 0 / 8                       |                    |                    | 0 / 18                  |                    |                    |
| Nickel                      | C     | 2 / 2                             | 3300.0             | 2650.0             |                                   |                    |                    |                                 |                    |                       | 2 / 8                       | 23.0               | 19.0               | 17 / 18                 | 47000.0            | 14670.6            |
| Tetrachloroethylene         | C     | 0 / 2                             |                    |                    |                                   |                    |                    |                                 |                    |                       | 0 / 8                       |                    |                    | 1 / 18                  | 21.0               | 21.0               |
| Trichloroethylene           | C     | 0 / 2                             |                    |                    |                                   |                    |                    |                                 |                    |                       | 0 / 8                       |                    |                    | 2 / 18                  | 69.0               | 66.0               |
| Vinyl chloride              | C     | 0 / 2                             |                    |                    |                                   |                    |                    |                                 |                    |                       | 0 / 8                       |                    |                    | 0 / 18                  |                    |                    |
| 1,2-trans-Dichloroethylene  | NC    | 0 / 2                             |                    |                    |                                   |                    |                    |                                 |                    |                       | 0 / 8                       |                    |                    | 0 / 18                  |                    |                    |
| 1,3-trans-Dichloropropylene | NC    | 0 / 2                             |                    |                    |                                   |                    |                    |                                 |                    |                       | 0 / 8                       |                    |                    | 0 / 18                  |                    |                    |
| 2-Butanone                  | NC    | 0 / 2                             |                    |                    |                                   |                    |                    |                                 |                    |                       | 2 / 8                       | 43.0               | 32.5               | 6 / 18                  | 110.0              | 53.3               |
| Barium                      | NC    | 2 / 2                             | 11000.0            | 10500.0            |                                   |                    |                    |                                 |                    |                       | 4 / 8                       | 32.0               | 25.8               | 18 / 18                 | 87000.0            | 33016.7            |
| Ethylbenzene                | NC    | 0 / 2                             |                    |                    |                                   |                    |                    |                                 |                    |                       | 0 / 8                       |                    |                    | 5 / 18                  | 910.0              | 248.6              |
| Fluoranthene                | NC    | 0 / 2                             |                    |                    |                                   |                    |                    |                                 |                    |                       | 0 / 8                       |                    |                    | 4 / 18                  | 55000.0            | 14417.5            |
| Lead                        | NC    | 2 / 2                             | 6200.0             | 5250.0             |                                   |                    |                    |                                 |                    |                       | 3 / 8                       | 6.2                | 5.1                | 18 / 18                 | 180000.0           | 44705.6            |
| Silver                      | NC    | 2 / 2                             | 300.0              | 225.0              |                                   |                    |                    |                                 |                    |                       | 1 / 8                       | 5.0                | 5.0                | 1 / 18                  | 640.0              | 640.0              |
| Toluene                     | NC    | 0 / 2                             |                    |                    |                                   |                    |                    |                                 |                    |                       | 1 / 8                       | 5.0                | 5.0                | 6 / 18                  | 130.0              | 42.5               |
| Xylenes (Tot) (Tech)        | NC    | 0 / 2                             |                    |                    |                                   |                    |                    |                                 |                    |                       | 0 / 8                       |                    |                    | 7 / 18                  | 1600.0             | 271.9              |
| Zinc                        | NC    | 2 / 2                             | 35000.0            | 28175.0            |                                   |                    |                    |                                 |                    |                       | 3 / 8                       | 115.0              | 40.3               | 18 / 18                 | 374000.0           | 113722.2           |
| Total Other PAHs            | SC    | 1 / 2                             | 16544.0            | 16544.0            |                                   |                    |                    |                                 |                    |                       | 1 / 8                       | 40.0               | 40.0               | 10 / 18                 | 235600.0           | 32907.0            |
| Dibenzofuran                | SCI   | 0 / 2                             |                    |                    |                                   |                    |                    |                                 |                    |                       | 0 / 8                       |                    |                    | 4 / 18                  | 11000.0            | 3957.5             |



TABLE 1-8

## SUMMARY OF RI ANALYTICAL DATA FOR CRITICAL CONTAMINANTS IN ZONE 7

| Compound                    | Group | (-- Surface Soils (to 4 feet) --) |                    |                    | (-- Deep Soils (below 4 feet) --) |                    |                    | Ground Water |                    |                    | Surface Water                |                    |                              | Sediments |                    |                    |
|-----------------------------|-------|-----------------------------------|--------------------|--------------------|-----------------------------------|--------------------|--------------------|--------------|--------------------|--------------------|------------------------------|--------------------|------------------------------|-----------|--------------------|--------------------|
|                             |       | Frequency                         | Maximum Conc (ppb) | Average Conc (ppb) | Frequency                         | Maximum Conc (ppb) | Average Conc (ppb) | Frequency    | Maximum Conc (ppb) | Average Conc (ppb) | Frequency                    | Maximum Conc (ppb) | Average Conc (ppb)           | Frequency | Maximum Conc (ppb) | Average Conc (ppb) |
| 1,1-Dichloroethylene        | C     | 0 / 1                             |                    |                    | 0 / 3                             |                    |                    | 0 / 28       |                    |                    |                              |                    |                              |           |                    |                    |
| 1,2-Dichloroethane          | C     | 0 / 1                             |                    |                    | 0 / 3                             |                    |                    | 0 / 28       |                    |                    |                              |                    |                              |           |                    |                    |
| 2,3,7,8-TCDD                | C     | 0 / 0                             |                    |                    | 0 / 0                             |                    |                    | 0 / 0        |                    |                    |                              |                    |                              |           |                    |                    |
| 4,4'-DDD                    | C     | 1 / 1                             | 86.0               | 86.0               | 0 / 3                             |                    |                    | 3 / 28       | 4.9                | 1.8                |                              |                    |                              |           |                    |                    |
| 4,4'-DDE                    | C     | 1 / 1                             | 27.0               | 27.0               | 0 / 3                             |                    |                    | 3 / 28       | 0.8                | 0.4                |                              |                    |                              |           |                    |                    |
| 4,4'-DDT                    | C     | 0 / 1                             |                    |                    | 0 / 3                             |                    |                    | 1 / 28       | 0.1                | 0.1                | Not Applicable for this zone |                    | Not Applicable for this zone |           |                    |                    |
| Aldrin                      | C     | 0 / 1                             |                    |                    | 0 / 3                             |                    |                    | 1 / 28       | 0.2                | 0.2                |                              |                    |                              |           |                    |                    |
| Arsenic                     | C     | 0 / 0                             |                    |                    | 2 / 3                             | 610.0              | 580.0              | 2 / 28       | 29.0               | 23.0               |                              |                    |                              |           |                    |                    |
| Benzene                     | C     | 0 / 1                             |                    |                    | 0 / 3                             |                    |                    | 6 / 28       | 180.0              | 60.2               |                              |                    |                              |           |                    |                    |
| Benidine                    | C     | 0 / 1                             |                    |                    | 0 / 3                             |                    |                    | 0 / 28       |                    |                    |                              |                    |                              |           |                    |                    |
| Benzo(a)pyrene              | C     | 1 / 1                             | 121.0              | 121.0              | 0 / 3                             |                    |                    | 0 / 28       |                    |                    |                              |                    |                              |           |                    |                    |
| Beryllium                   | C     | 0 / 0                             |                    |                    | 1 / 3                             | 280.0              | 280.0              | 8 / 28       | 6.7                | 1.9                |                              |                    |                              |           |                    |                    |
| BHC-alpha                   | C     | 0 / 1                             |                    |                    | 0 / 3                             |                    |                    | 3 / 28       | 0.2                | 0.1                |                              |                    |                              |           |                    |                    |
| BHC-beta                    | C     | 0 / 1                             |                    |                    | 0 / 3                             |                    |                    | 2 / 28       | 2.3                | 1.2                |                              |                    |                              |           |                    |                    |
| BHC-delta                   | C     | 0 / 1                             |                    |                    | 0 / 3                             |                    |                    | 2 / 28       | 0.1                | 0.1                |                              |                    |                              |           |                    |                    |
| BHC-gamma (Lindane)         | C     | 0 / 1                             |                    |                    | 0 / 3                             |                    |                    | 5 / 28       | 0.3                | 0.1                |                              |                    |                              |           |                    |                    |
| Cadmium                     | C     | 0 / 0                             |                    |                    | 2 / 3                             | 110.0              | 95.0               | 8 / 28       | 28.0               | 5.6                |                              |                    |                              |           |                    |                    |
| Chlordane                   | C     | 1 / 1                             | 230.0              | 230.0              | 0 / 3                             |                    |                    | 2 / 28       | 0.5                | 0.5                |                              |                    |                              |           |                    |                    |
| Chloroform                  | C     | 0 / 1                             |                    |                    | 0 / 3                             |                    |                    | 1 / 28       | 5.0                | 5.0                |                              |                    |                              |           |                    |                    |
| Dieldrin                    | C     | 0 / 1                             |                    |                    | 0 / 3                             |                    |                    | 2 / 28       | 0.1                | 0.1                |                              |                    |                              |           |                    |                    |
| Heptachlor                  | C     | 0 / 1                             |                    |                    | 1 / 3                             | 2.0                | 2.0                | 0 / 28       |                    |                    |                              |                    |                              |           |                    |                    |
| Heptachlor Epoxide          | C     | 0 / 1                             |                    |                    | 0 / 3                             |                    |                    | 1 / 28       | 0.9                | 0.9                |                              |                    |                              |           |                    |                    |
| Nickel                      | C     | 0 / 0                             |                    |                    | 3 / 3                             | 9700.0             | 6300.0             | 9 / 28       | 116.0              | 39.6               |                              |                    |                              |           |                    |                    |
| Tetrachloroethylene         | C     | 0 / 1                             |                    |                    | 0 / 3                             |                    |                    | 2 / 28       | 8.3                | 6.7                |                              |                    |                              |           |                    |                    |
| Trichloroethylene           | C     | 0 / 1                             |                    |                    | 0 / 3                             |                    |                    | 5 / 28       | 5.0                | 3.8                |                              |                    |                              |           |                    |                    |
| Vinyl chloride              | C     | 0 / 1                             |                    |                    | 0 / 3                             |                    |                    | 4 / 28       | 130.0              | 74.5               |                              |                    |                              |           |                    |                    |
| 1,2-trans-Dichloroethylene  | NC    | 0 / 1                             |                    |                    | 0 / 3                             |                    |                    | 6 / 28       | 238.0              | 79.8               |                              |                    |                              |           |                    |                    |
| 1,3-trans-Dichloropropylene | NC    | 0 / 1                             |                    |                    | 0 / 3                             |                    |                    | 1 / 28       | 540.0              | 540.0              |                              |                    |                              |           |                    |                    |
| 2-Butanone                  | NC    | 0 / 1                             |                    |                    | 0 / 3                             |                    |                    | 0 / 28       |                    |                    |                              |                    |                              |           |                    |                    |
| Barium                      | NC    | 0 / 0                             |                    |                    | 3 / 3                             | 18000.0            | 14333.3            | 12 / 28      | 207.0              | 68.5               |                              |                    |                              |           |                    |                    |
| Ethylbenzene                | NC    | 0 / 1                             |                    |                    | 0 / 3                             |                    |                    | 6 / 28       | 360.0              | 143.2              |                              |                    |                              |           |                    |                    |
| Fluoranthene                | NC    | 1 / 1                             | 400.0              | 400.0              | 0 / 3                             |                    |                    | 0 / 28       |                    |                    |                              |                    |                              |           |                    |                    |
| Lead                        | NC    | 0 / 0                             |                    |                    | 3 / 3                             | 4000.0             | 3433.3             | 8 / 28       | 190.0              | 29.7               |                              |                    |                              |           |                    |                    |
| Silver                      | NC    | 0 / 0                             |                    |                    | 0 / 3                             |                    |                    | 0 / 28       |                    |                    |                              |                    |                              |           |                    |                    |
| Toluene                     | NC    | 0 / 1                             |                    |                    | 1 / 3                             | 3.0                | 3.0                | 6 / 28       | 84.0               | 35.5               |                              |                    |                              |           |                    |                    |
| Xylenes (Tot) (tech)        | NC    | 0 / 1                             |                    |                    | 0 / 3                             |                    |                    | 5 / 28       | 370.0              | 237.0              |                              |                    |                              |           |                    |                    |
| Zinc                        | NC    | 0 / 0                             |                    |                    | 3 / 3                             | 40000.0            | 26666.7            | 28 / 28      | 1350.0             | 134.9              |                              |                    |                              |           |                    |                    |
| Total Other PAHs            | SC    | 1 / 1                             | 1295.0             | 1295.0             | 1 / 3                             | 310.0              | 310.0              | 10 / 28      | 15700.0            | 2912.6             |                              |                    |                              |           |                    |                    |
| Dibenzofuran                | SCI   | 0 / 1                             |                    |                    | 0 / 3                             |                    |                    | 5 / 28       | 200.0              | 82.8               |                              |                    |                              |           |                    |                    |

TABLE 1-9

## SUMMARY OF RI ANALYTICAL DATA FOR CRITICAL CONTAMINANTS IN ZONE 8

| Compound                    | Group | (-- Surface Soils (to 4 feet) --) |                    |                    | (-- Deep Soils (below 4 feet) --) |                    |                    | Ground Water |                    |                    | Surface Water |                    |                    | Sediments                    |                    |                              |
|-----------------------------|-------|-----------------------------------|--------------------|--------------------|-----------------------------------|--------------------|--------------------|--------------|--------------------|--------------------|---------------|--------------------|--------------------|------------------------------|--------------------|------------------------------|
|                             |       | Frequency                         | Maximum Conc (ppb) | Average Conc (ppb) | Frequency                         | Maximum Conc (ppb) | Average Conc (ppb) | Frequency    | Maximum Conc (ppb) | Average Conc (ppb) | Frequency     | Maximum Conc (ppb) | Average Conc (ppb) | Frequency                    | Maximum Conc (ppb) | Average Conc (ppb)           |
| 1,1-Dichloroethylene        | C     | 0 / 6                             |                    |                    | 0 / 8                             |                    |                    | 0 / 6        |                    |                    |               |                    |                    |                              |                    |                              |
| 1,2-Dichloroethane          | C     | 0 / 6                             |                    |                    | 0 / 8                             |                    |                    | 0 / 6        |                    |                    |               |                    |                    |                              |                    |                              |
| 2,3,7,8-TCDD                | C     | 0 / 8                             |                    |                    | 0 / 0                             |                    |                    | 0 / 0        |                    |                    |               |                    |                    |                              |                    |                              |
| 4,4'-DDD                    | C     | 3 / 6                             | 850.0              | 294.9              | 6 / 8                             | 270.0              | 81.7               | 1 / 6        | 0.0                | 0.0                |               |                    |                    |                              |                    |                              |
| 4,4'-DDE                    | C     | 1 / 6                             | 440.0              | 440.0              | 2 / 8                             | 50.0               | 30.5               | 0 / 6        |                    |                    |               |                    |                    |                              |                    |                              |
| 4,4'-DDT                    | C     | 3 / 6                             | 700.0              | 244.7              | 5 / 8                             | 51.0               | 18.2               | 0 / 6        |                    |                    |               |                    |                    |                              |                    |                              |
| Aldrin                      | C     | 0 / 6                             |                    |                    | 0 / 8                             |                    |                    | 0 / 6        |                    |                    |               |                    |                    | Not Applicable for this zone |                    | Not Applicable for this zone |
| Arsenic                     | C     | 1 / 3                             | 2500.0             | 2500.0             | 2 / 8                             | 2400.0             | 2050.0             | 0 / 6        |                    |                    |               |                    |                    |                              |                    |                              |
| Benzene                     | C     | 0 / 6                             |                    |                    | 0 / 8                             |                    |                    | 0 / 6        |                    |                    |               |                    |                    |                              |                    |                              |
| Benzidine                   | C     | 0 / 6                             |                    |                    | 0 / 8                             |                    |                    | 0 / 6        |                    |                    |               |                    |                    |                              |                    |                              |
| Benzo(a)pyrene              | C     | 0 / 6                             |                    |                    | 0 / 8                             |                    |                    | 0 / 6        |                    |                    |               |                    |                    |                              |                    |                              |
| Beryllium                   | C     | 0 / 3                             |                    |                    | 4 / 8                             | 420.0              | 372.5              | 0 / 6        |                    |                    |               |                    |                    |                              |                    |                              |
| BHC-alpha                   | C     | 0 / 6                             |                    |                    | 0 / 8                             |                    |                    | 0 / 6        |                    |                    |               |                    |                    |                              |                    |                              |
| BHC-beta                    | C     | 0 / 6                             |                    |                    | 0 / 8                             |                    |                    | 0 / 6        |                    |                    |               |                    |                    |                              |                    |                              |
| BHC-delta                   | C     | 1 / 6                             | 45.0               | 45.0               | 0 / 8                             |                    |                    | 0 / 6        |                    |                    |               |                    |                    |                              |                    |                              |
| BHC-gamma (Lindane)         | C     | 0 / 6                             |                    |                    | 0 / 8                             |                    |                    | 1 / 6        | 0.2                | 0.2                |               |                    |                    |                              |                    |                              |
| Cadmiun                     | C     | 0 / 3                             |                    |                    | 0 / 8                             |                    |                    | 1 / 6        | 28.0               | 28.0               |               |                    |                    |                              |                    |                              |
| Chlordane                   | C     | 1 / 6                             | 12.0               | 12.0               | 5 / 8                             | 300.0              | 88.4               | 0 / 6        |                    |                    |               |                    |                    |                              |                    |                              |
| Chloroform                  | C     | 0 / 6                             |                    |                    | 0 / 8                             |                    |                    | 1 / 6        | 5.0                | 5.0                |               |                    |                    |                              |                    |                              |
| Dieldrin                    | C     | 0 / 6                             |                    |                    | 2 / 8                             | 2.4                | 2.4                | 0 / 6        |                    |                    |               |                    |                    |                              |                    |                              |
| Heptachlor                  | C     | 0 / 6                             |                    |                    | 0 / 8                             |                    |                    | 0 / 6        |                    |                    |               |                    |                    |                              |                    |                              |
| Heptachlor Epoxide          | C     | 0 / 6                             |                    |                    | 0 / 8                             |                    |                    | 1 / 6        | 0.0                | 0.0                |               |                    |                    |                              |                    |                              |
| Nickel                      | C     | 2 / 3                             | 5800.0             | 5300.0             | 5 / 8                             | 14000.0            | 6880.0             | 0 / 6        |                    |                    |               |                    |                    |                              |                    |                              |
| Tetrachloroethylene         | C     | 0 / 6                             |                    |                    | 0 / 8                             |                    |                    | 0 / 6        |                    |                    |               |                    |                    |                              |                    |                              |
| Trichloroethylene           | C     | 0 / 6                             |                    |                    | 0 / 8                             |                    |                    | 0 / 6        |                    |                    |               |                    |                    |                              |                    |                              |
| Vinyl chloride              | C     | 0 / 6                             |                    |                    | 0 / 8                             |                    |                    | 0 / 6        |                    |                    |               |                    |                    |                              |                    |                              |
| 1,2-trans-Dichloroethylene  | NC    | 0 / 6                             |                    |                    | 0 / 8                             |                    |                    | 1 / 6        | 5.0                | 5.0                |               |                    |                    |                              |                    |                              |
| 1,3-trans-Dichloropropylene | NC    | 0 / 6                             |                    |                    | 0 / 8                             |                    |                    | 0 / 6        |                    |                    |               |                    |                    |                              |                    |                              |
| 2-Butanone                  | NC    | 0 / 6                             |                    |                    | 0 / 8                             |                    |                    | 3 / 6        | 10.0               | 10.0               |               |                    |                    |                              |                    |                              |
| Barium                      | NC    | 3 / 3                             | 28000.0            | 22333.3            | 8 / 8                             | 55000.0            | 18662.5            | 3 / 6        | 21.0               | 17.7               |               |                    |                    |                              |                    |                              |
| Ethylbenzene                | NC    | 0 / 6                             |                    |                    | 0 / 8                             |                    |                    | 0 / 6        |                    |                    |               |                    |                    |                              |                    |                              |
| Fluoranthene                | NC    | 2 / 6                             | 760.0              | 615.0              | 0 / 8                             |                    |                    | 0 / 6        |                    |                    |               |                    |                    |                              |                    |                              |
| Lead                        | NC    | 3 / 3                             | 119000.0           | 50000.0            | 8 / 8                             | 6100.0             | 4575.0             | 2 / 6        | 6.0                | 4.3                |               |                    |                    |                              |                    |                              |
| Silver                      | NC    | 1 / 3                             | 1900.0             | 1900.0             | 2 / 8                             | 2700.0             | 2250.0             | 0 / 6        |                    |                    |               |                    |                    |                              |                    |                              |
| Toluene                     | NC    | 2 / 6                             | 8.0                | 6.0                | 0 / 8                             |                    |                    | 0 / 6        |                    |                    |               |                    |                    |                              |                    |                              |
| Xylenes (Tot) (Tech)        | NC    | 0 / 6                             |                    |                    | 0 / 8                             |                    |                    | 0 / 6        |                    |                    |               |                    |                    |                              |                    |                              |
| Zinc                        | NC    | 3 / 3                             | 40000.0            | 32666.7            | 8 / 8                             | 60000.0            | 35625.0            | 6 / 6        | 98.0               | 40.9               |               |                    |                    |                              |                    |                              |
| Total Other PAHs            | SC    | 2 / 6                             | 2850.0             | 1926.0             | 0 / 8                             |                    |                    | 0 / 6        |                    |                    |               |                    |                    |                              |                    |                              |
| Dibenzofuran                | SC1   | 0 / 6                             |                    |                    | 0 / 8                             |                    |                    | 0 / 6        |                    |                    |               |                    |                    |                              |                    |                              |

TABLE 1-11

## SUMMARY OF RI ANALYTICAL DATA FOR CRITICAL CONTAMINANTS IN "UP" ZONE

| Compound                    | Group | (-- Surface Soils (to 4 feet) --) |                    | (-- Deep Soils (below 4 feet) --) |                                 | (<----- Ground Water ----->) |                                 | (<----- Surface Water ----->) |                                 | (<----- Sediments ----->) |           |                    |                    |
|-----------------------------|-------|-----------------------------------|--------------------|-----------------------------------|---------------------------------|------------------------------|---------------------------------|-------------------------------|---------------------------------|---------------------------|-----------|--------------------|--------------------|
|                             |       | Frequency                         | Maximum Conc (ppb) | Average Conc (ppb)                | Frequency                       | Maximum Conc (ppb)           | Average Conc (ppb)              | Frequency                     | Maximum Conc (ppb)              | Average Conc (ppb)        | Frequency | Maximum Conc (ppb) | Average Conc (ppb) |
| 1,1-Dichloroethylene        | C     | 0 / 2                             |                    |                                   |                                 |                              |                                 |                               |                                 |                           |           |                    |                    |
| 1,2-Dichloroethane          | C     | 0 / 2                             |                    |                                   |                                 |                              |                                 |                               |                                 |                           | 0 / 1     |                    |                    |
| 2,3,7,8-TCDD                | C     | 0 / 1                             |                    |                                   |                                 |                              |                                 |                               |                                 |                           | 0 / 1     |                    |                    |
| 4,4'-DDD                    | C     | 2 / 2                             | 310.0              | 198.5                             |                                 |                              |                                 |                               |                                 |                           | 0 / 1     |                    |                    |
| 4,4'-DDE                    | C     | 2 / 2                             | 43.0               | 33.0                              |                                 |                              |                                 |                               |                                 |                           | 1 / 1     | 75000.0            | 75000.0            |
| 4,4'-DDT                    | C     | 2 / 2                             | 2500.0             | 1289.5                            |                                 |                              |                                 |                               |                                 |                           | 1 / 1     | 13000.0            | 13000.0            |
| Aldrin                      | C     | 0 / 2                             |                    |                                   | There are no data for this zone |                              | There are no data for this zone |                               | There are no data for this zone |                           | 0 / 1     |                    |                    |
| Arsenic                     | C     | 0 / 0                             |                    |                                   |                                 |                              |                                 |                               |                                 |                           | 0 / 1     |                    |                    |
| Benzene                     | C     | 0 / 2                             |                    |                                   |                                 |                              |                                 |                               |                                 |                           | 0 / 1     |                    |                    |
| Benzidine                   | C     | 0 / 2                             |                    |                                   |                                 |                              |                                 |                               |                                 |                           | 0 / 1     |                    |                    |
| Benzo(a)pyrene              | C     | 0 / 2                             |                    |                                   |                                 |                              |                                 |                               |                                 |                           | 0 / 1     |                    |                    |
| Beryllium                   | C     | 0 / 0                             |                    |                                   |                                 |                              |                                 |                               |                                 |                           | 0 / 1     |                    |                    |
| BHC-alpha                   | C     | 0 / 2                             |                    |                                   |                                 |                              |                                 |                               |                                 |                           | 0 / 1     |                    |                    |
| BHC-beta                    | C     | 0 / 2                             |                    |                                   |                                 |                              |                                 |                               |                                 |                           | 0 / 1     |                    |                    |
| BHC-delta                   | C     | 0 / 2                             |                    |                                   |                                 |                              |                                 |                               |                                 |                           | 0 / 1     |                    |                    |
| BHC-gamma (Lindane)         | C     | 1 / 2                             | 43.0               | 43.0                              |                                 |                              |                                 |                               |                                 |                           | 0 / 1     |                    |                    |
| Cadatum                     | C     | 0 / 0                             |                    |                                   |                                 |                              |                                 |                               |                                 |                           | 0 / 1     |                    |                    |
| Chlordane                   | C     | 1 / 2                             | 300.0              | 300.0                             |                                 |                              |                                 |                               |                                 |                           | 0 / 1     |                    |                    |
| Chloroform                  | C     | 0 / 2                             |                    |                                   |                                 |                              |                                 |                               |                                 |                           | 0 / 1     |                    |                    |
| Dieldrin                    | C     | 0 / 2                             |                    |                                   |                                 |                              |                                 |                               |                                 |                           | 0 / 1     |                    |                    |
| Heptachlor                  | C     | 0 / 2                             |                    |                                   |                                 |                              |                                 |                               |                                 |                           | 0 / 1     |                    |                    |
| Heptachlor Epoxide          | C     | 0 / 2                             |                    |                                   |                                 |                              |                                 |                               |                                 |                           | 0 / 1     |                    |                    |
| Nickel                      | C     | 0 / 0                             |                    |                                   |                                 |                              |                                 |                               |                                 |                           | 0 / 1     |                    |                    |
| Tetrachloroethylene         | C     | 0 / 2                             |                    |                                   |                                 |                              |                                 |                               |                                 |                           | 0 / 1     |                    |                    |
| Trichloroethylene           | C     | 0 / 2                             |                    |                                   |                                 |                              |                                 |                               |                                 |                           | 0 / 1     |                    |                    |
| Vinyl chloride              | C     | 0 / 2                             |                    |                                   |                                 |                              |                                 |                               |                                 |                           | 0 / 1     |                    |                    |
| 1,2-trans-Dichloroethylene  | NC    | 0 / 2                             |                    |                                   |                                 |                              |                                 |                               |                                 |                           | 0 / 1     |                    |                    |
| 1,3-trans-Dichloropropylene | NC    | 0 / 2                             |                    |                                   |                                 |                              |                                 |                               |                                 |                           | 0 / 1     |                    |                    |
| 2-Butanone                  | NC    | 0 / 2                             |                    |                                   |                                 |                              |                                 |                               |                                 |                           | 0 / 1     |                    |                    |
| Barium                      | NC    | 0 / 0                             |                    |                                   |                                 |                              |                                 |                               |                                 |                           | 0 / 1     |                    |                    |
| Ethylbenzene                | NC    | 0 / 2                             |                    |                                   |                                 |                              |                                 |                               |                                 |                           | 1 / 1     | 87000.0            | 87000.0            |
| Fluoranthene                | NC    | 1 / 2                             | 149.0              | 149.0                             |                                 |                              |                                 |                               |                                 |                           | 0 / 1     |                    |                    |
| Lead                        | NC    | 0 / 0                             |                    |                                   |                                 |                              |                                 |                               |                                 |                           | 1 / 1     | 740.0              | 740.0              |
| Silver                      | NC    | 0 / 0                             |                    |                                   |                                 |                              |                                 |                               |                                 |                           | 1 / 1     | 110000.0           | 110000.0           |
| Toluene                     | NC    | 0 / 2                             |                    |                                   |                                 |                              |                                 |                               |                                 |                           | 0 / 1     |                    |                    |
| Xylenes (Tot) (tech)        | NC    | 0 / 2                             |                    |                                   |                                 |                              |                                 |                               |                                 |                           | 0 / 1     |                    |                    |
| Zinc                        | NC    | 0 / 0                             |                    |                                   |                                 |                              |                                 |                               |                                 |                           | 0 / 1     |                    |                    |
| Total Other PAHs            | SC    | 1 / 2                             | 166.0              | 166.0                             |                                 |                              |                                 |                               |                                 |                           | 1 / 1     | 193000.0           | 193000.0           |
| Dibenzofuran                | SCI   | 0 / 2                             |                    |                                   |                                 |                              |                                 |                               |                                 |                           | 1 / 1     | 1940.0             | 1940.0             |
|                             |       |                                   |                    |                                   |                                 |                              |                                 |                               |                                 |                           | 0 / 1     |                    |                    |



TABLE 1-12

PHASE II RI SOIL SAMPLING BENEATH BUILDINGS  
BAIRD & MCGUIRE SITE, HOLBROOK, MA

(concentrations in (ug/kg) ppb)

| Compounds                                                             | Frequency | Range        | Average  |
|-----------------------------------------------------------------------|-----------|--------------|----------|
| <u>Volatile Organics</u>                                              |           |              |          |
| chloroform                                                            | 0/18      | --           | --       |
| 1,1-dichloroethene                                                    | 0/18      | --           | --       |
| trans 1,1-dichloroethene                                              | 2/18      | 15-19        | 17       |
| trichloroethylene                                                     | 0/18      | --           | --       |
| tetrachloroethylene                                                   | 0/18      | --           | --       |
| vinyl chloride                                                        | 0/18      | --           | --       |
| benzene                                                               | 2/18      | 8-21         | 14.      |
| toluene                                                               | 10/18     | 42-8,469     | 2,478.   |
| acetone                                                               | 17/18     | 66-37,585    | 11,816.  |
| xylene (total)                                                        | 12/18     | 20-300,000   | 84,654.  |
| <u>Base/Neutral Organics</u>                                          |           |              |          |
| pyrene                                                                | 12/18     | 1,194-48,975 | 10,677.  |
| napthalene                                                            | 11/18     | 128-691,824  | 161,593. |
| acenaphthene                                                          | 6/18      | 128-50,114   | 22,389.  |
| benzo (a) pyrene                                                      | 0/18      | --           | --       |
| fluorene                                                              | 6/18      | 217-69,182   | 30,575.  |
| dibenzofuran                                                          | 10/18     | 117-75,472   | 32,899.  |
| benzidine                                                             | 0/18      | --           | --       |
| fluoranthene                                                          | 11/18     | 1,173-34,169 | 9,527.   |
| <u>Acid Extractable (Organics)</u>                                    |           |              |          |
| Phenols (total)                                                       | 3/18      | 761-86,560   | 32,406.  |
| <u>Pesticides/Herbicides</u>                                          |           |              |          |
| dieldrin                                                              | 16/18     | 83-52,000    | 14,742.  |
| chlordane                                                             | 18/18     | 46-2,800,000 | 629,840. |
| 4,4-DDT                                                               | 13/18     | 85-2,600,000 | 324,751. |
| 4,4-DDE                                                               | 17/18     | 42-420,000   | 75,585.  |
| 4,4-DDD                                                               | 16/18     | 43-1,300,000 | 183,953. |
| endosulfan (total)                                                    | 0/18      | --           | --       |
| endrin                                                                | 10/18     | 25-110,000   | 24,763.  |
| heptachlor (total)                                                    | 0/18      | --           | --       |
| BHC (total)                                                           | 13/18     | 370-38,500   | 11,098.  |
| 2,4,5-TP                                                              | 0/18      | --           | --       |
| 2,3,7,8-TCDD                                                          | 6/18      | 0.19-11.3    | 2.85     |
| <u>Inorganics</u>                                                     |           |              |          |
| (Inorganics data not received from CLP as of Report preparation date) |           |              |          |

1. All buildings are located in Zone I of the Site.
2. FREQUENCY = no. of samples in which compound was detected/no. of samples analyzed.
3. RANGE and AVERAGE are based on positive values reported.

Section 2.00 below presents the public health risk assessment performed for the Baird & McGuire Site. Section 3.00 presents the environmental risk assessment, focusing on food chain uptake implications. Section 4.00 addresses the identification and screening of remedial action alternatives for the Site. Section 5.00 is a detailed analysis of remedial alternatives identified and selected through the screening process.

THE TRACK RECORD OF THE HAZARDOUS  
WASTE INCINERATION INDUSTRY

There are many examples of failures of hazardous waste incinerators. In this summary, we list examples of situations where incinerators failed, broke down or in other ways created health or environmental threats to the surrounding community. This list is in no way complete and is presented to provide an overview of the types of problems that have occurred. For further information on any of these examples, contact CCHW. A more detailed discussion of the problems of hazardous waste incinerators can be found in CCHW's guidebook Hazardous Waste Incineration, The Burning Issue.

| <u>Location/City/State</u> | <u>Operator</u>              | <u>Problems</u>                                                                                                                                                                                                                                                                                                                                                                |
|----------------------------|------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Chicago, IL                | Waste Management             | PCBs were detected 1-1/2 miles downwind in soil at elementary school; levels were 16 times higher than school 2 miles up wind; facility has been fined for violations and has been accused of inadequate monitoring. (AC, 1987a and WSJ, 1985).                                                                                                                                |
| Coffeyville,<br>Kansas     | National Electric<br>(Aptus) | In June, 1988, failure of safety system in storage bins caused explosion blowing hole in roof and spraying oil over workers causing one to be taken to hospital (CJ, 1988); fined \$45,000 for 4 violations of storage and air pollution permits (CJ, 1986); groundwater contamination verified by state (CJ, 1987); nearby farmers blame infertility and stillborns in cattle |



Coffeyville, Pyrochem  
Kansas

on plant emissions (CJ, 1988a); truck carrying PCB transformers collided with car causing a "major" PCB spill (AG, 1986) closing interstate for 5 days (AG, 1986a).

Neighbors constantly reported black smoke coming from stacks; nearby cars would be covered with black powdery substance (CJ, 1987b); plant failed EPA emissions test (CJ, 1986a).

Calvert City, LWD, Inc.  
Kentucky

Cited 4 times since 1980 for releasing dark smoke caused by equipment failures (LCJ, 1987); fined for permit violations: \$100,000 in 1988; \$4,000 in 1987; and, \$3,000 in 1985 (LE, 1988); explosion in 1987 burned one worker (PS, 1987).

Clay, KY LWD, Inc.

Explosion and fire in 1982 injured one worker and caused company to close (LCJ, 1987); many violations including fire safety standards were found (LE, 1988).

Baton Rouge, Rollins Environ.  
LA Services

Citizens have complained for years of health problems they attribute to plant emissions; complaints include nausea, itchiness, sore throats, dead livestock, dirty cars; in August, 1985, inspectors found operator slumped against wall holding his head complaining he felt faint; they also found gauges malfunctioning, inadequate oxygen levels and other problems that sent "superheated" hazardous chemicals roaring into the

Morgan City, LA      Marine Shale Processors

sky; the incinerator was temporarily closed (AC, 1987a and WSJ, 1985).

Cement Kiln modified to burn hazardous waste; in 1985 state issued compliance order that asserted that kiln had released hazardous chemicals into the environment; evaluation by Tulane University concluded that facility was not in compliance with fugitive emission standards for volatile organic hydrocarbons (DR, 1987); cited by EPA for violating air pollution standards in April, 1988 (MA, 1988); in January, 1989 fined \$1.75 Million and charged with dozens of violations, including lack of waste storage permits, poor environmental safeguards, improperly trained personnel and improper sampling, record keeping and security procedures; 36 orders were issued seriously restricting operations; total fine is largest in state's history (WTN, 1989a).

Hope, ME      Union Chemical

Operated in old New England style church yard; violated state discharge, storage and air emission standards (MPA, 1983).

Grand Island, NB      IT Corp.

Explosion in mobile incinerator critically injured two workers in October, 1987 (AP, 1987).

Logan Township, NJ      Rollins Environ. Services

Began operating in 1971; in 1974 people complained of odors making them sick; in 1977, 45,000 gal of

PCBs in 3 tanks exploded killing 6 workers and seriously injuring several others; a huge cloud of smoke drifted over the community; the facility was closed for six months; located in a flood plain, groundwater and surface water contamination was detected in 1980; fined \$65,000 in 1980 by Justice Dept for violating consent decree intended to limit air emissions; in 1981, another explosion occurred caused by excess pressure buildup; the plant was closed again; in 1986, accidentally burned iodine causing huge purple clouds to be released; fined \$10,000 for violating operators permit; Rollins has been repeatedly cited for violations of its permits for storage and discharge of toxic chemicals (AC, 1987a, AEA, 1983 and WSJ, 1985).

Rockhill, SC      Thermalkem  
(Stablex)

Explosion due to pressure build-up damaged incinerator wall in building (RHH, 1987); safety valves failed causing dump stack to remain open; air pollution control equipment failed releasing heavy smoke (DHEC, 1985); second explosion occurred in 1988 that caused 100 employees to be evacuated and 2 to be taken to hospital for tests (YO, 1988); in late 1970's fire lasted several days with some permanent injuries but no deaths (Director of Municipal County Preparedness Agency as reported in LWV, 1988).



Roebuck, SC GSX/Thermal Oxid-  
ation Corp.

Neighbors became ill and experienced burning eyes, sore throats and strong odors almost 4 miles away (DHEC, 1987).

Deer Park, TX Rollins Environ.  
Services

In 1981 cited by state for illegal burns; ash released from afterburners in 1983 during tour of plant; later inspections found ash smoldering on ground outside the burner; local residents complain of highest cancer rate in nation; skin diseases have been linked to emissions; violated emissions permit on 29 separate days during 2 year period; TX Air Control Board cite plant for failure to keep proper records on chemicals processed and stored (AC, 1987a, EA, 1982, NSN, 1983 and WSI, 1985).

Toole, Utah U.S. Army (DOD)

Lethal nerve gas was released when pollution control equipment, piping ventilation and filtering systems railed at the same time; human error was also cited; an Army review panel also cited inadequate operational checks and balances, inadequate safety, training communication and procurement programs and misguided management at the plant; the original incinerator design was considered "state-of-the-art (CA, 1987).

Roebuck, SC      GSX/Thermal Oxid-  
ation Corp.

Neighbors became ill and experienced burning eyes, sore throats and strong odors almost 4 miles away (DHEC, 1987).

Deer Park, TX      Rollins Environ.  
Services

In 1981 cited by state for illegal burns; ash released from afterburners in 1983 during tour of plant; later inspections found ash smoldering on ground outside the burner; local residents complain of highest cancer rate in nation; skin diseases have been linked to emissions; violated emissions permit on 29 separate days during 2 year period; TX Air Control Board cite plant for failure to keep proper records on chemicals processed and stored (AC, 1987a, EA, 1982, NSN, 1983 and WSI, 1985).

Toole, Utah      U.S. Army (DOD)

Lethal nerve gas was released when pollution control equipment, piping ventilation and filtering systems railed at the same time; human error was also cited; an Army review panel also cited inadequate operational checks and balances, inadequate safety, training communication and procurement programs and misguided management at the plant; the original incinerator design was considered "state-of-the-art (CA, 1987).



PC A01/MF A01  
Innovative Technology: Soil Washing. Fact sheet (Final).  
Environmental Protection Agency, Washington, DC.  
Office of Emergency and Remedial Response.  
Nov 89, 5p EPA/9200.5-250/FS

The fact sheet provides technology description, site characteristics affecting treatment feasibility, technology considerations, and technology status for soil washing. The fact sheet describes how soil washing can be potentially beneficial in the separation/segregation and volumetric reduction of hazardous materials in solids, sludges, and sediments.

Keywords: \*Hazardous materials, \*Decontamination, Technology innovation, Technology assessment, Waste treatment, Site surveys, Feasibility, Performance evaluation, Separation, Sediments, Sludge disposal, Process charting, Dewatering, Portable equipment, Washing, \*Superfund, \*Waste management, \*Office of Solid Waste and Emergency Response, \*Soil treatment, Cleanup operations, Remedial action.

PC A01/MF A01  
Innovative Technology: In-situ Vittrification. Fact sheet (Final).  
Environmental Protection Agency, Washington, DC.  
Office of Emergency and Remedial Response.  
Nov 89, 5p EPA/9200.5-251/FS

The fact sheet provides technology description, site characteristics affecting treatment feasibility, technology considerations, and technology status for In-Situ Vittrification (ISV). The sheet describes how ISV can be used to treat soils and sludges contaminated with mixtures of various waste types (e.g. radioactive, inorganic and/or organic).

Keywords: \*Hazardous materials, \*Vittrification, Waste treatment, Site surveys, Feasibility, Radioactive materials, Organic compounds, Inorganic compounds, Technology innovation, Technology assessment, \*Superfund, \*Waste management, \*Office of Solid Waste and Emergency Response, \*In-situ processing, Soil treatment, Sludge treatment, Remedial action.

PC A01/MF A01  
Innovative Technology: Slurry-Phase Biodegradation. Fact sheet (Final).  
Environmental Protection Agency, Washington, DC.  
Office of Emergency and Remedial Response.  
Nov 89, 5p EPA/9200.5-252/FS

The fact sheet provides technology description, site characteristics affecting treatment feasibility, technology considerations, and technology status for Slurry Phase Biodegradation (SPB). The sheet describes how SPB is potentially effective in treating various organic contaminants.

Keywords: \*Hazardous materials, \*Biodeterioration, \*Slimes, \*Waste treatment, Site surveys, Organic compounds, Aeration, Process charting, Microorganisms, Technology assessment, Technology innovation, \*Superfund, \*Waste management, \*Office of Solid Waste and Emergency Response, \*Remedial action, Feasibility studies, Soil contamination.

PC A04/MF A01  
Environmental Protection Agency, Cincinnati, OH. Risk Reduction Engineering Lab.  
Operations and Research at the U.S. EPA Incineration Research Facility: Annual Report for FY89.  
Arcurex Corp., Jefferson, AR.  
L. R. Waterland, Mar 90, 73p EPA/600/9-90/012  
Contract EPA-68-03-3267  
Sponsored by Environmental Protection Agency, Cincinnati, OH. Risk Reduction Engineering Lab.

The Environmental Protection Agency's Incineration Research Facility in Jefferson, Arkansas, is an experimental facility which houses two pilot-scale incinerators and the associated waste handling emission control, process control, and safety equipment, as well as onsite laboratory facilities. During Fiscal Year 1989, a major facility expansion and reconfiguration construction effort was completed. Upon completion of the construction, incineration testing at the Facility was resumed. Hazardous waste incinerator trace metal emission regulation development for the Office of Solid Waste and a Superfund site remediation treatability study for Region I and the Office of Emergency and Remedial Response were major program support activities in Fiscal Year 1989.

Keywords: \*Research projects, \*Test chambers, \*Hazardous materials, \*Waste disposal, \*Air pollution control equipment, \*Soils, Incinerators, Performance evaluation, Scrubbers, Design criteria, Particle size distribution, Kilns, Tables(Data), Concentration(Composition), \*US EPA, \*Incineration, \*Air pollution sampling, Superfund program, Land pollution.

PC A01/MF A01  
Innovative Technology: BEST Solvent Extraction Process. Fact sheet (Final).  
Environmental Protection Agency, Washington, DC.  
Office of Emergency and Remedial Response.  
Nov 89, 5p EPA/9200.5-253/FS

The fact sheet provides technology description, site characteristics affecting treatment feasibility, technology considerations, and technology status for the BEST solvent extraction process. The sheet describes the BEST process as using one or more secondary or tertiary amines to separate toxic wastes and oils from sludges or soils.

Keywords: \*Hazardous materials, \*Solvent extraction, Technology assessment, Technology innovation,

Waste treatment, Site surveys, Performance evaluation, Separation, Amines, Feasibility, \*Superfund, \*Waste management, \*Office of Solid Waste and Emergency Response, \*Best technology, Soil treatment, Land pollution, Sludge treatment, Remedial action.

PC A01/MF A01  
Innovative Technology: Glycolate Dehalogenation. Fact sheet (Final).  
Environmental Protection Agency, Washington, DC.  
Office of Emergency and Remedial Response.  
Nov 89, 5p EPA/9200.5-254/FS

The fact sheet provides technology description, site characteristics affecting treatment feasibility, technology considerations, and technology status for Glycolate Dehalogenation. The sheet describes the process as being potentially effective in detoxifying specific types of aromatic organic contaminants, particularly dioxins and PCBs.

Keywords: \*Hazardous materials, Waste treatment, Process charting, Pesticides, Technology innovation, Technology assessment, \*Superfund, \*Waste management, \*Office of Solid Waste and Emergency Response, \*Dehalogenation, \*Glycolic acid, Dioxins, Polychlorinated biphenyls, Soil treatment, Remedial action.

PC A03/MF A01  
Bioremediation of Contaminated Surface Soils.  
Robert S. Kerr Environmental Research Lab., Ada, OK.

J. L. Sims, R. C. Sims, and J. E. Matthews. Aug 89, 28p  
EPA/600/9-89/073  
Prepared in cooperation with Dynamac Corp., Ada, OK, and Utah State Univ., Logan.

Biological processes, including microbial degradation, have been identified as critical mechanisms for attenuating organic contaminants during transit through the vadose zone to the groundwater. On-site soil remedial measures using biological processes can reduce or eliminate groundwater contamination, thus reducing the need for extensive groundwater monitoring and treatment requirements. On-site remedial systems that utilize the soil as the treatment system accomplish treatment by using naturally occurring microorganisms to treat the contaminants. Treatment often may be enhanced by a variety of physical/chemical methods, such as fertilization, tilling, soil pH adjustment, moisture control, etc. The development of a bioremediation program for a specific contaminated soil system includes: (1) a thorough site/soil/waste characterization; (2) treatability studies; and (3) design and implementation of the bioremediation plan. Biological remediation of soils contaminated with organic chemicals has been demonstrated to be an alternative treatment technology that can often meet the goal of achieving a permanent clean-up remedy at hazardous waste sites.

Keywords: \*Soils, \*Microorganisms control(Water), \*Water pollution control, Ground water, Contamination, Monitoring, Fertilizing, Cultivation, pH, Soil water, Organic compounds, Waste treatment, Clean up.

PC A03/MF A01  
Pilot-Scale Evaluation of Incinerating Listed Wastes from Specific Sources. Rept. for 1986-88.  
Environmental Protection Agency, Cincinnati, OH. Risk Reduction Engineering Lab.  
C. R. Demossey, and R. C. Thurnau. 1990, 14p EPA/600/D-90/141

Pilot-scale incineration testing was conducted at the United States Environmental Protection Agency's incineration Research Facility (IRF) to support the development of best demonstrated available technology (BDAT) standards for the treatment of several hazardous wastes from specific sources (K-Wastes). All testing was conducted in the IRF's rotary kiln system. The paper summarizes the results of this testing for four of these wastes. The objective was to determine if these wastes could be incinerated by a well designed, well operated incinerator based on compliance with the hazardous waste incinerator regulations and to characterize the incineration residuals for hazardous constituents. It was found that these wastes could generally be incinerated in compliance with these regulations. However, the mist carryover from the air pollution control device would have to be more effectively controlled to meet the particulate standard in some cases. No detectable amounts of principle organic hazardous constituents (POHC's) were found in either the kiln ash or scrubber blowdown.

Keywords: \*Hazardous materials, \*Waste disposal, \*Combustion efficiency, Pilot plants, Performance evaluation, Waste treatment, Standards, Air pollution control, Particles, Kilns, Organic compounds, \*Best technology, \*Incineration, Source Classification Codes, Pollution regulations, Standards compliance, Resource Conservation and Recovery Act, Physical chemical treatment.

PC A07/MF A01  
Environmental Protection Agency, Cincinnati, OH. Risk Reduction Engineering Lab.  
Development of Electro-Acoustic Soil Decontamination (ESD) Process for In situ Applications.  
Battelle Columbus Labs., OH.  
H. S. Muralidhara, B. F. Jirjis, F. B. Stulen, G. B. Wickramanayake, and A. Gill. Apr 90, 14p EPA/540/5-90/004  
Sponsored by Environmental Protection Agency, Cincinnati, OH. Risk Reduction Engineering Lab.

The technical feasibility of electro-acoustic soil decontamination process through lab experiments demonstrated the removal/concentration of heavy metals such as cadmium and zinc. Results of the decane contaminated soils were, however, inconclusive. The ESD process is based on the application of a d.c. electric field and acoustic field in the presence of a conven-

tional hydraulic gradient to contaminated soils to enhance the transport of liquid and metal ions through the soils. Electrodes (one or more anodes and a cathode) and an acoustic source were placed in contaminated soils to apply an electric field and an acoustic field to the soil. This process works especially well with clay-type soils having small pores or capillaries, where hydraulic permeability is very low. The development program included a literature review, soil characterization, design and construction of the laboratory ESD unit, and lab scale experiments with soils contaminated with decane, zinc and cadmium. Evaluation of the experimental results indicated that application of the field sources reduced the heavy metals zinc and cadmium more than 90% in the treated cake. Tests yielded 10-20% decane removal.

Keywords: \*Soils, \*Pollution control, Experimental design, Water pollution, Ground water, Performance evaluation, Soil surveys, Reviews, Tables(Data), Osmosis, Design criteria, Laboratory equipment, Zinc, Cadmium, Clay soils, Electrolysis, Superfund Innovative Technology Evaluation Program, \*Remedial action, \*Heavy metals, \*Electroacoustic waves, Environmental transport.



Human Health Effects Associated with Exposure to  
Herbicides and/or their Associated Contaminants:

A Review of the Literature

(Authors in Alphabetical Order)

Richard W. Clapp, M.P.H., Sc.D.  
JSI Research & Training Institute  
Boston, MA

Barry Commoner, Ph.D.  
Queens College  
Flushing, NY

John D. Constable, M.D.  
Harvard Medical School  
Boston, MA

Samuel S. Epstein, M.D.  
School of Public Health  
University of Illinois  
Chicago, IL

Peter C. Kahn, Ph.D.  
Rutgers University  
New Brunswick, NJ

James R. Olson, Ph.D.  
University of Buffalo  
School of Medicine and Biomedical Sciences  
Buffalo, NY

David M. Ozonoff, M.D., M.P.H.  
Boston University School of Public Health  
Boston, MA

Running Head: Human Health Effects of Herbicides

Abstract:

This review summarizes the scientific literature on the human health effects of exposure to phenoxyacetic acid herbicides and their associated contaminants (chlorinated dioxins). It was intended to include all studies reviewed by the Advisory Committee on Environmental Hazards of the U.S. Department of Veterans Affairs, and additional studies not reviewed to date by the Advisory Committee. The authors reviewed published and unpublished literature to determine the weight of the evidence for an association between specific toxic substances and health effects and concluded that there is a significant statistical association between exposure to phenoxyacetic acid herbicides and/or their associated contaminants (chlorinated dioxins) and the following diseases: non-Hodgkin's lymphoma, soft tissue sarcoma, skin disorders including chloracne, subclinical hepatotoxic effects, and porphyria cutanea tarda (most likely only in those with inherited uroporphyrinogen decarboxylase deficiency). The review included a recent cooperative study of the association between military service in Vietnam and selected cancers, as well as recent studies of persons occupationally exposed to herbicides. In addition, the authors found strong scientific evidence of an association between phenoxyacetic acid herbicides and/or their associated contaminants and Hodgkin's disease, neurologic effects, and reproductive and developmental effects. Based on these findings, the authors recommend that Vietnam veterans suffering from these eight adverse health effects be qualified for disability compensation. Other health effects for which the weight of evidence is not as strong are discussed.

Key Words: Agent Orange, dioxin, non-Hodgkin's lymphoma, soft tissue sarcoma, chloracne, hepatotoxic effects, porphyria cutanea tarda.

A review of scientific literature related to potential human health effects associated with exposure to phenoxyacetic acid herbicides and/or their associated contaminants (chlorinated dioxins) has been completed. This review included all studies and publications reviewed to date by the Advisory Committee on Environmental Hazards of the Department of Veterans Affairs, and additional pertinent studies not reviewed to date by the Advisory Committee. References to these publications and studies are included as appendices B-E. This review was directed primarily at assessing adverse health effects in Vietnam veterans which may be associated with exposure to Agent Orange, a phenoxyacetic acid herbicide which was contaminated with dioxin.<sup>1</sup>

#### The Standard Used by the Authors

This literature review focused on epidemiologic studies of exposed humans and used the standard "significant statistical association" because that is the standard used by the VA's Advisory Committee. At the outset, it should be made clear that the fact that the Task Force used this standard should not be interpreted to mean that the authors believe this is an appropriate standard for basing decisions on Agent Orange.

There are many reasons why use of this standard may be inappropriate. In order for epidemiologic studies to find statistically significant associations between exposure and health effects like cancers, these studies must have sufficient power and sensitivity. This generally requires large numbers of exposed subjects available for study and follow-up for many decades (if not for the lifetime of the subjects). A major problem with the various epidemiologic studies of people exposed to phenoxyacetic acid herbicides is

---

<sup>1</sup>References in this report to "dioxin," "TCDD," and "2,3,7,8-TCDD" all refer to 2,3,7,8-tetrachlorodibenzo-p-dioxin.



that there have not been many large populations with known exposures available for study and follow-up over long periods, or, where such populations exist, like Vietnam veterans and the Vietnamese, these have not been adequately studied. Thus, it is not surprising that, as reported below, only eight categories of adverse health effects have been found by the authors to have a "significant statistical association" (as defined by the VA) with exposure to phenoxyacetic acid herbicides and/or their associated contaminants even though many other adverse health effects have been shown to be associated with exposure.

#### The Methodology Used by the Authors

The authors limited their review to epidemiologic studies of exposed humans, excluding experimental animal studies, because the VA's Advisory Committee has apparently not reviewed experimental animal studies. However, there is an overwhelming scientific consensus that carcinogenicity data derived from well-designed animal studies can be extrapolated with confidence to predict human cancer risk. Illustrative statements in the scientific literature on extrapolation of experimental carcinogenicity data to human cancer risk is included as appendix A. Such experimental data have been and are accepted by legislators, regulators and courts in determining exposure risks and in establishing causal relationships. The epidemiologic evidence from a wide range of studies of an association between dioxin exposure and cancers and other chronic diseases is clearly supported by an extensive body of experimental data.

Carcinogenicity tests have demonstrated that dioxin is a potent chemical carcinogen which induces a wide range of cancers in a wide range of organs in a wide range of rodent strains and species. In fact, dioxin is the most

potent carcinogen ever evaluated by the Carcinogen Assessment Group of the Environmental Protection Agency; dioxin is some four orders of magnitude more potent than the well-recognized highly carcinogenic dimethylnitrosamine. Such data establish a strong basis for the validity of a causal relation between exposure to Agent Orange and the subsequent development of a range of cancers.

Finally, there is a critical difference between the methodology used by the authors and that used by the VA's Advisory Committee. In its review of literature on non-Hodgkin's lymphoma, the Advisory Committee simply classified studies as positive or negative and then tallied them, apparently under the theory that all studies are equal and can be viewed independently from all other knowledge on the subject. This procedure is unprecedented and was not followed by the authors. Individual studies show associations in varying degrees, but the ultimate conclusion about an association is the result of synthesizing all of the available data to determine their overall or aggregate meaning. The aggregate of all of the evidence derived from the available relevant epidemiologic studies establishes a causal relationship between Agent Orange exposure and a range of cancers and chronic diseases.

#### Primary Conclusions of the Authors

Following review of the scientific literature, it is concluded there is a significant statistical association between exposure to phenoxyacetic acid herbicides and/or their associated contaminants (chlorinated dioxins) and the following diseases: non-Hodgkin's lymphoma, soft tissue sarcoma, skin disorders/chloracne, subclinical hepatotoxic effects (including secondary coproporphyrinuria and chronic hepatic porphyria), and porphyria cutanea tarda (most likely only in individuals with inherited uroporphyrinogen decarboxylase deficiency). The aggregate interpretation of several sound studies showing a



statistically significant association for each of these conditions makes this conclusion inescapable.

Further, the scientific evidence supporting the existence of a significant statistical association between exposure to phenoxyacetic acid herbicides and/or their associated contaminants (chlorinated dioxins) is at least as strong as the scientific evidence of a lack of the association for the following adverse health effects: Hodgkin's disease, neurologic effects, and reproductive and developmental effects.<sup>2</sup> For each of these health effects, there are sound scientific studies showing statistical significance and strong scientific evidence of an association between exposure and effect. However, a statistically significant association is not as consistently supported for these effects as for the first group of health effects.

There are other adverse health effects for which there is sound scientific evidence of an association with exposure, but the evidence does not reach the level of formal statistical significance. Nevertheless, were these authors a policy-making body concerned with disability compensation for veterans, they might conclude that compensation was due. However, the authors are limited to determining the existence of a significant statistical

---

<sup>2</sup>The Task Force is informed that the law requires that the benefit of the doubt be given to veterans in determining whether an association between exposure and disease exists. See 38 U.S.C. Sec. 354 note section 5(b)(2)(A)(i); Nehmer v. United States Veterans Administration, 712 F.Supp. 1404, 1420-1422 (N.D. Cal. 1989); 38 C.F.R. Sec. 1.17; 54 Fed. Reg. 40389 (October 2, 1989). The VA has apparently defined this requirement to mean that, for disability compensation purposes, a statistically significant association will be deemed to exist if the evidence for and against the association is at least equally balanced, i.e., the association is "at least as likely as not." 38 C.F.R. Sec. 1.17(d)(1). Because the Task Force found, for these three health effects, that the scientific evidence of a significant statistical association is at least as strong as the evidence of a lack of the association, these three health effects qualify under the VA's "at least as likely as not" test.



association, and the limited data available at this time show an association, but not a significant statistical association, between exposure to phenoxyacetic acid herbicides and/or dioxin and the following diseases: leukemias, cancers of the kidney, testis, pancreas, stomach, prostate, colon, hepatobiliary tract, and brain, psychosocial effects, immunological abnormalities, gastrointestinal ulcer, and altered lipid metabolism. Further research should be directed at these associations, and policy-makers, cognizant of the limitations on finding significant statistical associations and of the obligation to give the veteran the benefit of the doubt, would be justified in viewing these disorders in a more conclusive light for the purpose of establishing entitlement to disability compensation.

Finally, the epidemiologic evidence on the associations between exposure and the adverse health effects described above is strongly supported by a wide range of experimental animal studies (EPA, 1985).

Evidence in support of the above conclusions is found in the summary statements which follow.

#### CANCER

Following review of the scientific literature, it is concluded there is a significant statistical association between exposure to phenoxyacetic acid herbicides and/or their associated contaminants (chlorinated dioxins) and non-Hodgkin's lymphoma and soft tissue sarcoma, and that the evidence supporting the existence of such an association is at least as strong as the evidence of a lack of the association for Hodgkin's disease. Evidence in support of these conclusions follows.

### Non-Hodgkin's Lymphoma

The veterans who served in the Marine Corps in Vietnam were seen to have a statistically significant ( $P < 0.025$ ) excess of non-Hodgkin's lymphoma when compared with Marines who did not serve in Vietnam (Breslin, et al. 1987; 1988). Non-Hodgkin's lymphoma has been associated with exposure to phenoxy herbicides (Hardell, et al. 1981; Hoar, et al. 1986) and arsenicals (Axelson, et al. 1978). The men who served in Vietnam had the potential for exposure to these agents. Agent Orange and Agent Blue, herbicides used in Vietnam, contained phenoxy herbicides and an organic arsenical, respectively. Several additional studies support the association between exposure to phenoxy herbicides and/or their associated contaminants (TCDD) and increase risk of non-Hodgkin's lymphoma. A significantly increased risk of localized skin lymphoma was associated with phenoxy herbicide exposure (Olsson and Brandt, 1988), confirming results from an earlier case report (Olsson and Brandt, 1981). A significantly increased risk of non-Hodgkin's lymphoma has also been reported in a number of studies of agricultural and forestry workers who were potentially exposed to phenoxy herbicides (Alavanja, et al. 1988, 1989; Woods, et al. 1987, 1989; Burmeister, et al. 1983; Cantor, 1982; Giles, et al. 1984; Buesching and Wollstadt, 1984; Blair, et al. 1985; Hoar, et al. 1986; Pearce, et al. 1985; Wigle, et al. 1990). Furthermore, Hoar, et al. (1986) reported that the relative risk of non-Hodgkin's lymphoma dramatically increased with the number of days of phenoxy herbicide use per year among agricultural workers in Kansas. An increased risk of non-Hodgkin's lymphoma in agricultural, forestry, and chemical workers, with potential exposure to phenoxy herbicides and/or their associated contaminants (TCDD) has been



reported by Bond, et al., (1989), Wiklund, et al., (1989), Ott, et al., (1987), Bishop and Jones (1981), Schumacher (1985), Dubrow, et al., (1988), and Lynge (1985), although these results were not found to be statistically significant.

The Advisory Committee on Environmental Hazards of the Department of Veterans Affairs did not review the following studies (cited above) at its meeting of November, 1989, which considered non-Hodgkin's lymphoma: Breslin, et al. (1988); Axelson, et al. (1978); Olsson and Brandt (1988); Woods, et al. (1989); Burmeister, et al. (1983); Cantor (1982); Giles, et al. (1984); Buesching and Wollstadt (1984); Blair, et al. (1985); Bond, et al. (1989); Wiklund, et al. (1989); Ott, et al. (1987); Bishop and Jones (1981).

Further, with the studies it did review, the Advisory Committee used a simplistic tallying system, wherein positive studies were somehow counterbalanced by studies classified as negative, with apparently no regard for the holistic, multidisciplinary approach that is standard practice in health assessment for regulatory and compensatory purposes. See National Academy of Sciences, Principles for Evaluating Chemicals in the Environment (1975). The need for such an approach has recently been reiterated by the National Academy of Sciences in its deliberations on the methods for the in vivo testing of complex mixtures (NRC 1988).

One of the studies called negative by the Advisory Committee was the Monsanto Company study of workers in its Nitro, West Virginia plant. This study has been relied upon in risk estimates of the human effects of dioxin exposure, but it has recently been challenged on the ground that exposed workers were improperly classified as non-exposed. This would produce a biased estimate of the risk of cancer and other diseases in these workers; the



magnitude of the bias may be such that in the original study by Zack and Gaffey, which reported nine exposed workers with cancer and a relative risk of less than 1 compared to the U.S. reference population, should have reported eighteen exposed workers with cancer and a relative risk as high as 2.2. The EPA has apparently called for a reassessment of the Monsanto data with the goal of correcting the erroneous estimate of the risk of cancer by properly classifying the exposure status of the decedents.<sup>3</sup> Until this is done, this study should not be relied upon and any positions which relied upon the original results should be reconsidered.

The CDC Selected Cancers Study, released in April, 1990, found that veterans who served in Vietnam had a significantly increased risk of non-Hodgkin's lymphoma over veterans who served elsewhere during the same period. This study may actually add support to the evidence that exposures in Vietnam caused increased risk of non-Hodgkin's lymphoma, even though its authors deny that their data support the contention that Agent Orange was the cause. Although the study did not focus on any direct measure of Agent Orange exposure, and the proposed blood sampling to determine dioxin levels in patients was never carried out, the authors made conclusions concerning Agent Orange exposure.

First, the CDC authors contend that Vietnam veterans who served in III Corps were most likely to be exposed to Agent Orange, and the results of their study indicate that they were at decreased risk of non-Hodgkin's lymphoma. Second, the CDC study found excessive risk of non-Hodgkin's lymphoma in "blue-

---

<sup>3</sup>See Cate Jenkins, Characterization and Assessment Division, EPA, "Memo to Raymond Loehr [Chairperson of the Executive Committee of the Science Advisory Board, EPA]: Newly Revealed Fraud by Monsanto in an Epidemiological Study Used by EPA to Assess Human Health Effects from Dioxins," dated February 23, 1990.

water" Navy veterans whom the authors presume had no exposure to Agent Orange. Finally, the CDC authors state that the responses to questions about spraying, handling or being around Agent Orange were similar among veterans with non-Hodgkin's lymphoma and veterans with no cancer of any type.

Critics have challenged these CDC interpretations of the data because the study did not contain any direct measure of exposure to Agent Orange. In addition, some indirect exposure criteria not emphasized by CDC do lead to the conclusion of adverse health effects in exposed veterans. For example, one of the heavily sprayed regions in Vietnam was I Corps. If the CDC data on veterans in I Corps and III Corps are taken together, they show an increased risk of both non-Hodgkin's lymphoma and soft tissue sarcoma. These two cancers have been found elevated in other studies of veterans done by state health departments in Massachusetts, West Virginia and Wisconsin. At a minimum, the CDC findings should be put in the context of these other studies of veterans, as well as studies of agricultural workers exposed to herbicides. It is impossible, without access to CDC's complete data, to conclusively determine whether Agent Orange played a part in the increased risk reported in the study.

A hearing on the Selected Cancers Study before the House Veterans Affairs Committee was conducted on April 4, 1990. It is reported that CDC's Dr. William Roper, although acknowledging that the Selected Cancers Study was not a dioxin study, repeatedly pointed to the Air Force's Ranch Hand study as a dioxin study with good exposure data that showed no increased cancer risk. However, in the February, 1990 release of the "1987 Follow-up Examination Results" on Ranch Hand, it is stated that the exposure index used in the data analysis "is not a good measure of actual dioxin exposure," and it is also



stated that statistically significant individual findings are not possible because of the size of the group under study. Furthermore, in this release, statistically significant group differences with a harmful impact on Ranch Hand veterans were detected in several health areas, including all cancers combined, both verified and suspected, and skin cancers alone.<sup>4</sup>

Regarding CDC studies and Agent Orange exposure, the CDC cancelled its study of Vietnam veterans exposed to Agent Orange, claiming it was not possible to determine exposure to Agent Orange from military records. CDC instead conducted an Agent Orange validation study which concluded there was no correlation between exposure, as predicted by certain military records, and dioxin levels in tissue and serum samples of certain veterans. CDC's conclusions in cancelling the Agent Orange exposure study and its conclusions in the validation study were the subject of a Congressional hearing on July 11, 1989. At the hearing, scientists who worked on or were associated with the projects testified and submitted statements criticizing the studies and the conclusions, and they can no longer be taken at face value. See Oversight Review of CDC's Agent Orange Study, Hearing before the Human Resources and Intergovernmental Relations Subcommittee of the Committee on Government Operations, House of Representatives (101st Congress, First Session, July 11, 1989).

---

<sup>4</sup>The 1990 Ranch Hand release also showed statistically significant group differences, with a harmful impact on Ranch Hand veterans, in the following additional health areas: hereditary and degenerative neurological diseases; coordination abnormalities; psychological and sleep disorders; certain dermatologic disorders; pulse irregularities; increase in thyroid stimulating hormone; among black Ranch Hands, higher mean counts for "natural killer cells" as compared to blacks in the control group; and among Ranch Hands who are heavy smokers, more abnormal composite skin reactions as compared to heavy smokers in the control group.



### Soft Tissue Sarcoma (STS)

Kogan and Clapp (1988) reported that STS mortality was significantly elevated among Vietnam veterans in Massachusetts from 1972 - 1983. In a follow-up study, Clapp (1988) found that STS mortality was still significantly elevated among Vietnam veterans in Massachusetts from 1982 - 1988. Studies of West Virginia and Wisconsin veterans also reported that STS mortality was significantly elevated among veterans who served in Vietnam (Holmes, et al. 1986; Anderson, et al., 1986). In a case-control study, Kang, et al. (1987) reported a greater risk of STS (odds ratio of 8.64) in a subgroup of Vietnam veterans who served in an area where Agent Orange spraying was reported to be extensive and thus who had higher opportunities for exposure to Agent Orange. However, this risk was not statistically significant based in part on the weak study power of the subgroup comparison.

An association between STS and occupational exposure to phenoxyacetic acid herbicides and/or their associated contaminants (TCDD) has been reported in a number of studies. Case-control studies from Sweden reported a statistically significant increased risk of STS in workers exposed to phenoxyacetic acids, chlorophenols, and their associated contaminants including chlorinated dioxins (Hardell and Sandstrom, 1979; Eriksson, et al., 1981). The publication of these initial studies was followed by several case reports from the United States of STS associated with exposure to these chemicals (Moses and Selikoff, 1981; Honchar and Halperin, 1981; Cook, 1981; Johnson, et al., 1981). More recently, 4 new studies reported a statistically significant increased risk of STS in workers exposed to phenoxyacetic acids and/or their associated contaminants, including chlorinated dioxins (Lynge, 1985; Vineis, et al., 1986; Hardell and Eriksson, 1988; Bond, et al., 1989).

The most recent report of Bond, et al., (1989) was an update on a cohort of 2192 employees potentially exposed to chlorinated dioxins, including TCDD. Cancer deaths were analyzed in a subset of 323 men in which exposure was confirmed by the presence of chloracne. In men with chloracne, only STS displayed a statistically significant increase over the expected levels (2 observed; <0.1 expected).

A recent study (JNCI, 1990) by Eriksson, Hardell and Adami re-evaluated the association between exposure to TCDD and other chlorinated isomers of dioxin and the risk of soft tissue sarcoma. This study was based on 237 cases from a Regional Cancer Registry in central Sweden and it confirmed findings from the earlier studies in northern Sweden. These authors conclude that the study supports previous findings of increased risk of soft tissue sarcoma in patients exposed to phenoxyacetic acids or chlorophenols, and furthermore that 2,3,7,8-TCDD and other chlorinated isomers may be the specific risk factor for this cancer.

Environmental and human exposure to TCDD occurred in 1976, following an accidental explosion in a plant near Seveso, Italy. In 1986, a report of cancer-specific incidence rates for the Seveso population found only STS at a higher incidence in the exposed than in the unexposed group (Puntoni, et al., 1986). In a ten-year mortality study of the population involved in the Seveso incident, although not statistically significant, Bertazzi, et al., (1989) reported elevated relative risks of STS of 24 and 6.33 in two subgroups of this population.

#### Hodgkin's Disease

Among cancer deaths, there was strong statistical evidence to suggest that Hodgkin's disease was more common among West Virginia veterans who served



in Vietnam than among veterans who did not (Holmes, et al., 1986). Wiklund, et al., (1988) reported a significant increase in the relative risk of Hodgkin's disease in men engaged in silviculture who were exposed to phenoxy acid herbicides. A time-related rising trend in the relative risk of Hodgkin's disease was also found in the silviculture cohort. In another study of 20,245 Swedish pesticide applicators who had exposure to phenoxy acid herbicides, Wiklund, et al. (1989) reported a statistically significant increased risk of Hodgkin's disease in the licensed pesticide applicators. A significantly elevated proportionate mortality ratio for Hodgkin's disease was also reported in a study of agricultural extension agents in the cooperative extension service of the USDA (Alavanja, et al., 1988). And an increased mortality rate for Hodgkin's disease was also reported in a ten-year mortality study of the population involved in the Seveso incident in 1976 (Bertazzi, et al., 1989).

#### Other Cancers

Other site-specific cancers which are associated, but not with formal statistical significance, with exposure to phenoxyacetic acid herbicides and/or their associated contaminants (chlorinated dioxins) include: leukemias (Bertazzi, et al., 1989; Alavanja, et al., 1988); and cancers of the kidney (Kogan and Clapp, 1988; Alavanja, et al., 1988, 1989), testis (Holmes, et al., 1986), pancreas (Anderson, et al., 1986), stomach (Bond, et al., 1989), prostate (Bond, et al., 1989; Alavanja, et al., 1988, 1989), colon (Alavanja, et al., 1988, 1989; Pratt, et al., 1987), hepatobiliary tract (Bertazzi, et al., 1989), and brain (Bertazzi, et al., 1989; Alavanja, et al., 1988; Blair, et al., 1983; Coggon, et al., 1986). (Also, as stated earlier, the 1990 Ranch Hand release showed an increased risk for all cancers combined and skin



cancers alone). The limited data available at this time do not permit a conclusion of a formal statistically significant association between exposure to phenoxyacetic acid herbicides and/or dioxin and these diseases. Further research should be directed at these associations.

It should be noted that one reason why studies are finding cancers at diverse sites may be that dioxin is a potent promoter and may well interact with other coexposures such that tumors may be induced at many sites depending upon these interactions (e.g., the initiator exposure may determine site, the promoter may then determine actual expression).

#### SKIN CONDITIONS/CHLORACNE

Following review of the scientific literature, it is concluded there is a significant statistical association between exposure to phenoxyacetic acid herbicides and/or their associated contaminants (chlorinated dioxins) and skin conditions/chloracne. Evidence in support of this conclusion follows.

American Legionnaires who served during the Vietnam war were studied via a mailed questionnaire. Agent Orange exposure was significantly dosage-related to history of adult acne, skin rash with blisters and change of skin color (Stellman, et al., 1988). Several other studies have confirmed that Chloracne is associated with human exposure to TCDD (Taylor, 1974; MMWR, 1988; Suskin, 1985; Caputo, et al, 1988; Tindall, 1985; Del Corno, et al., 1985; Moses and Prioleau, 1985).

However, it is important to note that recent studies in the Seveso population have found no threshold level for expression of chloracne (MMWR, 1988). Serum TCDD levels (on a lipid weight basis) range from 828 to 27,821 ppt in individuals with chloracne and 1,772 to 10,439 ppt in individuals with

no chloracne. Thus, there is great variability in individual responses in TCDD exposure and chloracne may not be a reliable single marker of exposure (Del Corno and Montesarchio, 1985). This means that although chloracne may be taken as indicative of exposure to dioxin or to a dioxin-like compound, the absence of chloracne does not, by itself, necessarily imply a lack of exposure.

#### SUBCLINICAL HEPATOTOXIC EFFECTS

Following review of the scientific literature, it is concluded there is a significant statistical association between exposure to phenoxyacetic acid herbicides and/or their associated contaminants (chlorinated dioxins) and subclinical hepatotoxic effects. Evidence in support of this conclusion follows.

Subclinical hepatotoxic effects, including elevated serum liver enzymes and elevated urine coproporphyrin, have been reported in Ranch Hand personnel who were responsible for herbicide spraying in Vietnam (Albanese, 1988). The CDC Vietnam Experience Study (II Physical Health, 1988) also found Vietnam veterans to have statistically elevated levels of the serum liver enzyme, gamma-glutamyl transferase. Studies of residents of Quail Run mobil home park in Missouri also suggest subclinical hepatotoxic effects associated with long-term low level exposure to TCDD (Hoffman, et al., 1986; Knutsen, et al., 1987; Stehr-Green, et al., 1987, 1988). Elevated serum liver enzymes have been reported in children exposed to dioxin in Seveso, Italy (Mocarelli, et al., 1986). All of the above findings are supported by studies of industrial workers which reported subclinical liver injury associated with dioxin exposure (Moses, et al., 1984; May, 1982; Pazderova-Vejlupkova, et al., 1981).



### PORPHYRINOPATHY

Following review of the scientific literature, it is concluded there is a significant statistical association between exposure to phenoxyacetic acid herbicides and/or their associated contaminants (chlorinated dioxins) and porphyria cutanea tarda (most likely only in individuals with inherited uroporphyrinogen decarboxylase deficiency). Evidence in support of this conclusion follows.

In the CDC Vietnam Experience Study (II Physical Health, 1988), one Vietnam veteran had a clearly abnormal pattern of urinary porphyrin levels (none in the non-Vietnam group).

Recently, Doss (1987) concluded that individuals exposed to TCDD can develop a secondary coproporphyrinuria with transition to latent chronic hepatic porphyria as a toxic hepatic response, and probably do not suffer from the clinical stage of porphyria cutanea tarda unless a hereditary disposition exists. In other words, TCDD induces an incipient subclinical stage of chronic hepatic porphyria in persons with normal red cell uroporphyrinogen decarboxylase. In contrast, exposure to dioxin in persons with inherited uroporphyrinogen decarboxylase deficiency can cause latent chronic hepatic porphyria to develop into porphyria cutanea tarda. Coproporphyrinuria and latent chronic hepatic porphyria do not produce clinical symptoms. Secondary porphyrinuria with transition to chronic hepatic porphyria is a metabolic response following various toxic and pathologic conditions; it serves as a sensitive index for chemical exposure and occupational disease. The conclusions of Doss (1987) are also supported by Strik (1987), Doss and Colombi (1986), and Doss, et al. (1984).



There are several older cases of occupational exposure to TCDD which do support the relationship between acquired porphyria and TCDD exposure (Bleiberg, et al., 1964; Jirasek, et al., 1973; Jirasek, et al., 1974).

#### NEUROLOGIC EFFECTS

Following review of the scientific literature, it is concluded that the evidence supporting the existence of a significant statistical association between exposure to phenoxyacetic acid herbicides and/or their associated contaminants (chlorinated dioxins) and neurologic effects, both central and peripheral, is at least as strong as the evidence of a lack of the association. Evidence in support of this conclusion follows.

In the baseline Ranch Hand morbidity study (Lathrop, et al., 1984), an extensive battery of neurologic function tests showed an increased incidence of abnormal Babinski reflexes in Ranch Hand personnel compared to the comparison group and an exposure-related decrease in nerve conduction velocity of the ulnar nerve only in enlisted flyers. The authors dismissed these effects because they did not find defined neurologic disease in the cohort. The same measures of neurologic health and function (except for nerve conduction velocity) were evaluated in the follow-up morbidity study of Ranch Hand personnel (Lathrop, et al., 1987) as in the baseline study. The results of this analysis were similar to those of the baseline study. Overall, the number of abnormalities decreased in both the Ranch Hand and the comparison group during the interval between the studies. The difference between the groups with regard to Babinski reflex seen in the baseline study was not seen in the follow-up. In fact, the Ranch Hand cohort had fewer abnormal Babinski reflexes than the comparison group in this study. While there were no

statistically significant differences between the Ranch Hand cohort and the comparison group in any of the 27 measures of neurologic function in the follow-up study, abnormalities in some of these measures tended to cluster in the Ranch Hand cohort. The authors concluded, therefore, that continued surveillance of neurologic function was necessary within the cohort. Finally, as stated earlier, in the February, 1990 release of the "1987 Follow-up Examination Results" on Ranch Hand, statistically significant group differences with a harmful impact on Ranch Hand veterans were detected in several health areas, including, hereditary and degenerative neurological diseases.

The recent CDC Vietnam Experience Study (II Physical Health, 1988) reported that Vietnam veterans had a higher incident (3.0%) of symptoms of peripheral neuropathy (numbness, tingling, burning sensation, or weakness of arms or legs) than non-Vietnam veterans (1.9%). However, this difference was not statistically significant.

Klawans (1987) and Klawans, et al. (1987) reported neurologic problems in 47 railroad workers who were exposed to polychlorinated phenols contaminated by dioxin in early 1979 while cleaning up the chemical spillage following damage to a tank car filled with these chemicals. The initial neurological complaints included a sense of fatigue and muscle aching, both of which have been reported in other individuals following dioxin exposure (Holmstedt, 1980; Oliver, 1975; Bogen, 1979; Pazderova-Vejlupkova, et al., 1981). On detailed neurological examination in December, 1985, 24 of 45 workers (2 had committed suicide) had dystonic writer's cramp and/or action dystonias of the hands. None of the involved individuals had a family history of the dystonia, and all 24 dated the onset of the dystonia to the first 2 to 3 years subsequent to



early 1979. Thirty-five of the 45 workers also manifested postural and terminal intention tremor which resembled benign essential tremor. None of the involved individuals had a family history of tremor and all dated the onset of the tremor after early 1979. Forty-three of the 45 patients had histories and findings suggestive of peripheral neuropathy. In summary, Klawans (1987) and Klawans, et al., (1987) reported a rather stereotyped set of neurologic problems following exposure to TCDD. This syndrome initially included fatigue, muscle cramping and peripheral neuropathy followed by depression, changes in mentation and finally by action dystonias and tremors on the hands.

Peripheral neuropathy following accidental exposure to TCDD has also been reported by other investigators. Subclinical neurologic damage, including reduced nerve conduction velocity, was reported at a greater incidence in residents of Seveso, Italy, who were exposed to TCDD (Pocchiari, et al., 1979). Barbieri, et al. (1988) recently reported that clinical and electrophysiological signs of peripheral nervous system involvement occurred with a statistically increased frequency in the Seveso population 6 years after the accident, although a peripheral neuropathy was not evident in any of the chloracne patients using the WHO diagnostic criteria. In a 10- year study of 80 workers exposed to TCDD between 1965 and 1968, Pazderova-Vejlupkova, et al. (1981), reported that 23% of the exposed workers had peripheral neuropathy predominantly involving the lower extremities. Singer, et al. (1982) also performed nerve conduction velocity studies in workers employed in the manufacture of phenoxy herbicides. Duration of employment was significantly correlated with slowing of sural nerve conduction velocity. Altogether, 46%



of the study group had one or more slowed nerve conduction velocities, versus 5% of the control group ( $P < 0.001$ ).

Goldstein, et al. (1959) reported that humans exposed to 2,4-D have neurologic symptoms which include numbness in the fingers and toes, muscle aches and fatigue, and tetany of the limb muscles and ataxia. 2,4-D has been reported to inhibit normal nerve functioning, decreasing nerve conduction velocities and damaging peripheral nerves. These effects have been described as peripheral neuropathy (Wallis, et al., 1970). The neuromuscular syndrome in humans associated with 2,4-D exposure thus consists of hyperesthesia and myotonia in the muscles of the extremities, hyporeflexia, and general muscular weakness leading to ataxia. Central nervous system effects have also been reported and were manifested as aberrant spontaneous electrical activity of the cerebral cortex and reticular formation as measured by EEG (Kontek, et al., 1973).

#### REPRODUCTIVE AND DEVELOPMENTAL EFFECTS

Following review of the scientific literature, it is concluded that the evidence supporting the existence of a significant statistical association between exposure to phenoxyacetic acid herbicides and/or their associated contaminants (chlorinated dioxins) and reproductive and developmental effects is at least as strong as the evidence of a lack of the association. Evidence in support of this conclusion follows.

##### Fertility

The CDC Vietnam Experience Study (1988) found Vietnam veterans to have significantly lower mean sperm concentration and significantly lower levels of morphologically "normal" sperm than non-Vietnam veterans. Both of these

parameters have traditionally been used as indicators of reduced fertility potential.

#### Miscarriage

The percentage of spouses' pregnancies which resulted in miscarriages was significantly higher for Vietnam veterans than controls. Logistic regression analysis showed that Agent Orange exposure and maternal smoking were both independently and significantly associated with miscarriage rates in a dose-related manner (Stellman, et al., 1989). A statistically significant association between increasing herbicide exposure and miscarriage was also reported in the officer subgroup in the Air Force Study of Ranch Hand personnel who were responsible for herbicide spraying in Vietnam (Albanese, 1988). Greater fetal loss was also reported in a population of Vietnam veterans currently living in Tasmania (Field and Kerr, 1988). Accidental exposure to TCDD in 1976 in Seveso, Italy, has also been associated with an apparent elevation in the rate of spontaneous abortions in the exposed population (Bruzzi, 1983; Bianco, et al., 1984).

Of all the Vietnamese studies, the North Vietnamese studies by Nguyen Can, et al. (1983) and Ton Duc Lang, et al. (1983, 1986) appear to have been conducted most nearly in accordance with accepted epidemiologic methods. They both support the hypothesis that paternal exposure to the components of Agent Orange (while serving in South Vietnam) can adversely affect the products of conceptions occurring considerably later (post-war North Vietnam). Nguyen Can, et al. (1983) reported that elevated incidences of spontaneous abortion and congenital malformation, but not stillbirth or molar pregnancy, were associated with the father having been in South Vietnam during the war. Ton Duc Lang, et al. (1983, 1986) also claimed that the degree of the father's



exposure, determined by the region of South Vietnam in which they had served, was associated with the extent to which the incidence of malformations was increased.

#### Birth Defects

Several studies report a higher incidence of selected birth defects in children of Vietnam veterans than controls. An Air Force study of Ranch Hand personnel, responsible for the herbicide spraying in Vietnam, reported a statistically significant increase in reported birth defects in the Ranch Hand group (Albanese, 1988). Defects reported in the Ranch Hand group included skin defects, neural tube defects, heart defects, oral clefts, and kidney defects. A preliminary analysis of medical records of children reported abnormal has also indicated that overreporting of defects may not account for the excess in birth defects in the Ranch Hand group. A recent CDC study (CDC, 1988) reported that hospital birth records did show a higher incidence of live births with cerebrospinal malformations in children of Vietnam veterans, however the results were not statistically evaluated. Erickson, et al. (1984) also reported that the risks for fathering an infant with spinabifida, cleft lip (with or without cleft palate), and "other neoplasms" such as neuroblastomas were higher for Vietnam veterans than controls. These increases were also significantly associated with increased scores on the Agent Orange Exposure Opportunity Index (Erickson, et al., 1984). An increased incidence of birth defects was also reported in a population of Vietnam veterans currently living in Tasmania (Field and Kerr, 1988). The veteran's reproductive outcome contained significantly more children with major and minor abnormalities, tumors, chronic health problems, and learning, behavioral, sensory and other relatively minor problems. Field and Kerr



(1988) found three tissue systems were predominantly affected: the central nervous, the skeletal, and cardiovascular systems. Reproductive studies in North Vietnamese populations also report an association between paternal exposure to Agent Orange, while serving in South Vietnam, and an elevated incidence of congenital malformation (Nguyen Can, et al., 1983; Ton Duc Lang, et al., 1983 and 1986).

Additional reports of reproductive studies of populations potentially exposed to dioxins in Seveso, Italy, and in Midland County Michigan suggest the possibility of increased incidences of birth defects. A suggestive increase in the rates of certain birth defects (angioma, CNS defects, hypospadias, hip dislocation, defects of the digestive tract) has been reported in the Seveso population potentially exposed to dioxin (Bruzzi, 1983; Bianco, et al., 1984). The Michigan Dept. of Public Health (MDPH, 1983) examined the rates of birth defects in Midland County and for the period from 1970 to 1975 reported significantly elevated rates of hip dislocations, cleft lip with or without cleft palate, cleft palate without cleft lip, hypospadias, and epispadias relative to the rate in the state as a whole. In a subsequent investigation of the potential association between exposure to trichlorophenol and its associated chlorinated dioxin contaminants and birth defects, Lock, et al. (1984) investigated birth outcomes in 29 trichlorophenol-producing counties in the United States. The rates of hip dislocation without CNS involvement and atrial septal defects were significantly elevated in 6 to 29 trichlorophenol-producing counties.

In summary, elevated incidences of specific birth defects have been found in several studies. Elevated rates of hypospadias, oral clefts, cardiovascular defects, and hip dislocations have been reported in more than

one study and are thus suggestive of an association between these defects and exposure to phenoxy herbicides, chlorophenols and their associated chlorinated dioxin contaminants. Definitive interpretation of the assembled data on the reproductive toxicity of these substances in humans is constrained by limited power of the studies to detect modest increase in detrimental effects, inadequate characterization of actual exposure, and possible biases in reporting of adverse effects.

#### OTHER HEALTH EFFECTS

Other health effects which are associated, but not with formal statistical significance, with exposure to phenoxyacetic acid herbicides and/or their associated contaminants (chlorinated dioxins) are described below.

##### Immunological Abnormalities

Jennings, et al. (1988) investigated immunological abnormalities 17 years after accidental exposure to TCDD. Antinuclear antibodies and immune complexes were detected significantly more frequently in the peripheral blood of workers exposed to dioxin. Although the significance of this finding is not clear, it may reflect prior tissue damage and cellular destruction in the exposed population. The number of natural killer cells identified by the monoclonal antibody Leu-7 was significantly higher in workers exposed to dioxin. Natural killer cells are believed to contribute to defense against viruses and tumors. If exposure to dioxin is associated with an increased risk of neoplastic disease, the number and function of natural killer (NK) cells may be important in its pathogenesis. Alternatively, changes in the number of NK cells may show activation of the body's defenses. The authors



suggest that further studies of NK cell number and function should be conducted in subjects exposed to dioxin.

Studies of residents of Quail Run mobile home park in Missouri suggest alterations in immune function, but these were not consistently found (Hoffman, et al., 1986; Knutsen, et al., 1987; Stehr-Green, et al., 1987, 1988). Immunologic tests showed that the exposed group had an increased frequency of anergy (11.8% vs. 1.1%) and relative anergy (35.4% vs. 11.8%); the exposed group also had non-statistically significant increased frequency of abnormal T-cell subset tests (10.4% vs. 6.8%), a T4/T8 ratio  $< 1.0$  (8.1% vs. 6.4%) and an abnormality in the in vitro functional T-cell tests (12.6% vs. 8.5%). The authors concluded that these findings suggest an association between long-term exposure to TCDD and depressed cell-mediated immunity, although the effects have not resulted in an excess of clinical illness in the exposed group.

Immune function was evaluated between 1976 and 1979 in 48 children from Seveso who were heavily exposed to TCDD (Mocarelli, et al., 1985). Exposed children showed higher titers of total hemolytic complement activity than controls in all the screens. They also had lymphocyte responses to phytohemagglutinin and poke weed mitogen significantly higher than controls in the first half of the screens.

#### Gastrointestinal Tract Ulcer

Two studies of workers exposed to 2,4,5-T and TCDD have reported a statistically significant greater frequency of gastrointestinal ulcer in the exposed populations (Bond, et al., 1983; Suskind and Hertzberg, 1984). The CDC Vietnam Experience Study (II Physical Health, 1988) reported that occult blood was found in the stool samples of more Vietnam (1.3%) than non-Vietnam



(0.5%) veterans. While this finding is suggestive of injury to the gastrointestinal tract, there was no report of a greater frequency of ulcer in the population of Vietnam veterans.

#### Psychosocial Effects

A CDC Vietnam Experience Study (1988) reported that 15 to 20 years afterward, more Vietnam veterans have psychological and emotional problems compared with veterans who did not serve in Vietnam. Psychological problems significantly more prevalent among Vietnam veterans include depression (4.5% of Vietnam veterans vs 2.3% of non-Vietnam veterans), anxiety (4.9% vs 3.2%), and alcohol abuse or dependence (13.7% vs 9.2%). About 15% of Vietnam veterans experienced combat-related post-traumatic stress disorder at some time during or after military service, and 2.2% had the disorder during the month before the examination.

Through use of a battery of neuropsychological tests, Levy (1988) reported evidence of organic psychological deficits in Vietnam veterans exposed to Agent Orange. The exposed group consisted of 6 individuals with active cases of Chloracne, a medical indication of exposure to Agent Orange. The 25 control subjects also served in Vietnam, may have been exposed to Agent Orange, but apparently never showed signs of chloracne. It is important to note that there is a large interindividual variability in the expression of chloracne and no apparent threshold of exposure necessary for this response. The exposed Vietnam veterans showed a significantly higher rate of post-traumatic stress disorder and its associated features of depression, anxiety, and increased aggression. Levy suggests that for certain individuals this condition cannot be explained by combat stress alone and that Agent Orange exposure may contribute to this disorder. Industrial workers who have been

exposed to TCDD present psychological symptoms (Bauer, et al., 1961; Oliver, 1975) which duplicate those that have been attributed to the delayed effects of combat stress in Vietnam veterans.

Stellman, et al., (1988) investigated the social and behavioral consequences of the Vietnam experience among American Legionnaires. They reported that men who faced high levels of combat intensity were found to be at greater risk for divorce and for generally being less happy and satisfied with their lives, their marriages, their role as fathers, and as sexual human beings. Their data also gave some indication that certain behavioral effects related to combat intensity may be exacerbated by concurrent exposure to herbicides and indicate the need for further exploration of this issue. In a related study, Snow, et al., (1988) found a distinct linear dose-response relationship between combat stress and a quantitative measure of post-traumatic stress disorder intensity. The potential contributing role of Agent Orange exposure was not considered in this study.

Poland (1971) found high scores for hypomania on the Minnesota Multiphasic Personality Inventory to be associated with chloracne and 2,4-D and 2,4,5-T exposure. Oliver (1975) reported personality changes in a small number of laboratory workers exposed to TCDD.

Green (1987) reported a statistically significant excess number of deaths due to suicide in a group of 1,222 male forestry workers who were exposed to 2,4-D and 2,4,5-T. Fitzgerald, et al. (1989) reported on health effects 3 years after potential exposure to the toxic contaminants of an electrical transformer fire (potential exposure to PCBs, PCDFs and PCDDs). Two suicides were observed compared with 0.31 expected, but the difference was not statistically significant, (482 persons were potentially exposed).



### Altered Lipid Metabolism

There is a relatively consistent finding in many populations of altered lipid metabolism, expressed as altered HDL/LDL, cholesterol, and triglyceride levels, which is consistent with what is known about the metabolic effects of dioxin in animal studies. This has implications for the potential risk of cardiovascular disease (Silbergeld and Gasiewicz, 1989).

### HUMAN EXPOSURE TO 2,3,7,8-TCDD

#### 2,3,7,8-TCDD in Human Adipose Tissue

In human adipose tissue, levels of 2,3,7,8-TCDD averaging 5-10 ppt have been reported for background populations in St. Louis, MO, by Graham, et al. (1986), in Atlanta, GA, and Utah by Patterson, et al. (1986), and in Canada by Ryan, et al. (1985). Sielken (1987) evaluated these data and concluded that the levels of 2,3,7,8-TCDD in human adipose tissue are log-normally distributed and positively correlated with age. Among the observed United States background levels of 2,3,7,8-TCDD in human adipose tissue, more than 10% were >12 ppt.

Patterson, et al. (1986) analyzed the adipose tissue of 39 persons with a history of residential, recreational or occupational exposure in Missouri, and in 57 persons in a control group. All participants had detectable levels of 2,3,7,8-TCDD in their adipose tissue, but the exposed group had significantly higher levels. Levels in six of the exposed persons were more than 5 times greater than the level of the highest control. Thus, measuring 2,3,7,8-TCDD in adipose tissue can provide an index of exposure.

Adipose tissue has been examined to determine if levels of 2,3,7,8-TCDD in this reservoir correlated with exposure. Adipose tissues of Vietnam



veterans exposed to Agent Orange and humans occupationally exposed to potential sources of 2,3,7,8-TCDD were reported to have up to 10 times the level of 2,3,7,8-TCDD than unexposed control subjects (Schechter, et al., 1985, 1987, 1989; Gross, et al., 1984, Kahn, et al., 1988); however, another study by Weerasinghe, et al. (1986) failed to detect any difference between a group of 13 veterans and unexposed subjects. In the most recent study, Schechter, et al., (1989) reported the highest adipose tissue levels of 2,3,7,8-TCDD in veterans who handled the Agent Orange herbicide.

#### 2,3,7,8-TCDD in human blood

Henderson and Patterson (1988) investigated the distribution of [<sup>3</sup>H]2,3,7,8-TCDD in human whole blood and its association with lipoproteins. They found that [<sup>3</sup>H]2,3,7,8-TCDD was associated entirely with the red cell free phase and that >80% was associated with lipoproteins. The distribution of [<sup>3</sup>H]2,3,7,8-TCDD among lipoprotein fractions from three fasting, normolipemic donors found 55, 17 and 27% of the compound associated with LDL, VLDL and HDL fractions, respectively. The authors indicated that since 2,3,7,8-TCDD in blood favors the lipoprotein vehicle, the cellular lipoprotein receptors, especially LDL receptors, may be important in the uptake and subsequent cellular effects of 2,3,7,8-TCDD.

Recently, Patterson, et al. (1987) developed a high-resolution gas chromatographic/high-resolution mass spectrometric analysis for 2,3,7,8-TCDD in human serum. The arithmetic mean of the individual human serum samples was 47.9 ppq on a whole-weight basis and 7.6 ppt on a lipid weight basis. Paired human serum and adipose tissue levels of 2,3,7,8-TCDD have been compared by Patterson, et al. (1988) and Kahn, et al. (1988). Both laboratories reported a high correlation between adipose tissue and serum 2,3,7,8-TCDD levels when

the samples were adjusted for total lipid content. This correlation indicates that serum 2,3,7,8-TCDD is a valid measurement of 2,3,7,8-TCDD body burden concentration.

A lack of correlation between estimated exposure to 2,3,7,8-TCDD and sera levels of 2,3,7,8-TCDD was reported in a preliminary report in the MMWR (1987) which compared Vietnam veterans with military histories indicating exposure to herbicides containing 2,3,7,8-TCDD and non-Vietnam veterans with presumably no unusual exposure to 2,3,7,8-TCDD. At least in these preliminary results there was no difference in the range of 2,3,7,8-TCDD levels (1-9 ppt based on lipid weight) or the median 2,3,7,8-TCDD level (3.9 ppt for the presumably exposed group and 3.8 ppt for the non-exposed group). The completed CDC Veterans Health Study (1988) assessed serum levels of 2,3,7,8-TCDD in 646 ground combat troops who served in Vietnam and in 97 veterans who did not serve in Vietnam. The serum 2,3,7,8-TCDD levels in Vietnam veterans was  $4.2 \pm 2.6$  (mean  $\pm$  S.D.) ppt on a lipid weight basis and  $4.1 \pm 2.3$  ppt for non-Vietnam veterans. Only two men, both Vietnam veterans, had clearly elevated levels ( $>20$  ppt). The authors of the study suggest that most U.S. Army ground troops who served in Vietnam were not heavily exposed to 2,3,7,8-TCDD, with the possible exception of men involved in handling herbicides, but, as stated earlier, this study has been criticized by scientists who were at one time involved with it. In a study of potentially heavily exposed Vietnam veterans, MMWR (1988) reported on an Air Force study of Ranch Hand veterans who were either herbicide loaders or herbicide specialists in Vietnam. The mean serum 2,3,7,8-TCDD level of 147 Ranch Hand personnel was 49 ppt, based on total lipid-weight, while the mean serum level of the 49 controls was 5 ppt. Additionally, 79% of the Ranch Hand personnel and 2% of the controls had 2,3,7,8-TCDD levels  $\geq 10$  ppt. The



distribution of 2,3,7,8-TCDD levels in this phase of the Air Force health study indicates that some Ranch Hand personnel had unusually heavy 2,3,7,8-TCDD exposure. This report also estimated the half-life of 2,3,7,8-TCDD in humans to be 7 years on the basis of 2,3,7,8-TCDD levels in serum samples taken in 1982 and 1987 from 36 of the Ranch Hand personnel who had 2,3,7,8-TCDD levels >10 ppt in 1987. Similar results were obtained by another laboratory, which compared 2,3,7,8-TCDD levels in blood and adipose tissue of Agent Orange-exposed Vietnam veterans and matched controls (Kahn, et al., 1988). This study also examined heavily exposed Vietnam veterans who handled herbicides regularly while in Vietnam. Vietnam veterans who were heavily exposed to Agent Orange exceeded matched control subjects in both blood and adipose tissue levels of 2,3,7,8-TCDD but not in the levels of the 12 other 2,3,7,8- substituted dioxins and dibenzofurans that were detected. Since only 2,3,7,8-TCDD among these compounds was present in Agent Orange but all are present in the population of the industrialized world, it is likely that the elevated 2,3,7,8-TCDD levels arose from wartime exposure. Although this study may be able to distinguish heavily exposed men from others, the data do not address the question of identifying persons whose exposures are moderate and who may constitute the bulk of the population, both military and civilian, who have been exposed to greater than background levels of 2,3,7,8-TCDD.

#### Excretion of 2,3,7,8-TCDD in Humans

Poiger and Schlatter (1986) investigated the excretion of 2,3,7,8-TCDD in a 42-year old man after injection of 105 ng [<sup>3</sup>H]-2,3,7,8-TCDD in 6 ml corn oil. The half-life for elimination was estimated to be 2120 days. In another study, the half-life of 2,3,7,8-TCDD in humans was estimated to be 7 years on the basis of 2,3,7,8-TCDD levels in serum samples taken in 1982 and 1987 from



36 of the ranch hand personnel who had 2,3,7,8-TCDD levels >10 ppt in 1987 (MMWR, 1988). In a subsequent report, Pirkle, et al., (1989) reported that the median half-life of 2,3,7,8-TCDD in these Ranch Hand veterans was 7.1 years (95% confidence interval about the median of 5.8 - 9.6 years), [however, this study also shows that serum dioxin testing is unreliable 16% of the time and that dioxin in humans has a potentially wide range for half-life, which, at the low end, would bring subjects down to background in relatively short periods.] These studies indicate that 2,3,7,8-TCDD is exceedingly persistent in humans.

The caveat in the use of any of this data, due to problems with test reliability and sensitivity, and half-life variability, is that, although the presence of elevated 2,3,7,8-TCDD in tissue, serum or excreta indicates exposure, its absence does not necessarily indicate lack of exposure.

#### CONCLUSIONS

This review of the scientific literature leads to the following conclusions:

(1) There is a significant statistical association between exposure to phenoxyacetic acid herbicides and/or their associated contaminants (chlorinated dioxins) and non-Hodgkin's lymphoma, soft tissue sarcoma, skin disorders/chloracne, subclinical hepatotoxic effects (including secondary coproporphyrinuria and chronic hepatic porphyria), and porphyria cutanea tarda (most likely only in individuals with inherited uroporphyrinogen decarboxylase deficiency). The aggregate interpretation of several sound studies showing a statistically significant association for each of these conditions makes this conclusion inescapable.

(2) The scientific evidence supporting the existence of a significant statistical association between exposure to phenoxyacetic acid herbicides and/or their associated contaminants (chlorinated dioxins) is at least as strong as the scientific evidence of a lack of the association for the following adverse health effects: Hodgkin's disease, neurologic effects, and reproductive and developmental effects. For each of these health effects, there are sound scientific studies showing statistical significance and strong scientific evidence of an association between exposure and effect. However, a statistically significant association is not as consistently supported for these effects as for the first group of health effects.

(3) The above eight adverse health effects satisfy the VA's test for an association which qualifies for disability compensation, i.e., where the scientific evidence shows that a significant statistical association is "at least as likely as not." 38 C.F.R. § 1.17(d)(1).

(4) There are other adverse health effects for which there is sound scientific evidence of an association with exposure, but the evidence does not reach the level of formal statistical significance. The limited data available at this time show an association, but not a significant statistical association, between exposure to phenoxyacetic acid herbicides and/or dioxin and the following diseases: leukemias, cancers of the kidney, testis, pancreas, stomach, prostate, colon, hepatobiliary tract, and brain, psychosocial effects, immunological abnormalities, gastrointestinal ulcer, and altered lipid metabolism. Further research should be directed at these associations, and policy-makers, cognizant of the limitations on finding significant statistical associations and of the obligation to give the veteran the benefit of the doubt, would be justified in viewing these



disorders in a more conclusive light for the purpose of establishing entitlement to disability compensation.

(5) The epidemiologic evidence on the associations between exposure and the adverse health effects described above is strongly supported by a wide range of experimental animal studies.

#### SELECTED SECONDARY CONCLUSIONS

(1) Contrary to the contention of the authors, the CDC Selected Cancers Study may provide additional support to the evidence that exposure to Agent Orange in Vietnam caused an increased risk of non-Hodgkin's lymphoma.

(2) The exposure index used in the Air Force's Ranch Hand Study is not a good measure of actual dioxin exposure, and statistically significant individual findings are not possible because of the small size of the group under study. Statistically significant group differences with a harmful impact on Ranch Hand veterans have been detected in several health areas, including: all cancers combined, both verified and suspected; skin cancers alone; hereditary and degenerative neurological diseases; coordination abnormalities; psychological and sleep disorders; certain dermatologic disorders; pulse irregularities; increase in thyroid stimulating hormone; among black Ranch Hands, higher mean counts for "natural killer cells" as compared to blacks in the control group; and among Ranch Hands who are heavy smokers, more abnormal composite skin reactions as compared to heavy smokers in the control group.

(3) Although the presence of elevated 2,3,7,8-TCDD in tissue, serum or excreta indicates dioxin exposure, its absence does not necessarily indicate a lack of exposure because of problems with test reliability and sensitivity,



and half-life variability.

## APPENDIX A

### ILLUSTRATIVE STATEMENTS IN THE LITERATURE ON THE SCIENTIFIC VALIDITY OF EXTRAPOLATION OF EXPERIMENTAL ANIMAL CARCINOGENICITY DATA TO HUMAN CANCER RISK

Report of the Secretary's Commission on Pesticides and Their Relationship to Environmental Health, 1969 (Advisory Panel on Carcinogenicity of Pesticides, U.S. Dept. HEW, December 1969).

"Any substance which is shown conclusively to cause cancers in animals, when tested under (adequate) conditions, should be considered potentially carcinogenic for man --."

Ad Hoc Committee on the Evaluation of Low Levels of Environmental Chemical Carcinogens, 1970 (Report to the Surgeon General, USPHS, April 22, 1970).

"Any substance which is shown conclusively to cause tumors in animals should be considered carcinogenic and therefore a potential cancer hazard for man. Exceptions should be considered only where the carcinogenic effect is clearly shown to result from physical, rather than chemical, induction, or where the route of administration is shown to be grossly inappropriate in terms of conceivable human exposure."

Interagency Regulatory Liaison Group, Working Group on Risk Assessment, 1979 ("Scientific Basis for Identification of Potential Carcinogens and Estimation of Risks", J. Nat. Cancer Inst. 63:243-268, 1979).

"Ordinarily, if a substance has produced positive results in a single adequately designed and conducted animal bioassay and no other data are available, the conclusion is that the substance is likely to pose a risk of cancer to humans. --Further confirmation that the substance poses a carcinogenic hazard to humans is obtained from bioassay data showing reproducibility of results, positive dose-response relationships and concordance of results."

"Moreover, negative epidemiologic data, questionable because of limitations in the power of detection of such studies, do not deny the conclusion of carcinogenicity on the basis of animal bioassays."

Occupational Safety and Health Administration, 1980 ("Identification, Classification and Regulation of Potential Occupational Carcinogens", Fed. Reg. 45:5001-5296, 1980).

Based on detailed, testimony from a wide range of recognized scientific authorities, and on an extensively documented record, OSHA concluded as follows:



"The validity of qualitatively extrapolating animal test results to humans is firmly based upon substantial and empirical evidence in the Record, ---. Not only have experiments in test mammalian animals given positive carcinogenic test results for every compound known to cause cancer in humans, except arsenic and perhaps benzene, but although there may be wide variations in the susceptibility of various species to cancer, evidence indicates that a substance that causes cancer in one mammalian animal species is likely to do so in most other mammalian species tested. Substantial evidence and scientific data in the Record indicate, in sum, that laboratory animals are suitable test models for determining the cancer-causing potential of a toxic substance to humans."

"OSHA concludes that the general principle that substances shown to be carcinogenic in test animals should be presumed to pose a qualitative carcinogenic hazard to exposed humans was overwhelmingly supported, except as so qualified below (in relation to the adequacy of the carcinogenicity test); indeed, the specific scientific documentation for the principle is steadily being enlarged."

"Retrospective epidemiologic studies of exposed workers are very difficult to carry out in a systematic and unbiased manner, and in fact comparatively few good studies have been reported."

"Epidemiologic studies are complicated by many factors, including the selection of exposed and control groups, definition and measurement of exposure, length of exposure and follow-up periods, and various kinds of bias."

"'Non-positive' epidemiologic studies cannot, in principle, establish the safety of agents under suspicion on other grounds. None of the studies presented as 'non-positive' in this rulemaking (including those on DDT, Aldrin/Dieldrin, Chlordane/Heptachlor, Phenobarbital, 3,3'-Dichlorobenzidine, Isoniazid, 2,4-Dinitrotoluene, Fibrous Glass and Saccharin) stands up to critical scrutiny."

Toxic Substances Strategy Committee, 1980 ("Toxic Chemicals and Public Protection", Council on Environmental Quality, May, 1980).

"Properly designed and conducted tests using appropriate animal species are accepted valid ways to identify chemical substances that may cause cancer in humans. -- Most data for identifying potential cancer risks must come from animal studies. -- Animal tests are a scientifically sound and valid way to identify substances that are likely to cause human cancer."

"In one study of chemicals and chemical processes, 26 substances linked to human cancers were examined. All but two produced cancer in animals (Tomatis et al, 1978). Six were first identified as animal carcinogens and only later were found to cause cancer in humans."

Office of Technology Assessment, 1981 ("Assessment of Technologies for Determining Cancer Risks from the Environment", Congress, U.S., OTA, June 1981).



"Chemicals cannot be tested for carcinogenicity in humans because of ethical considerations. A substantial body of experimentally derived knowledge and the preponderance of expert opinion support the conclusion that testing of chemicals in laboratory animals provides reliable information about carcinogenicity. Animal tests employ whole mammal systems, and although they differ one from another, all mammals, including humans, share many biological features (NRC, 1977)."

"Effects in animals, properly qualified, are applicable to man. This premise underlies all of experimental biology and medicine, but because it is continually questioned with regard to human cancer, it is desirable to point out that cancer in men and animals is strikingly similar. Virtually every form of human cancer has an experimental counterpart, and every form of multicellular organism is subject to cancer, including insects, fish, and plants. Although there are differences in susceptibility between different animal species, and between individuals of the same strain, carcinogenic chemicals will affect most test species, and there are large bodies of experimental data that indicate that exposures that are carcinogenic to animals are likely to be carcinogenic to man, and vice versa."

State of California, Department of Health Sciences, 1982 ("Carcinogen Identification Policy: A Statement of Science as a Basis for Policy". Cal. DHS, July, 1982).

"The validity of using animal bioassays to identify substances that pose cancer risks to humans rests upon both theoretical and empirical evidence. On the theoretical side, cancer in humans is likely to be biologically similar to cancer in other mammals (see "Oncogens", page 11); and most carcinogens are believed to act on the same basic biological systems in all mammalian species. Empirically, most substances that are carcinogenic in one animal species are also found to be carcinogenic in other animal species when adequately tested. Further, almost all substances that are known to be carcinogenic in humans, for which animal data exist, are also carcinogenic in animals. Thus, there is substantial scientific support for the assumption that a substance carcinogenic in animals will, with high probability, be carcinogenic in humans."

Office of Science and Technology Policy, 1985 ("Chemical Carcinogens: A Review of the Science and Its Associated Principles". Federal Register 50:10372-10440, March 14, 1985).

"In the absence of adequate data in humans, it is reasonable for practical purposes to regard chemicals for which there is sufficient evidence of carcinogenicity in animals as if they presented a carcinogenic risk to humans."

NRC/NAS, 1986 ("Drinking Water and Health", Safe Drinking Water Committee, NAS/NRC, National Academy Press, Washington, D.C., 1986).

"Positive results in properly conducted animal bioassays are considered to be predictors of qualitative response in humans (IARC, 1980; NRC, 1977,



1983; NTP, 1984; OSTP, 1985; OTA, 1981). The scientific rationale for this approach is simply that animals are the closest models to the human for cancer studies. In addition, many carcinogens produce cancer in several species, and all known human carcinogens have been shown to produce tumors in at least one animal model (NTP, 1984). Benzene and arsenic trioxide, the two former holdouts from this general rule, have now been shown to be carcinogenic in animals (Goldstein, et al., 1982; Maltoni and Scarnato, 1979; Pershagen, et al., 1984). For some chemicals (e.g., aflatoxin B1, DES, vinyl chloride, mustard gas, melphalan, and 4-aminobiphenyl), the positive results in experimental animals preceded the epidemiological evidence. The overall patterns of chemical metabolism are generally similar in humans and laboratory animals (Rall, 1979), although the rates of metabolism and the type and site of cancer may differ (IRLG, 1979; OTA, 1981). For example, the metabolism of B(a)P is qualitatively the same in all species and systems studied (Sims, 1976)."

Office of Technology Assessment, 1987 ("Identifying and Regulating Carcinogens: A Background Paper", Congress U.S., OTA, November, 1987).

"All policies accept the use of animal data as predictive for human beings. Explicitly or implicitly, all the policies acknowledge that substances shown to be carcinogenic in animals should be presumed to present a carcinogenic hazard to humans.

"An often-quoted statement on the value of animal data in assessing human risk is that of IARC. Their principle is based on two points: that a number of chemicals were first identified as animal carcinogens, and then evidence confirmed carcinogenicity in humans. Second, all chemicals accepted as human carcinogens that have been adequately studied in animals are positive in at least one species. IARC concluded:

"Although this association cannot establish that all animal carcinogens also cause cancer in humans, nevertheless, in the absence of adequate data on humans, it is biologically plausible and prudent to regard agents for which there is sufficient evidence of carcinogenicity in experimental animals as if they presented a carcinogenic risk to humans.'" (IARC, 1987).

Huff, et al. (NIEHS), 1988 ("Carcinogenesis Studies: Results of 398 Experiments in 104 Chemicals from the U.S. National Toxicology Program." Ann. N.Y.A.S., 534:1-30, 1988).

"All chemicals known to increase cancer in humans that have been studied under adequate experimental conditions, also cause cancer in laboratory animals."

Nicholson, 1988 ("IARC Evaluation in the Light of Limitations of Human Epidemiologic Data", Ann. N.Y.A.S. 534:44-54, 1988).

Based on a detailed review of the limitations and difficulties in epidemiologic studies, Nicholson concluded:



"Considerable human data are available that would causally associate human cancer with occupational exposures through the identification of substantial workplace risks. Much additional data are available, indicating lesser risks, that have not achieved widespread acceptance because of the limitations of epidemiologic techniques. Limitations of epidemiologic techniques also limit the associations that can be made, using general population data, between cancer mortality and occupation. These same uncertainties, however, also affect assertions of absence of effect. Apparently 'negative' results must be evaluated with the same critical view as are most 'positive' results."

Rall, (NIEHS), 1988 ("Laboratory Animal Toxicity and Carcinogenesis: Testing, Underlying Concepts, Advantages and Constraints." Ann. N.Y.A.S. 534:78-83, 1988).

"A National Academy of Sciences/National Research Council (NAS/NRC) panel on pesticide use (published as Contemporary Pest Control Practices and Prospects) examined the relationship between dose of various chemicals that appeared to cause cancer in humans and in laboratory animals. When the lowest carcinogenic dose in the most sensitive species was compared to that in humans for three compounds -- benzidine, chlornaphazine and cigarette smoke -- a close relationship was found. The animals were more sensitive for another three compounds: aflatoxin, diethylstilbestrol (DES), and vinyl chloride.

"In summary, of the 23 compounds or mixtures (which are carcinogenic in humans), 21 are positive in animal carcinogenicity studies, one is questionable (azathioprine), and one has simply not been studied (treosulphan, an obscure cancer chemotherapeutic agent). In terms of site-specificity, one or more sites in the human were predicted by laboratory animals for 18 of the 23 agents, including treosulphan and azathioprine. If these two are not included since they were not tested there in laboratory animals, the sites were the same for 18 out of 21 compounds. I have grouped leukemia, lymphoma, and reticuloendothelial disease. This all suggests that animals predict fairly well for humans."

There are "-- seven compounds or groups of compounds which were discovered to be carcinogenic first in laboratory animals. Demonstration of carcinogenicity in human studies came later: 4-aminobiphenyl, diethylstilbestrol, mustard gas, vinyl chloride, aflatoxins, bis(chloromethyl) ether, and melphalan."

Tomatis (IARC), 1988 ("The Contribution of the IARC Monographs to the Identification of Cancer Risk Factors", Ann. N.Y.A.S. 534:31-38, 1988).

It is fallacious to assume "-- that the existence of human data per se (independently of their quality) indicated a higher probability that the exposure was carcinogenic to humans, or even that exposures for which only experimental results are available do not represent a human health hazard. In fact, within the IARC Monographs, it is considered reasonable, for practical purposes, to regard chemicals for which there is sufficient evidence of carcinogenicity derived from experimental results, in the absence of adequate human data, as if they were carcinogenic to humans."



"There are now 119 chemicals evaluated in the Monographs for which experimental data provide sufficient evidence of carcinogenicity but for which there are absolutely no human data. The IARC Directory of Ongoing Research in Cancer Epidemiology for 1985 reports that only nine of these 119 chemicals are subjects of epidemiological surveys."

"In a study undertaken a few years ago, a similar proportion (about nine percent) of the chemicals in current commercial use in the USA, for which there is sufficient evidence of carcinogenicity in experimental animals, was found to be the object of epidemiological study or medical surveillance. -- Small numbers of exposed individuals, short durations of exposure or simultaneous exposure to such a variety of compounds as to obscure the effect of the one compound in particular, may in some instances raise insurmountable difficulties for carrying out an epidemiological study."

"Obviously, the existence of sufficient evidence of carcinogenicity in experimental tests has not exerted the same attraction for epidemiologists as for experimentalists, as evidenced by this relatively low frequency of epidemiological surveys."

AFL-CIO v. Duekmejian, 1989 (212 Cal. App. 3d 425; Cal. Rptr., July 1989).

The qualitative assessment of carcinogenic risks to humans ordinarily is based on data from experiments in animals. (Guidelines for Chemical Carcinogen Risk Assessments and their Scientific Rationale, Cal. Health and Welfare Agency, Dept. of Health Services (Nov. 1985) p. C-20 [hereafter cited as California Cancer Guidelines]). It is unethical to test humans, and because of 20 to 30 year latency period of many human cancers, epidemiological studies do not adequately warn humans and protect them from the risk of exposure to new carcinogens. (Id., at p. B-10). For recognized human carcinogens, the first evidence of carcinogenicity frequently is found in test animals; only afterwards are cancer effects looked for, and found, in humans (Id., at p. B-24). Thus, the principle which supports qualitative animal to human extrapolation from carcinogenesis "has been accepted by all health and regulatory agencies and is regarded widely by scientists in industry and academia as a justifiable and necessary inference." (Rep., Office of Science and Technology Policy, 50 Fed. Reg. 10375 (March 14, 1985)).

NOTE: Although this appendix refers solely to the extrapolation to humans of animal carcinogenicity data, the same extrapolation holds for other medical effects and for the same reasons. For example, dioxin induced atrophy of the thymus gland and liver damage are seen in all species tested.



## APPENDIX B

### Literature Considered by the Authors but not by the VA's Advisory Committee

- Agent Orange Studies [Letter] Science 245(4922): 1031 September 8 (1989).
- Al-Rajeh, S., Iyer, V., Olson, W.H. Effect of diltiazem on 2,4,- D-induced myotonia in rats. Muscle Nerve 12(6): 470 - 472 June (1989).
- Andrews, J.S. Missouri dioxin studies; an update on long-term health effects. Dioxin '89, Abstract # EPI07.
- Axelsson, O., Dahlgren, E., Jansson, C.D., et al. Arsenic exposure and mortality: A case referent study for a Swedish copper smelter. Br. J. Ind. Med. 35: 8 - 15 (1978).
- Balarajan, R. and Acheson, E.D. Soft tissue sarcomas in agriculture and forestry workers. J. Epidemiology Comm. Health 38: 113 - 116 (1984).
- Bianco, V., Meazza, L., and Remotti, G. Obstetric monitoring in Brianza di Seveso from 1975 to 1981. Report to the Special Office for Seveso, Seveso, Italy. 15 pages (1984).
- Bickers, D.R. The dermatologic manifestations of human porphyria. Ann. N.Y. Acad. Sci. 514: 261 - 338 (1987).
- Bishop, C.M. and Jones, A.H. Non-Hodgkin's lymphoma of the scalp in workers exposed to dioxins. Lancet 2: 369 (1981).
- Blair, A., Malaker, H., Cantor, K.P., Burmeister, L. and Wiklund, K. Cancer among farmers. A review. Scand. J. Work Environ. Health 11: 397 - 407 (1985).
- Bogen, G. Symptoms in Vietnam veterans exposed to Agent Orange. JAMA 242: 2391 (1979).
- Bond, G.G., Bodner, K.M., and Cook, R.R. Phenoxy Herbicides and Cancer: Insufficient epidemiologic evidence for a casual relationship. Fund. Appl. Toxicol. 12: 172 - 188 (1989).
- Bond, G.G., McLaren E.A., Lipps, T.E., Cook, R.R. Update of mortality among chemical workers with potential exposure to the higher chlorinated dioxins. J. Occup. Med. 31(2): 121 - 123 (1989).
- Breslin, P., Kang, H.K., Lee, Y., Burt, V., and Shepard, B.M. Proportionate mortality study of U.S. Army and U.S. Marine Corps veterans of the Vietnam War. J. Occup. Med. 30: 412 - 419 (1988).

- Bruzzi, P. Birth defects in the TCDD polluted area of Seveso: Results of a four-year follow-up. In Coulston, F., and Pocchiari, F., eds. Accidental Exposure to Dioxins, Human Health Aspects. Academic Press, New York. pp. 271 - 280 (1983).
- Buesching, D. P. and Wollstadt, L. Cancer mortality among farmers. JNCI 72: 503 - 504 (1984).
- Burg, R.V. Toxicology update - TCDD. J. Appl. Toxicol. 8: 145 - 148 (1988).
- Burmeister, L.F. Cancer mortality in Iowa farmers, 1971 - 78. JNCI 66: 461 - 464 (1981).
- Burmeister, L.F., Everett, G.D., VanLier, S.F., and Isacson, P. Selected cancer mortality and farm practices in Iowa. Amer. J. Epidemiol. 118: 72 - 77 (1983).
- Calvert, G.M., Sweeney, M.H., Morris, J.A., Fingerhut, M.A., and Hornung, R.W. Pulmonary function and the incidence of chronic bronchitis among workers exposed to TCDD-contaminated substances. Dioxin '89, Abstract # EPIO2.
- Cantoni, L., Rizzardini, M., Graziani, A., Carugo, C., and Garattini, S. Effects of chlorinated organics on intermediates in the heme pathway and on uroporphyrinogen decarboxylase. Ann. N.Y. Acad. Sci. 514: 128 - 140 (1987).
- Cantor, K.P. Farming and mortality from non-Hodgkin's lymphoma: a case-control study. Int. J. Cancer 29: 239 - 247 (1982).
- Cartwright, R.A., McKinney, P.A., O'Brien, C., Richards, D.G., Roberts, B., Lauder, I., Darwin, C.M., Bernard, S.M., and Bird, C.C. Non-Hodgkin's lymphoma: Case control epidemiological study in Yorkshire. Leuk. Res. 12: 81 - 88 (1988).
- CDC Veterans Health Study. Serum 2,3,7,8-Tetrachlorodibenzo-p- dioxin levels in U.S. Army Vietnam-era Veterans. JAMA 260: 1249 - 1254 (1988).
- Constable, J.M., Timperi, R., Clapp, R., Antman, K., and Boynton, B. Vietnam veterans and soft tissue sarcoma. JOM. 29: 726 (1987).
- Cook, R.R. Dioxin, chloracne, and soft tissue sarcoma. Lancet 1: 618 - 619 (1981).
- Council on Scientific Affairs. Council Report: Cancer risk of pesticides in agricultural workers. JAMA. 260: 959 - 966 (1988).
- Council on Scientific Affairs. Health effects of Agent Orange and dioxin contaminants. JAMA 248: 1895 - 1897 (1982).



- Dalager, N., Kang, H., and Burt, V. Non-Hodgkin's lymphoma among Vietnam-era veterans. Dioxin '89, Abstract # EPI10.
- Dalderup, L.M. and Zellenrath, D. Dioxin exposure: 20 year follow-up. The Lancet 1134 - 1135. Nov 12 (1983).
- DelCorno, G., Montesarchio, E., and Fara, G.M. Problems in the assessment of human exposure to tetrachlorodibenzodioxin (TCDD): The marker chloracne. Eur. J. Epidemiol. 1: 139 - 144 (1985).
- Dolan, M.B. A legacy from Vietnam. Am. J. Nurs. 88(4): 594 (1988).
- Doss, M.O., Porphyrinurias and occupational disease. Ann. N.Y. Acad. Sci. 514: 204 - 218 (1987).
- Doss, M., Sauer, H., von Tiepermann, R., and Colombi, A.M. Development of chronic hepatic porphyria (porphyria cutanea tarda) with inherited uroporphyrinogen decarboxylase deficiency under exposure to dioxin. Int. J. Biochem. 16: 369 - 373 (1984).
- Duffard, R.O., Mori de Moro, G.B., and de Duffard, A.M.E. Vulnerability of myelin development of the chick to the herbicide 2,4-dichlorophenoxyacetic butyl ester. Neurochem. Res. 12: 1077 - 1080 (1987).
- Elo, H.A., Hervonen, H., Ylitalo, P. Comparative study on cerebrovascular injuries by three chlorophenoxyacetic acids (2,4-D, 2,4,5-T and MCPA). Comp. Biochem. Physiol. [C] 90: 65 - 68 (1988).
- Elo, H.A., MacDonald, E. Effects of 2,4-dichlorophenoxyacetic acid (2,4-D) on biogenic amines and their acidic metabolites in brain and cerebrospinal fluid of rats. Arch. Toxicol. 63(2): 127 - 130 (1989).
- Erickson, J.D., Mulinare, J., McClain, P.W., Fitch, T.G., James, L.M., McClearn, A.B., and Adams, M.J. Vietnam veterans risks for fathering babies with birth defects. JAMA 252: 903 - 912 (1984).
- Eriksson, M., Hardell, L., and Adami, H-O. Exposure to Dioxins as a Risk Factor for Soft Tissue Sarcoma: A Population-based Case-Control Study. J. Natl. Cancer Inst. 82:486-490 (1990).
- Ettlinger, C., Lehle, L. Auxin induces rapid changes in phosphatidylinositol metabolites. Nature 331(6152): 176 - 178 (1988).
- Evans, R.G., Webb, K.B., Knutsen, A.P., Roodman, S.T., Roberts, D.W., Bagby, J.R., Garrett, W.A., and Andrews, J.S. A medical follow-up of the health effects of long-term exposure to 2,3,7,8-tetrachlorodibenzo-p-dioxin. Arch. Environ. Health 43: 273 - 278 (1988).
- Fingerhut, M.A. and Halperin, W.E. Dioxin exposure and sarcoma JAMA 249: 3176 - 3177 (1983).

- Fingerhut, M.A., Halperin, W.E., Honchar, P.A., Smith, A.B., Groth, D.H., and Russell, W.O. An evaluation of reports of dioxin exposure and soft tissue sarcoma pathology among chemical workers in the United States. *Scand. J. Work Environ. Health* 10: 299 - 303 (1984).
- Fitzgerald, E.F., Weinstein, A.L., Youngblood, L.G., Standfast, S.J., Melius, J.M. Health effects three years after potential exposure to the toxic contaminants of an electrical transformer fire. *Arch. Environ. Health* 44(4): 214 - 221 (1989).
- Friedman, J.M. Does Agent Orange cause birth defects? *Teratology* 29: 193 - 221 (1984).
- Giles, G.G., Lickiss, J.N., Baikie, M.J., Lowenthal, R.M., and Panton, J. Myeloproliferative and lymphoproliferative disorders in Tasmania, 1972 - 80: Occupational and familial aspects. *JNCI* 72: 1233 - 1240 (1984).
- Giri, A.K. Mutagenic and genotoxic effects of 2,3,7,8-tetrachlorodibenzo-p-dioxin, A Review. *Mutation Res.* 168: 241 - 248 (1986).
- Gochfeld, M., Gallo, M., Kahn, P. Dioxin exposure and health. Review Article: 32 Refs. *N.J. Med* 85(11): 907 - 912 (1988).
- Gochfeld, M., Nygren, M., Hansson, M., Rappe, C., Velez, H., Ghent-Guenther, T., Wilson, W.P., and Kahn, P.C. Correlation of adipose and blood levels of several dioxins and dibenzofuran congeners in Agent Orange exposed Vietnam veterans. *Chemosphere* 18: 517 - 524 (1989).
- Goldstein, N.P., Jones, P.H., and Brown, J.R. Peripheral neuropathy after exposure to an ester of dichlorophenoxyacetic acid. *J. Amer. Med. Assoc.* 171: 1306 - 1309 (1959).
- Grasso, P. Epidemiology and experimental toxicology--is there a meeting ground? Discussion paper. *J.R. Soc. Med.* 82(8): 470 - 473 (1989).
- Green, L.M. Suicide and exposure to phenoxy acid herbicides. *Scand. J. Work Environ. Health.* 13: 460 (1987).
- Gross, M.L., Lay, J.O., Lyon, P.A., Lippstreu, D., Kangas, N., Harless, R.L., Taylor, S.E., Dupuy, A.E. 2,3,7,8-tetrachlorodibenzo-p-dioxin levels in adipose tissue of Vietnam veterans. *Environ. Res.* 33: 261 - 268 (1984).
- Hall, W. The logic of a controversy: The case of Agent Orange in Australia. *Soc. Sci. Med.* 29(4): 537 - 544 (1989).
- Hardell, L. Relation of soft-tissue sarcoma, malignant lymphoma and colon cancer to phenoxy acids, chlorophenols, and other agents. *Scand. J. Work Environ. Health* 7: 119 - 130 (1981).



- Hardell, L. and Eriksson, M. Soft-tissue sarcoma and exposure to dioxins. *The Lancet* p. 868, October 11 (1986).
- Hardell, L. and Eriksson, M. HIV infection and dioxin exposure: risk factors for kaposi sarcoma and malignant lymphoma? *The Lancet*, p. 591, March 12 (1988).
- Hay, A. and Silbergeld, E. Assessing the risk of dioxin exposure. *Nature* 315: 102 - 103 (1985).
- Henderson, L.O. and Patterson, D.G. Distribution of 2,3,7,8-TCDD in human whole blood and its association with, and extractability from, lipoproteins. *Bull. Environ. Contam. Toxicol.* 40: 604 - 611 (1988).
- Hernberg, S. Recent epidemiologic studies of occupational cancer in Finland. *Scand. J. Work Environ. Health* 14: Suppl. 1, 14 - 16 (1988).
- Holmstedt, B. Prolegomena ta Seveso. *Arch. Toxicol.* 44: 211 - 230 (1980).
- Honchar, P.A. and Halperin, W.E. 2,4,5-T, trichlorophenol, and soft tissue sarcoma. *Lancet* 1: 268 - 269 (1981).
- Huong, L.D., Phuong, N.T.N., Thuy, T.T., and Hoan, N.T.K. An estimate of the incidence of birth defects, hydatidiform mole and fetal death in utero between 1952 and 1985 at the obstetrical and gynecological hospital of Ho Chi Minh City, Republic of Vietnam. *Chemosphere* 18: 805 - 810 (1989).
- Hryhorczuk, D.O., Wallace, W.H., Persky, V., Furner, S., Oleske, D.M., and Levy, P. General health status of workers who had been engaged in the production of chlorinated phenols and chlorophenoxy acid esters: W.G. Krummrich Study. Dioxin '89, Abstract # EPI06.
- Irey, N.S., Mullick, F.G., Foster, W.D. A morphologic study of Vietnam veterans. *Mod. Pathol.* 2(4): 360 - 364 (1989).
- Jennings, A.M., Wild, G., Ward, J.D., and Ward, A.M. Immunological abnormalities 17 years after accidental exposure to 2,3,7,8-tetrachlorodibenzo-p-dioxin. *Br. J. Ind. Med.* 45: 701 - 704 (1988).
- Johnson, E.S. Association between exposure to phenoxys/chlorophenols and soft-tissue sarcomas and malignant lymphomas - A critical review. *Fund. Appl. Toxicol.* (in press as of 11/24/89).
- Johnson, F.E., Kugler, M. A., Brown, S.M. Soft tissue sarcomas and chlorinated phenols. *Lancet* 2: 40 (1981).
- Kahn, P.C., Gochfeld, M., Nygren, M., Hansson, M., Rappe, C., Velez, H., Ghent-Guenther, T. and Wilson, W.P. Dioxins and dibenzofurans in blood and adipose tissue of Agent Orange-exposed Vietnam veterans and matched controls. *JAMA* 259: 1661 - 1667 (1988).

- Kaye, C.I., Rao, S., Simpson, S.J., Rosenthal, F.S. and Cohen, M.M. Evaluation of chromosomal damage in males exposed to Agent Orange and their families. *J. Craniofacial Genetics and Develop. Biol. Suppl.* 1: 259 - 265 (1985).
- Kim, C.S., Keizer, R.F., Pritchard, J.B. 2,4-Dichlorophenoxyacetic acid intoxication increases its accumulation within the brain. *Brain Res.* 440(2): 216 - 226 (1988).
- Kimbrough, R.D. Porphyrins and hepatotoxicity. *Ann. N.Y. Acad. Sci.* 514: 289 - 296 (1987).
- Klawans, H.L., Wilson, R.S. and Garron, D.C. Neurologic problems following exposure to 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD, Dioxin) in *Neurotoxins and their pharmacological implications*, Ed. P. Jenner, Raven Press, New York pp. 279 - 285 (1987).
- Klawans, H.L. Dystonia and tremor following exposure to 2,3,7,8-tetrachlorodibenzo-p-dioxins. *Movement Disorders* 2: 255 - 261 (1987).
- Kontek, M., Jasinski, K. Marcinkowska, B., Takarz, R., Pietraszek, Z., and Handschuh, R. Electroencephalographic study of farm workers exposed to derivatives of arylalcanocarboxylic acids. *Poly. Tyg. Lek.* 28: 937 - 939 (1973).
- Knutsen, A.P. Immunologic effects of TCDD exposure in humans. *Bull. Environ. Contam. Toxicol.* 33: 673 - 681 (1984).
- Knutsen, A.P., Roodman, S.T., Evans, R.G., Mueller, K.R., Webb, K.B., Stehr-Green, P., Hoffman, R.E. and Schramm, W.F. Immune studies in dioxin-exposed Missouri residents: Quail Run. *Bull. Environ. Contam. Toxicol.* 39: 481 - 489 (1987).
- Lock, J.H., Barone, M., and Eyster, J. Birth defect data and the production of chlorophenolic compounds. Office on Vital and Health Statistics, Michigan Department of Public Health. 18 pages. (1984).
- Lukowicz-Ratajczak, J., Krechniak, J. Effects of sodium 2,4-dichlorophenoxyacetate on renal function in the rat. *Bull. Environ. Contam. Toxicol.* 41(6): 815 - 821 (1988).
- McGourty, C. Dioxin and Health. Agent Orange study blasted [News] *Nature* 340 (6230): 179 (1989).
- Michigan Department of Public Health (MDPH). Evaluation of congenital malformation rates for Midland and other selected Michigan counties compared nationally and statewide: 1970-1981. Lansing, Michigan. 33 pages. (1983).



- MMWR. Preliminary report: 2,3,7,8-tetrachlorodibenzo-p-dioxin exposure to humans--Seveso, Italy. JAMA 261(6): 831 - 832 (1989).
- MMWR. Preliminary report: 2,3,7,8-tetrachlorodibenzo-p-dioxin exposure to humans--Seveso, Italy. Arch. Dermatol. 125(3): 329 -330 (1989).
- MMWR. Serum 2,3,7,8-tetrachlorodibenzo-p-dioxin levels in Air Force health study participants - preliminary report. JAMA 259: 3533 - 3535 (1988).
- MMWR. Preliminary report: 2,3,7,8-tetrachlorodibenzo-p-dioxin exposure to humans - Seveso, Italy. MMWR/CDC 37: 733 - 736 (1988).
- Mohammad, F.K. and St. Omer, V.E.V. Behavioral and neurochemical alterations in rats prenatally exposed to 2,4- dichlorophenoxyacetate (2,4-D) and 2,4,5- trichlorophenoxyacetate (2,4,5-D) mixture. Teratology. 37: 515 (1988).
- Mohammad, F.K., St. Omer, V.E. Effects of prenatal exposure to 2,4-D/2,4,5-T mixture on postnatal changes in rat brain glutamate, GABA, protein, and nucleic acid levels. Bull. Environ. Contam. Toxicol. 40(2): 294 - 300 (1988).
- Moses, M. and Prioleau, P.G. Cutaneous histologic findings in chemical workers with and without chloracne with past exposure to 2,3,7,8-tetrachlorodibenzo-p-dioxin. J. Am. Acad. Dermatol. 12: 497 - 506 (1985).
- Moses, M. and Selikoff, I.J. Soft tissue sarcomas, phenoxy herbicides, and chlorinated phenols. Lancet 1: 1370 (1981).
- Novey, L.B. Collective judicial management of mass toxic tort controversies: Lessons and issues from the Agent Orange Litigation. Review Article: 37 Refs. Soc. Sci. Med. 27(10): 1071 - 1084 (1988).
- Nguyen, C., Nguyen, T.X., Tran, T.H., Nguyen, K.T., and Do, B.D. [Study of the gravidity of females in 3 districts of North Vietnam.] Proceedings of the International Symposium on the use of Herbicides and Defoliants in Warfare: Long-Term Effects on Man and the Environment. Ho Chi Minh City, January 13-20, 1983. Comite' National d'Investigation des Consequences de la Guerre Chimique des E.U.A. au Vietnam, Hanoi. 3: 81 - 88 (1983a)
- Oliver, R.M. Toxic effects of 2,3,7,8-tetrachlorodibenzo-p-1,4 dioxin in laboratory workers. British J. Indust. Med. 32: 49 - 53 (1975).
- Olsson, H. and Brandt, L. Risk of non-Hodgkin's lymphoma among men occupationally exposed to organic solvents. Scand. J. Work Environ. Health. 14: 246 - 251 (1988).
- Patterson, D.G., Jr., Fingerhut, M.A., Roberts, D.W., Needham, L.L., Seeney, M.H., Marlow, D.A., Andrews, J.S., Jr., Halperin, W.E. Levels of polychlorinated dibenzo-p-dioxins and dibenzofurans in workers exposed to

- 2,3,7,8- tetrachlorodibenzo-p-dioxin. Am. J. Ind. Med. 16(2): 135 - 146 (1989).
- Pazderova-Vejlupkova, J., Nemcova, M., Pickova, J., Jirasek, L., and Lukas, E. The development and prognosis of chronic intoxication by tetrachlorodibenzo-p-dioxin in men. Arch. Environ. Health 36: 5 - 11 (1981).
- Pearn, J.H. Herbicides and congenital malformations: A review for the paediatrician. Aust. Paediatr. J. 21: 237 - 242 (1985).
- Pirkle, J.L., Wolfe, W.H., Patterson, D.G., Needham, L.L., Michalek, J.E., Miner, J.C., Peterson, M.R. and Phillips, D.L. Estimates of the half-life of 2,3,7,8-tetrachlorodibenzo-p- dioxin in Vietnam veterans of operation Rand Hand. J. Toxicol. Environ. Health 27: 165 - 171 (1989).
- Poland, A.P. and Smith, D. A health survey of workers in a 2,4- D and 2,4,5-T plant with special attention to chloracne, porphyria cutanea tarda, and psychologic parameters. Arch. Environ. Health 22: 316 - 327 (1971).
- Puntoni, R., Merlo, F., Fini, A., Meazza, L, and Santi, L. The Lancet p. 525 August 30, (1986).
- Ramirez, B.U., Soza, M.A. Intramuscular pH and endurance are abnormal in skeletal muscles from rats with experimental myotonia. Exp. Neurol. 101(3): 347 -355 (1988).
- Rohleder, F. Dioxins and cancer mortality - reanalysis of the BASF cohort. Dioxin '89, Abstract # EPI05.
- Schechter, A., Constable, J.D., Arghestani, S., Tong, H., and Gross, M.L. Elevated levels of 2,3,7,8-TCDD in adipose tissue of certain U.S. Veterans of the Vietnam War. Chemosphere 16: 1997 - 2002 (1987).
- Schechter, A., Constable, J.D., Bangert, J.V., Tong, H., Arghestani, S., Monson, S., and Gross, M. Elevated body burdens of 2,3,7,8-TCDD in adipose tissue of U.S. Vietnam Veterans. Chemosphere 18: 431 - 438 (1989).
- Schechter, A., Constable, J., Bangert, J.V., Wiberg, K., Hansson, M., Nygren, M., and Rappe, C. Isomer specific measurement of polychlorinated dibenzodioxin and dibenzofuran isomers in human blood from American Vietnam veterans two decades after exposure to Agent Orange. Chemosphere 18: 531 - 538 (1989).
- Schulz, C.O., Segal, S.A., and Reichardt, W.D. An update of the review of literature on the health effects of phenoxy herbicides and associated dioxins. Dioxin '89, Abstract # EPI09.
- Schulze, G.E. 2,4,-D-n-butyl ester (2,4-D ester) induced ataxia in rats: Role for n-butanol formation. Neurotoxicol. Teratol. 10: 81 - 84 (1988a).



- Schulze, G.E. and Dougherty, J.A. Neurobehavioral toxicity of 2,4-D-n-butyl ester (2,4-D ester): Tolerance and lack of cross-tolerance. *Neurotoxicol. Teratol.* 10: 75 - 79 (1988b).
- Schulze, G.E. and Dougherty, J.A. Neurobehavioral toxicity and tolerance to the herbicide 2,4-dichlorophenoxyacetic acid-n-butyl ester (2,4-D ester). *Fund. Appl. Toxicol.* 10: 413 - 424 (1988c).
- Shopp, G.M., Edwards, B.S., Coons, T.A., Sweeney, M.H., Vogt, R.F., Ashmore, L.M., Harper, D.J., Lane, K.A., and Nolla, H.A. Laboratory assessment of the immune system in individuals occupationally exposed to 2,3,7,8-TCDD: Quality control in a cross-sectional epidemiological study. *Chemosphere* 18: 867 - 874 (1989).
- Shu, H.P., Paustenbach, D.J., and Murray, F.J. A critical evaluation of the use of mutagenesis, carcinogenesis, and tumor promotion data in the cancer risk assessment of 2,3,7,8-TCDD. *Reg. Toxicol. Pharmacol.* 7: 57 - 88 (1987).
- Sielken, R.L. Quantitative cancer risk assessments for 2,3,7,8-TCDD. *Fd. Chem. Toxic.* 25: 257 - 267 (1987).
- Silbergeld and Gasiewicz, Dioxins and the AH Receptor, *American Journal of Industrial Medicine*, V. 16, pp. 455-474 (1989).
- Silbergeld, E.K. and Mattison, D.R. Experimental and clinical studies on the reproductive toxicology of 2,3,7,8-TCDD. *Amer. J. Indust. Med.* 11: 131 - 144 (1987).
- Stehr-Green, P., Hoffman, R., Webb, K., Evans, R.G., Knutsen, A., Schramm, W., Staake, J., Gibson, B., and Steinberg, K. Health effects of long-term exposure to 2,3,7,8-TCDD. *Chemosphere* 16: 2089 - 2094 (1987).
- Stehr-Green, P., Andrews, J.S., Hoffman, R.E., Webb, K.B., Schramm, W.F. An overview of the Missouri Dioxin Study. *Arch. Environ. Health* 43: 174 - 177 (1988).
- Sterling, T.D. Health effects of Dioxin. *Science* 223: 1202 (1984).
- Stockbauer, J.W., Hoffman, R.E., Schramm, W.F., and Edmonds, L.D. Reproductive outcomes of mothers with potential exposure to 2,3,7,8-tetrachlorodibenzo-p-dioxin. *Am. J. Epidemiol.* 128: 410 - 419 (1988).
- Sugar, J., Toth, K., Olah, E. Carcinogenicity and gentoxicity of the herbicide 2,4,5-trichlorophenoxyethanol (TCPE) contaminated with dioxin. Review Article: 21 Refs. *Ann. N.Y. Acad. Sci.* 534: 706 - 713 (1988).
- Thomas, T.L. and Kang, H.K. Mortality study of Army Chemical Corps Vietnam veterans. Dioxin '89, Abstract # EPI04.
- Ton, D.L., Do, D.V., Ton, T.T. [Mutagenic effects of the herbicide Agent Orange on progeny.] *Proceedings of the International Symposium on the Use of Herbicides and Defoliants in Warfare: Long Term Effects on Man and the*

- Environment. Ho Chi Minh City, January 13-20, 1983. Comte' National d'Investigation des Consequences de la Guerre Chimique des E.U.A. au Vietnam, Hanoi. 3: 92 - 98 (1983).
- Ton, D.L. Possible teratogenic effects of dioxin among the first generation and the concordance between the rate of birth defects and reproductive abnormalities with the degree of potential paternal exposure to Agent Orange in Vietnam. Abstract of a paper presented at the 6th International Symposium on Chlorinated Dioxin and Related Compounds, September 16-19, 1986, Fukuoka, Japan. P. 169 (1986).
- Vineis, P. and Zahm, S.H. Immunosuppressive effects of dioxin in the development of kaposi's sarcoma and non-Hodgkin's lymphoma. The Lancet, p. 55, January 2/9 (1988).
- Wallace, W., Hryhorczuk, D.O., Persky, V., Furner, S., Oleske, D.M., Cole, T., and Levy, P. Chloracne, liver function, and lipids in workers exposed to chlorinated phenols and phenoxy acid esters. Dioxin '89, Abstract # EPI13.
- Wallis, W.E., Van Poznak, A., and Plum, F. Generalized muscular stiffness, fasciculations, and myokymia of peripheral nerve origin. Arch. Neurol. 22: 430 - 439 (1970).
- Webb, K., Evans, R.G., Stehr, P., and Ayres, S.M. Pilot study on health effects of environmental 2,3,7,8-TCDD in Missouri. Am. J. Indust. Med. 11: 685 - 691 (1987).
- Webb, K.B., Ayres, S.M., Mikes, J., and Evans, R.G. The diagnosis of dioxin-associated illness. Am. J. Prev. Med. 2: 103 - 108 (1986).
- Weerasinghe, N.C.A., Schecter, A.J., Pan, J.C., Lapp, R.L., Giblin, D.E., Meehan, J.L., Hardell, L., and Gross, M.L. Levels of 2,3,7,8-TCDD in adipose tissue of U.S. Vietnam veterans seeking medical assistance. Chemosphere 15: 1787 - 1794 (1986).
- White, F.M.M., Cohen, F.G., Sherman, G., and McCurdy, R. Chemicals, birth defects and stillbirths in New Brunswick: Associations with agricultural activity. Can. Med. Assoc. J. 138: 117 - 124 (1988).
- Wigle, D.T., Semenciw, R.W., Wilkins, K., et al. "Mortality Study of Canadian Male Farm Operators: Non-Hodgkin's Lymphoma Mortality and Agricultural Practices in Saskatchewan." JNCI 1982: 575-582 (1990).
- Wiklund, K., Dich, J. and Holm, L.-E. Risk of soft-tissue sarcoma, Hodgkin's disease, and non-Hodgkin's lymphoma among Swedish licensed pesticide applicators. Chemosphere 18: 395 - 400 (1989).
- Wiklund, K., Dich, J., and Holm, L.E. Risk of malignant lymphoma in Swedish pesticide appliers. Br. J. Cancer. 56: 505 - 508 (1987a).
- Wiklund, K. and Holm, L.E. Soft tissue sarcoma risk in Swedish agricultural and forestry workers. JNCI 76: 229 - 234 (1986).



Wolfe, W.H., Michalek, J.E. and Miner, J.C. An epidemiologic investigation of health effects in Air Force personnel following exposure to herbicides - mortality update, 1989. Dioxin '89, Abstract # EPI03.

Woods, J.S. Non-Hodgkin's lymphoma among phenoxy herbicide-exposed farm workers in western Washington state. Chemosphere 18: 401 - 406 (1989).

## APPENDIX C

### Literature Considered by the VA Advisory Committee By October, 1988 (And Also by the Authors)

- Abraham and Merrill, "Scientific Uncertainty in the Courts," Issues in Science and Technology, Winter 1986, pp. 93-107.
- Albanese, Richard A. "United States Air Force Personnel and Exposure to Herbicide Orange" USAF School of Aerospace Medicine (February 1988).
- Anderson, et al., Wisconsin Vietnam Veteran Mortality Study; Proportionate Mortality Ratio Study Results. (1985).
- Anderson, et al., Wisconsin Vietnam Veteran Mortality Study: Proportionate Mortality Ratio Results; Standardized Mortality Ratio Results. Final Report. (1986).
- Breslin, et al., "Proportionate Mortality Study of Army and Marine Corps Veterans of the Vietnam War," VA Office of Environmental Epidemiology. (1987).
- Boyle, et al., Postservice mortality among Vietnam Veterans, Centers for Disease Control CEH #86-0076 Feb. 1987.
- Can, "Effects on Offspring of Paternal Exposure to Herbicides," Herbicides in War: The Long-Term Ecological and Human Consequences, Westin, ed. (1984).
- Centers for Disease Control. "Postservice Mortality Among Vietnam Veterans." JAMA 257(6): 790-795 (1987).
- Centers for Disease Control. "Serum Dioxin in Vietnam-Era Veterans - Preliminary Report," MMWR 36(28): 470-475 (1987).
- Coggon, et al., "Mortality of Workers Exposed to 2 Methyl- 5 Chloro-phenoxy Acetic Acid," Scand. J. Work Environ. Health 12: 448-454 (1986).
- Cohen, "Paternal Contributions to Birth Defects," Nursing Clinics of North America 21: 49-64 (1986).
- Commonwealth of Massachusetts, Health Survey of Massachusetts Vietnam Veterans. (1986).
- Constable and Hatch, "Reproductive Effects of Herbicide Exposure in Vietnam: Recent Studies by the Vietnamese and Others." Teratogenesis, Carcinogenesis, and Mutagenesis 5: 231-250 (1985).
- Cook, et al., "Evaluation of the Mortality Experience of Workers Exposed to the Chlorinated Dioxins," Chemosphere 15: 1769-1776 (1986).



- Del Corno, et al., "Problems in the Assessment of Human Exposure to TCDD: The Marker Chloracne," Eur. J. Epidemiol 1:139- 144 (1985).
- D. Domenico and Zapponi. "2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD) in the Environment" Human Health Risk Estimation and its Application to the Seveso Case as an Example". Regulatory Toxicology and Pharmacology 6: 248-260 (1986).
- Dwyer and Epstein, "Cancer and Clinical Epidemiology: An Over view," Herbicides in War: The Long-Term Ecological and Human Consequences, Westin, ed. (1984).
- Environmental Protection Agency, "Health Assessment Document for Polychlorinated Dibenzo-p-Dioxin." (Chapter 11) (1985).
- Erickson, Hardell, et al., Soft tissue sarcomas and exposure to chemical substances: A Case-reference study. Br. J. Ind. Med. 38: 27-33 (1981).
- Erickson and Mulinare, Letter to the Editor, "Agent Orange and Risks to Reproduction: The Limits of Epidemiology," Teratogenesis, Carcinogenesis, and Mutagenesis 7: 197-200 (1987).
- Eschenroeder, et al., "Health Risk Analysis of Human Exposures to Soil Amended with Sewage Sludge Contaminated with Polychlorinated Dibenzodioxins and Dibenzofurans," Vet. Hum. Toxicol. 28(5): 435-442 (1986).
- Evatt, Report of the Royal Commission on the Use and Effects of Chemical Agents on Australian Personnel in Vietnam. (1985).
- Ferioli, A. The use of urinary prophyri to monitor occupational and environmental exposure to chemicals in Occupational and Environmental Chemical Hazards: Cellular and Biochemical Indices for Monitoring Toxicity, Chichester, Howard E., ed. 241-249 (1987).
- Forcier, et al., "Mortality of Australian Veterans of the Vietnam Conflict and the Period and Location of Their Vietnam Service" Military Medicine 152: 117-123 (1987).
- Geyer, et al., "Bioconcentration Potential of Organic Environmental Chemicals in Humans," Regulatory Toxicology and Paramacology 6: 313-347 (1986).
- Gough, "Environmental Epidemiology Separating Politics and Science," Issues in Science and Technology, Summer 1987, pp. 20-31.
- Greenwald, P., Kovasznay, B., Collins, D.N., and Therriault, G. Sarcomas of Soft Tissues After Vietnam Service. JNCI 73: 1107-1107, (1984).
- Hall, "The Agent Orange Controversy After the Evatt Royal Commission." Med. J. of Australia 145: 219-224 (1986).

- Hardell and Axelson, "Phenoxyherbicides and other Pesticides in the Etiology of Cancer: Some Comments on Swedish Experiences," Chapter 12, pp. 107-119, Cancer Prevention: Strategies in the Workplace, Becker and Coye, eds., Hemisphere Publishing Corp.
- Hardell, L. & Sandstrom, A. Case-control study: Soft tissue sarcomas and exposure to phenoxyacetic acids or chlorophenols. Br. J. Cancer 39: 711-717 (1979).
- Hatch and Stein, "Agent Orange and Risks to Reproduction: The Limits of Epidemiology." Teratogenesis, Carcinogenesis, and Mutagenesis 6: 1985-202 (1986).
- Hatch and Stein, Response to Letter to the Editor, "Agent Orange and Risks to Reproduction: The Limits of Epidemiology," Teratogenesis, Carcinogenesis, and Mutagenesis 7: 423-424 (1987).
- Hoar, et al., "Agricultural Herbicide Use and Risk of Lymphoma and Soft-Tissue Sarcoma." JAMA 256(9): 1141-1147 (1986).
- Hoffman, et al., "Health Effects of Long-term Exposure to 2,3,7,8-Tetrachlorodibenzo-p-Dioxin." JAMA 256(15): 2031-2038 (1986).
- Holmes, et al., West Virginia Vietnam-Era Veterans Mortality Study. (1986).
- IARC Monograph, "Occupational Exposure to Chlorophenoxy Herbicides" 41: 357-407 (1987).
- IARC Monographs "Occupational Exposure to Chlorophenols" 41: 319- 356 (1987).
- Jensen, "Polychlorobiphenyls (PCB's), Polychlorodibenzo-p-Dioxins (PCDD's) and Polychlorodibenzofurans (PCDF's) in Human Milk, Blood, and Adipose Tissue," Science of the Total Environm 64: 259-293 (1987).
- Jones and Chelsky, "Further Discussion Concerning Porphyria Cutanea Tarda and Exposure." Arch. Environ. Health 41: 100-103 (1986).
- Kang, et al., "Soft Tissue Sarcomas and Military Service in Vietnam: A Case Comparison Group Analysis of Hospital Patients." J. Occupational Med. 28: 1215-1218 (1986).
- Kang, et al., "Soft tissue Sarcoma and Military Service in Vietnam: A Case-Control Study," JNCI 79: 693-699 (1987).
- Kogan, M.D. and Clapp, R.W. Mortality among Vietnam Veterans in Massachusetts, 1972-1983. Office of the Commissioner of Veterans Services Agent Orange Program, 1/18/85.
- Kunstadter, "Herbicides and Birth Defects in the Republic of Vietnam: An Analysis of Hospital Records," Assembly of Life Sciences, National Academy Press (1982).



- Lathrop, et al., Air Force Health Study: First Follow-up Examination Results (October 1987).
- Lawrence, et al. Mortality Patterns of New York State Vietnam Veterans. Amer. J. Public Health 75: 277-279 (1985).
- Lynge, "A Follow-up Study of Cancer Incidence Among Workers in Manufacture of Phenoxy Herbicides in Denmark." Br. J. Cancer 52(2): 259-270 (1985).
- Lynge, et al., "The Evaluation of Trends in Soft Tissue Sarcoma According to Diagnostic Criteria and Consumption of Phenoxy Herbicides" Cancer 60: 1896-1901 (1987).
- Merlo and Puntoni, "Soft Tissue Sarcomas, Malignant Lymphomas, and 2,3,7,8-TCDD Exposure in Seveso," Lancet, December 20/27, 1986, p. 1455.
- Merlo, Puntoni and Santi, "The Seveso Episode: The Validity of Epidemiological Inquiries in Relation with the Definition of Population at Risk," Chemosphere 15: 1777-1786 (1986).
- Mocarelli, et al., "Clinical Laboratory Manifestations of Exposure to Dioxin in Children; A Six Year Study of the Effects of an Environmental Disaster Near Seveso, Italy," JAMA 256: 2687-2695 (1986).
- Ott, et al., "Cohort Mortality Study of Chemical Workers with Potential Exposure to the Higher Chlorinated Dioxins," J. Occup. Med. 29: 422-429 (1987).
- Patterson, et al., "2,3,7,8-Tetrachlorodibenzo-p-dioxin Levels in Adipose Tissue of Exposed and Control Persons Missouri: An Interim Report." JAMA 256(19): 2683-2686 (1986).
- Paustenbach, et al., "A Critical Examination of Assumptions Used in Risk Assessments of Dioxin Contaminated Soil," Regulatory Toxicology and Pharmacology 6: 284-307 (1986).
- Pearn, "Herbicides and Congenital Malformations: A Review for the Pediatrician." Aust. Paediatr. J. 21: 237-307 (1986).
- Pratt, et al., "Adolescent Colorectal Cancer and Dioxin Exposure," Lancet, October 3, 1987, p. 803.
- Puntoni, Merlo, Fini and Meazza, "Soft Tissue Sarcoma in Seveso," Lancet, August 30, 1986, p. 525.
- Rall, et al., "Alternatives to Using Human Experience in Assessing Health Risks," Ann. Rev. Public Health 8: 355-85 (1987).
- Schecter, et al., "Human Tissue Levels of Dioxin and Furan Isomers in Potentially Exposed and Control Patients Up to 15 Years After Cessation of 2,3,7,8-TCDD Environmental Contamination" Unpublished presentation before the American Chemical Society National Meeting (1986).

- Schrag and Dixon, "Occupational Exposures Associated with Male Reproductive Dysfunction," *Ann. Rev. Pharmacol. Toxicol.* 25: 567-592 (1985).
- Silbergeld and Mattison, "Experimental and Clinical Studies on the Reproductive Toxicology of 2,3,7,8 TCDD." *Am. J. Ind. Med.* 11: 131-144 (1987).
- Smityh and Pearce, "Update on Soft Tissue Sarcoma and Phenoxherbicides in New Zealand," *Chemosphere* 15: 1795-1798 (1986).
- Smith, A.H., Pearce, N.E., Fisher, D.O., Giles, H.J., Teague, C.A., and Howard, J.K. Soft Tissue sarcoma and exposure to phenoxyherbicide and chlorophenols in New Zealand. *JNCI* 73: 1111-1117 (1984).
- Stehr, et al., "A Pilot Epidemiologic Study of Possible Health Effects Associated with 2,3,7,8-Tetrachlorodibenzo-p-Dioxin Contaminations in Missouri." *Arch. Environ. Health* 41: 16-22 (1986).
- Stellman, et al., American Legion Vietnam Veterans Study (1985) (Columbia Univ.).
- Suskind, "Choracne, The Hallmark of Dioxin Intoxication," *Scand. J. Work Environ. Health* 11: 165-171 (1985).
- Trinh, "Long-lasting Morbid Effects Following Herbicidal Attack," Herbicides in War: The Long-Term Ecological and Human Consequences, Westin, ed. (1984).
- Trung and Van Dieu, "Chromosomal Aberrations in Humans Following Exposure to Herbicides," Herbicides in War: The Long-Term Ecological and Human Consequences, Westin, ed. (1984).
- Tschirley, "Dioxin," *Scientific American* 254: 29, et seq. (1986).
- USAF School of Aerospace Medicine (AFSC) An epidemiologic investigation of health effects in air force personnel following exposure to herbicides, 6/30/83.
- Van, "Herbicides as a Possible Cause to Liver Cancer," Herbicides in War: The Long-Term Ecological and Human Consequences Westin, ed. (1984).
- Vineis, et al., "Phenoxy Herbicides and Soft-Tissue Sarcomas in Female Rice Weeders, A Population-based Case-referent Study," *Scand. J. Work Environ. Health* 13: 9-17 (1986).
- Wendt, Iowa Agent Orange Survey of Vietnam Veterans. (1985). C&E
- Webb, et al., "The Diagnosis of Dioxin-Associated Illness." *Am. J. Prev. Med.* 2(2): 103-108 (1986).
- Weerasighne, et al., "Level of 2,3,7,8-Tetrachlorodibenzo-p-dioxin



(2,3,7,8-TCDD) in Adipose Tissue of U.S. Vietnam Veterans Seeking Medical Assistance," Chemosphere 15: 1787-1794 (1986).

West and Leon, "Health Needs of the Vietnam Veteran Exposed to Agent Orange." Nurse Practitioner 11: 33-40 (1986).

Westing, "Reproductive Epidemiology: An Overview," Herbicides in War: The Long-Term Ecological and Human Consequences, Westin, ed. (1984).

Wolfe, et al., Project Ranch Hand II, An Epidemiologic Investigation of Health Effects in Air Force Personnel Following Exposure to Herbicides, Mortality update - 1985.

Wolfe, et al., Project Ranch Hand II, An Epidemiologic Investigation of Health Effects in Air Force Personnel Following Exposure to Herbicides, Mortality Update - 1986.

Woods, et al., "Soft Tissue Sarcoma and Non-Hodgkins Lymphoma in Relation to Phenoxy Herbicides and Chlorinated Phenol Exposure in Western Washington." JNCI 78: 899-910 (1987).

#### APPENDIX D

Literature Considered by the VA  
Advisory Committee After October, 1988  
(And Also by the Authors)

- Axelsson, O. A review of porphyria and cancer and the missing link with human exposure to hexachlorobenzene. IARC Scientific Publications 77: 585 - 589 (1986).
- Barbieri, S., Pirovano, C., Scarlato, G., Tarchini, P., Zappa, A., and Maranzana, M. Long-term effects of 2,3,7,8 tetrachlorodibenzo-p-dioxin on the peripheral nervous system. Neuroepidemiology. 7: 29 -37 (1988).
- Beck, H., Eckart, K., Kellert, M., Mathar, W., Ruhl, Chi.-S, and Wittkowski, R. Levels of PCDFs and PCDDs in samples of human origin and food in the Federal Republic of Germany. Chemosphere 16: 1977 - 1982 (1987).
- Bond, G.G., Wetterstroem, N.H., Roush, G.J., McLaren, E.A., Lipps, T.E., and Cook, R.R. Case specific mortality among employees engaged in the manufacture, formulation, or packaging of 2,4- dichlorophenoxyacetic acid and related salts. Br. J. Ind. Med. 45: 98 - 105 (1988).
- Caputo, R., Monti, M., Ermacora, E., Carminati, G., Gelmetti, C., Gianotti, R., Gianni, E., and Puccinelli, V. Cutaneous manifestation of tetrachlorodibenzo-p-dioxin in children and adolescents. Follow-up 10 years after the Seveso, Italy, accident. J. Am. Acad. Dermatol. 19: 812 - 819 (1988).
- CDC Vietnam Experience Study. Health status of Vietnam veterans psychosocial characteristics. JAMA 259: 2701 - 2707 (1988).
- CDC Vietnam experience study. Health status of Vietnam veterans II. Physical Health. JAMA 259: 2708 - 2714 (1988).
- CDC Vietnam experience study. Health status of Vietnam veterans III. Reproductive outcomes and child health. JAMA 259: 2715 - 2719 (1988).
- Clapp, R.W. Cancer surveillance of veterans in Massachusetts, 1982 - 1988. Presentation at APHA Annual Meeting, November 16, 1988.
- Dai, L.C. The ecological effects of the herbicides used during wartime in Vietnam. Paper presented at the Am. Public Health Assoc. Meeting, November, 1988.
- Dai, L.C. Review of Vietnam's research on the health consequences of Agent Orange and dioxin in Vietnam. Paper presented at the American Health Association Meeting, November, 1988.



- Doss, M.O. and Colombi, A.M. Chronic hepatic porphyria induced by chemicals: the example of dioxin. In Foa, V., Emmett, E.A., Maroni, M., and Colombi, A. (eds.) Occupational and Environmental Chemical Hazards: Cellular and Biochemical Indices for Monitoring Toxicity. Ellis Horwood Limited, 1986, Chichester, England. Pp. 237 - 240, (1986).
- Dubrow, R., Paulson, J.O., Indian, R.W. Farming and malignant lymphoma in Hancock County, Ohio. Br. J. Ind. Med. 45: 25 - 28 (1988).
- Field, B. and Kerr, C. Reproductive behavior and consistent patterns of abnormality in offspring of Vietnam veterans. J. Med. Genetics. 25: 819 - 826 (1988).
- Fingerhut, M.A., Sweeney, M.H., Halperin, W.E., and Schnorr, T.M. Epidemiology of populations exposed to dioxins in Solving Hazardous Waste Problems, pp. 142 - 161, American Chemical Society (1987).
- Fishbein, L. Health-risk estimates for 2,3,7,8-TCDD: an overview. Toxicol. Indust. Health 3: 91 - 133 (1987).
- Furst, P., Meemken, H. - A., Kruger, Chr. and Groebel. Polychlorinated dibenzodioxins and dibenzofurans in human milk samples from western Germany. Chemosphere 16: 1983 - 1988 (1987).
- Hardell, L. and Eriksson, M. The association between soft tissue sarcomas and exposure to phenoxy acetic acids. A new case-referent study. Cancer 62: 652 - 656 (1988).
- Kogan, M.D. and Clapp, R.W. Soft tissue sarcoma mortality among Vietnam veterans in Massachusetts, 1972 - 1983. Int. J. Epidemiol. 17: 39 - 43 (1988).
- Konheim, C.S. Dioxin exposure and motor vehicle emissions. Waste Age, pp. 71 - 73. November (1986).
- Landrigan, P.J. Principles for application of porphyrin markers in epidemiological studies. Annals N.Y. Academy of Sciences pp. 323 - 326.
- Leung, H.W., Murray, F.J., and Paustenbach, D.J. A proposed occupational exposure limit for 2,3,7,8-tetrachlorodibenzo-p-dioxin. Am. Ind. Hyg. Assoc. J. 49: 466 - 474 (1988).
- Levy, C.J. Agent Orange exposure and posttraumatic stress disorder. J. Nervous Mental Disease 176: 242 - 245 (1988).
- Mastroiacovo, P., Spagnolo, A., Marni, E., Meazza, L., Bertollini, R., and Segni, G. Birth defects in the Seveso area after TCDD contamination. JAMA 259: 1668 - 1672 (1988).
- McConkey, D.J., Hartzell, P., Duddy, S.K., Hakansson, H., and Orrenius, S.

- 2,3,7,8-TCDD kills immature thymocytes by  $\text{Ca}^{2+}$ -mediated endonuclease activation. *Science* 242: 256 - 259 (1988).
- Nauman, C.H. and Schaum, J.L. Human exposure estimation for 2,3,7,8-TCDD\_
- 
- Olafsson, P.G., Bryan, A.M., and Stone, W. Polychlorinated biphenyls and polychlorinated dibenzofurans in the tissues of patients with Yusho or Yu-Chen: Total toxicity. *Bull. Environ. Contam. Toxicol.* 41: 63 - 70 (1988).
- Patterson, D.G., Jr., Needham, L.L., Pirkle, J.L., Roberts, D.W., Bagby, M., Garrett, W.A., Andrews, J.S., Falk, H., Bernert, T., Sampson, E.J., and Houk, V.N. Correlation between serum and adipose tissue levels of 2,3,7,8-TCDD in 50 persons from Missouri. *Arch. Environ. Contam. Toxicol.* 17: 139 - 143 (1988).
- Pearce, N.E., Sheppard, R.A., Smith, A.H., and Teague, C.A. Non-Hodgkin's lymphoma and farming: an expanded case-control study. *Int. J. Cancer* 39: 155 - 161 (1987).
- Preslan, M.W., Beauchamp, G.R., and Zakov, Z.N. Congenital glaucoma and retinal dysplasia. *J. Pediatric Ophthalmol. Strabismus* 22: 166 - 170 (1985).
- Rappe, C. Swedish view of the dioxin issue. *Vatten* 44: 137 - 144 (1988).
- Rogan, W.J., Gladen, B.C., Hung, K.L., Koong, S.L., Shih, L.y., Taylor, J.S., Wu, Y.C., Yang, D., Ragan, N.B., and Hsu, C.C. Congenital poisoning by polychlorinated biphenyls and their contaminants in Taiwan. *Science* 241: 334 - 336 (1988).
- Ryan, J.J., Lizotte, R. and Lewis, D. Human tissue levels of PCDDs and PCDFs from a fatal pentachlorophenol poisoning. *Chemosphere* 16: 1989 - 1966 (1987).
- Schechter, A. and Ryan, J.J. Polychlorinated dibenzo-para-dioxin and dibenzofuran levels in human adipose tissue from workers 32 years after occupational exposure to 2,3,7,8-TCDD. *Chemosphere* 17: 915 - 920 (1988).
- Schechter, A., Dekin, A., Weerasinghe, N.C.A., Arghestani, S. and Gross, M.L. Sources of dioxins in the environment: a study of PCDDs and PCDFs in ancient, frozen Eskimo tissue. *Chemosphere* 17: 627 - 631 (1988).
- Schwenk, N.M., Griffin, M.R., Offord, K.P., and Reiman, H.M. A population-based study of soft tissue sarcomas in Olmsted county, MN: Difficulties in case determinations. *Clinical Res.* 34: 913A (1986).
- Snow, B.R., Stellman, J.M., Stellman, S.D. and Sommer, J.F., Jr. Post-traumatic stress disorder among American Legionnaires in relation to combat



- experience in Vietnam: Associated and contributing factors. Environ. Res. 47: 175 - 192 (1988).
- Stellman, J.M., Stellman, S.D., and Sommer, J.F., Jr. Social and behavioral consequences of the Vietnam experience among American Legionnaires. Environ. Res. 47: 129 - 149 (1988).
- Stellman, J.M., Stellman, S.D., and Sommer, J.F., Jr. Utilization, attitude, and experiences of Vietnam-era veterans with Veterans Administration health facilities: The American Legion Experience. Environ. Res. 47: 193 - 209 (1988).
- Stellman, S.D., Stellman, J.M., and Sommer, J.F., Jr. Combat and herbicide exposures in Vietnam among a sample of American Legionnaires. Environ. Res. 47: 112 - 128 (1988).
- Stellman, S.D., Stellman, J.M.; and Sommer, J.F., Jr. Health and reproductive outcomes among American Legionnaires in relation to combat and herbicide exposure in Vietnam. Environ. Res. 47: 150 - 174 (1988).
- Sterling, T.D. and Arundel, A.V. Health effects of phenoxy herbicides. Scand. J. Work Environ. Health 12: 161 - 173 (1986).
- Stowell, R.E., et al. Human health aspects of environmental exposure to polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs). Universities Associated for Research and Education in Pathology, Inc. Bethesda, Maryland (June, 1988).
- Strik, J.J.T.W.A. Porphyrins in urine as an indication of exposure to chlorinated hydrocarbons. Annals NY Acad. Sci. pp. 219 - 221. \_\_\_\_\_.
- Strom, S.C. Issues in biochemical applications to risk assessment: can in vitro studies assist us in species extrapolation? Environ. Health Perspec. 76: 181 - 184 (1987).
- Taylor, J.S. and Lloyd, K.M. Chloracne from 3,3<sup>1</sup>,4,4<sup>1</sup>-tetrachloroazoxybenzene and 3,3<sup>1</sup>,4,4<sup>1</sup>-tetrachloroazobenzene update and review. Ann. N.Y. Acad. Sciences 2: 243 - 247 (1979).
- Taylor, J.S. Chloracne - A continuing problem. Cutis 13: 585 - 591 (1974).
- Tindall, J.P. Chloracne and chloracnegens. J. Am. Acad. Dermatol. 13: 539 - 558 (1985).
- Travis, C.C. and Hattemer-Frey, H.A. Human exposure to 2,3,7,8- TCDD. Chemosphere 16: 2331 - 1242 (1987).
- Une, H., Schuman, S.H., Caldwell, S.T., and Whitlock, N.H. Agricultural life-style: a mortality study among male farmers in South Carolina, 1983 - 1984. Southern Med. J. 80: 1137 - 1140 (1987).

West, A.M. and Leon, C.A. Health needs of the Vietnam veteran exposed to Agent Orange. Nurse Practitioner 11: 33 - 40 (1986).

Whitlock, J.P. The regulation of gene expression by 2,3,7,8-tetrachlorodibenzo-p-dioxin. Pharmacol. Rev. 39: 147 - 161 (1987).



- Olsson, H. and Brandt, L. Non-Hodgkin's lymphoma of the skin and occupational exposure to herbicides. *The Lancet*, p. 579, September 12 (1981).
- Pearce, N.E., Smith, A.H., Howard, J.K., Sheppard, R.A., Giles, H.J. and Teague, C.A. Non-Hodgkin's lymphoma and exposure to phenoxyherbicides, chlorophenols, fencing work, and meat works employment: a case-control study. *Br. J. Ind. Med.* 43: 75 - 83 (1985).
- Pearce, N.E., Smith, A.H., and Fisher, D.O. Malignant lymphoma and multiple myeloma linked with agricultural occupations in a New Zealand cancer registry-based study. *Am. J. Epidemiol.* 121: 225 - 237 (1985).
- Riihimaki, V., Asp, S., and Hernberg, S. Mortality of 2,4-dichlorophenoxyacetic acid and 2,4,5-trichlorophenoxyacetic acid herbicide applicators in Finland. *Scand. J. Work Environ. Health* 8: 37 - 42 (1982).
- Riihimaki, V., Asp, S., Pukkala, E., and Hernberg, S. Mortality and cancer morbidity among chlorinated phenoxyacid applicators in Finland. *Chemosphere* 12: 779 - 784 (1983).
- Schumacher, M.C. Farming occupations and mortality from non-Hodgkin's lymphoma in Utah. *J. Occupational Med.* 27: 580 - 584 (1985).
- Suskind, R.R. and Hertzberg, V.S. Human health effects of 2,4,5-T and its toxic contaminants. *JAMA* 251: 2372 - 2380 (1984).
- Wiklund, K. Swedish agricultural workers - a group with a decreased risk of cancer. *Cancer* 51: 566 - 568 (1983).
- Wiklund, K., Lindefors, B.M., and Holm, L.E. Risk of malignant lymphoma in Swedish agricultural and forestry workers. *Br. J. Ind. Med.* 45: 19 - 24 (1988).
- Wolfe, et al. Project Ranch Hand II, An epidemiologic investigation of health effects in Air Force personnel following exposure to herbicides. Mortality Update - 1984.
- Zack, J.A. and Suskind, R.R. The mortality experience of workers exposed to tetrachlorodibenzodioxin in a trichlorophenol process accident. *J. Occup. Med.* 22: 11 - 14 (1980).
- Zack, J. A. and Gaffey, W.R. A mortality study of workers employed at the Monsanto Company plant in Nitro, West Virginia. Pp. 575 - 591.

Union Chemical Co., Inc.  
NPL Site Administrative Record

Volume XV

Compiled: May 1, 1990  
Updated: December 17, 1990  
ROD Signed: December 27, 1990

Prepared for  
  
Region I  
Waste Management Division  
U.S. Environmental Protection Agency

With Assistance from  
  
**AMERICAN MANAGEMENT SYSTEMS, INC.**  
One Kendall Square, Suite 2200 • Cambridge, Massachusetts 02139 • (617) 577-9915



TABLE 1  
SUMMARY OF GROUND WATER SAMPLING RESULTS

| Chemical                   | Frequency<br>of Detection | Lowest<br>Concentration<br>Detected<br>(PPM) | Highest<br>Concentration<br>Detected<br>(PPM) | Location of<br>Highest<br>Concentration | Geometric<br>Mean<br>Concentration<br>(PPM) | Range of Detection<br>Limits for ND Samples<br>(PPM) |        |
|----------------------------|---------------------------|----------------------------------------------|-----------------------------------------------|-----------------------------------------|---------------------------------------------|------------------------------------------------------|--------|
|                            |                           |                                              |                                               |                                         |                                             | Highest                                              | Lowest |
| 1,1,1-TRICHLOROETHANE      | 45 / 137                  | 0.0005                                       | 73                                            | B-6B(I)                                 | 0.0065                                      | 0.50                                                 | 0.0005 |
| 1,1,2-TRICHLOROETHANE      | 2 / 137                   | 0.061                                        | 0.080                                         | B-8B(I)                                 | 0.0027                                      | 5.0                                                  | 0.0005 |
| 1,1-DICHLOROETHANE         | 79 / 137                  | 0.0005                                       | 12                                            | B-9A(D)                                 | 0.0193                                      | 5.0                                                  | 0.0005 |
| 1,1-DICHLOROETHYLENE       | 49 / 137                  | 0.0007                                       | 2.7                                           | B-9A(D)                                 | 0.0064                                      | 5.0                                                  | 0.0005 |
| TRICHLOROETHYLENE          | 61 / 137                  | 0.0005                                       | 84                                            | B-9B(I)                                 | 0.0103                                      | 0.050                                                | 0.0005 |
| 1,2-DICHLOROETHANE         | 5 / 137                   | 0.0006                                       | 0.080                                         | B-9A(S)                                 | 0.0027                                      | 5.0                                                  | 0.0005 |
| 1,2-DICHLOROETHYLENE-CIS   | 32 / 91                   | 0.0005                                       | 19                                            | MW-15(D)                                | 0.0076                                      | 5.0                                                  | 0.0005 |
| 1,3-DICHLOROBENZENE        | 2 / 125                   | 0.0059                                       | 0.175                                         | MW-15(D)                                | 0.0027                                      | 5                                                    | 0.0005 |
| 2-BUTANONE                 | 10 / 69                   | 0.0205                                       | 28                                            | B-12C(S)                                | 0.0531                                      | 20                                                   | 0.0005 |
| 2-METHYLNAPHTHALENE        | 1 / 48                    | 0.027                                        | 0.027                                         | B-12B(I)                                | 0.0051                                      | 0.010                                                | 0.0050 |
| ARSENIC                    | 49 / 118                  | 0.0060                                       | 0.025                                         | B-1B(S)                                 | 0.0077                                      | 0.010                                                | 0.0050 |
| BIS(2-ETHYLHEXYL)PHTHALATE | 2 / 48                    | 0.19                                         | 0.59                                          | B-13C(S)                                | 0.0059                                      | 0.010                                                | 0.0050 |
| CARBON TETRACHLORIDE       | 2 / 137                   | 0.021                                        | 0.025                                         | B-5B(S)                                 | 0.0027                                      | 5.0                                                  | 0.0005 |
| CHLOROBENZENE              | 1 / 123                   | 0.0090                                       | 0.009                                         | MW-15(D)                                | 0.0028                                      | 5                                                    | 0.0005 |
| CHLOROETHANE               | 5 / 137                   | 0.0007                                       | 0.037                                         | B-2B(S)                                 | 0.0036                                      | 5.0                                                  | 0.0005 |
| CHLOROFORM                 | 18 / 137                  | 0.0012                                       | 0.77                                          | B-12C(S)                                | 0.0033                                      | 5.0                                                  | 0.0005 |
| CHROMIUM                   | 5 / 118                   | 0.0070                                       | 0.037                                         | MW-13A(D)                               | 0.0049                                      | 0.050                                                | 0.0050 |
| COPPER                     | 9 / 165                   | 0.0070                                       | 0.26                                          | B-14C(S)                                | 0.0249                                      | 0.050                                                | 0.0050 |
| CYANIDE                    | 4 / 104                   | 0.012                                        | 0.028                                         | B-13B(I)                                | 0.0052                                      | 0.010                                                | 0.010  |
| ETHYLBENZENE               | 22 / 137                  | 0.0010                                       | 2.7                                           | B-3A(S)                                 | 0.0087                                      | 50                                                   | 0.0005 |

TABLE 1  
SUMMARY OF GROUND WATER SAMPLING RESULTS

| Chemical                 | Frequency<br>of Detection | Lowest<br>Concentration<br>Detected<br>(PPM) | Highest<br>Concentration<br>Detected<br>(PPM) | Location of<br>Highest<br>Concentration | Geometric<br>Mean<br>Concentration<br>(PPM) | Range of Detection<br>Limits for ND Samples<br>(PPM) |        |
|--------------------------|---------------------------|----------------------------------------------|-----------------------------------------------|-----------------------------------------|---------------------------------------------|------------------------------------------------------|--------|
|                          |                           |                                              |                                               |                                         |                                             | Highest                                              | Lowest |
| FREON 113                | 10 / 45                   | 0.10                                         | 17                                            | B-6B(I)                                 | 0.0156                                      | 5.0                                                  | 0.0005 |
| ISOPHORONE               | 8 / 48                    | 0.034                                        | 0.32                                          | MW-13A(D)                               | 0.0083                                      | 0.010                                                | 0.010  |
| LEAD                     | 18 / 121                  | 0.005                                        | 0.027                                         | B-12A(D)                                | 0.0030                                      | 0.005                                                | 0.0020 |
| METHYLENE CHLORIDE       | 20 / 137                  | 0.0006                                       | 20                                            | B-6B(I)                                 | 0.0036                                      | 5.0                                                  | 0.0005 |
| NICKEL                   | 4 / 118                   | 0.055                                        | 0.07                                          | B-9B(I)                                 | 0.0248                                      | 0.050                                                | 0.010  |
| TETRACHLOROETHYLENE      | 4 / 137                   | 0.0050                                       | 0.15                                          | MW-14(S)                                | 0.0027                                      | 5.0                                                  | 0.0005 |
| TOLUENE                  | 24 / 137                  | 0.0006                                       | 4.4                                           | MW-15(D)                                | 0.0088                                      | 50                                                   | 0.0005 |
| TRANS-1,2-DICHLOROETHENE | 2 / 98                    | 1.7                                          | 8.5                                           | MW-15(D)                                | 0.0025                                      | 5.0                                                  | 0.0005 |
| TRICHLOROFLUOROMETHANE   | 2 / 136                   | 0.0007                                       | 0.0014                                        | RES WELL-2                              | 0.0026                                      | 5.0                                                  | 0.0005 |
| VINYL CHLORIDE           | 1 / 137                   | 0.0076                                       | 0.0076                                        | B-8B(I)                                 | 0.0038                                      | 5.0                                                  | 0.0005 |
| XYLENE                   | 21 / 84                   | 0.0038                                       | 80                                            | B-6B(I)                                 | 0.0356                                      | 50                                                   | 0.0005 |
| ZINC                     | 26 / 165                  | 0.022                                        | 0.27                                          | NPW                                     | 0.0299                                      | 0.060                                                | 0.040  |



TABLE 2  
SUMMARY OF SOIL SAMPLING RESULTS

| Chemical                   | Frequency<br>of Detection | Lowest<br>Concentration<br>Detected<br>(PPM) | Highest<br>Concentration<br>Detected<br>(PPM) | Location of<br>Highest<br>Concentration | Geometric<br>Mean<br>Concentration<br>(PPM) | Range of Detection<br>Limits for ND Samples<br>(PPM) |        |
|----------------------------|---------------------------|----------------------------------------------|-----------------------------------------------|-----------------------------------------|---------------------------------------------|------------------------------------------------------|--------|
|                            |                           |                                              |                                               |                                         |                                             | Highest                                              | Lowest |
| 1,1,1-TRICHLOROETHANE      | 145 / 420                 | 0.020                                        | 490                                           | N210E210                                | 0.052                                       | 25                                                   | 0.0050 |
| 1,1,2,2-TETRACHLOROETHANE  | 1 / 420                   | 2.7                                          | 2.7                                           | N240E360                                | 0.022                                       | 50                                                   | 0.0050 |
| 1,1-DICHLOROETHANE         | 48 / 420                  | 0.020                                        | 1.3                                           | N240E450                                | 0.028                                       | 50                                                   | 0.0050 |
| 1,1-DICHLOROETHYLENE       | 30 / 420                  | 0.020                                        | 4.1                                           | N120E120                                | 0.027                                       | 50                                                   | 0.0050 |
| TRICHLOROETHYLENE          | 110 / 419                 | 0.020                                        | 46                                            | N240E330                                | 0.041                                       | 50                                                   | 0.0050 |
| 1,2-DICHLOROETHANE         | 2 / 420                   | 0.041                                        | 0.46                                          | N270E300                                | 0.022                                       | 50                                                   | 0.0050 |
| 1,2-DICHLOROETHYLENE-CIS   | 37 / 355                  | 0.020                                        | 39                                            | N260E140                                | 0.018                                       | 25                                                   | 0.020  |
| 1,4-DICHLOROBENZENE        | 1 / 418                   | 0.56                                         | 0.56                                          | N180E480                                | 0.020                                       | 25                                                   | 0.0200 |
| 2-BUTANONE                 | 2 / 198                   | 0.87                                         | 12                                            | N215E150                                | 0.483                                       | 1000                                                 | 0.025  |
| 2-METHYLNAPHTHALENE        | 2 / 72                    | 0.38                                         | 1.6                                           | N210E360                                | 0.190                                       | 1.65                                                 | 0.33   |
| ACETONE                    | 2 / 61                    | 0.21                                         | 15                                            | N215E150                                | 0.100                                       | 50                                                   | 0.0050 |
| ANTIMONY                   | 1 / 98                    | 10                                           | 10                                            | N180E180                                | 2.816                                       | 6.0                                                  | 5.0    |
| ARSENIC                    | 80 / 98                   | 5.0                                          | 55                                            | MW-4(S)                                 | 7.712                                       | 5.0                                                  | 0.10   |
| BENZO(A)ANTHRACENE         | 2 / 72                    | 0.38                                         | 0.41                                          | POWERS                                  | 0.187                                       | 1.65                                                 | 0.33   |
| BENZO(A)PYRENE             | 2 / 72                    | 0.58                                         | 0.61                                          | HASTINGS                                | 0.189                                       | 1.65                                                 | 0.33   |
| BENZO(B)FLUORANTHENE       | 3 / 72                    | 0.78                                         | 0.83                                          | N300E60                                 | 0.193                                       | 1.65                                                 | 0.33   |
| BENZO(G,H,I)PERYLENE       | 2 / 72                    | 0.50                                         | 0.54                                          | POWERS                                  | 0.188                                       | 1.65                                                 | 0.33   |
| BENZO(K)FLUORANTHENE       | 2 / 72                    | 0.42                                         | 0.51                                          | HASTINGS                                | 0.187                                       | 1.65                                                 | 0.33   |
| BIS(2-ETHYLHEXYL)PHTHALATE | 11 / 72                   | 0.39                                         | 6.6                                           | N210E210                                | 0.247                                       | 1.65                                                 | 0.33   |
| BUTYL BENZYL PHTHALATE     | 1 / 72                    | 0.59                                         | 0.59                                          | CSB1                                    | 0.185                                       | 1.65                                                 | 0.33   |

TABLE 2  
SUMMARY OF SOIL SAMPLING RESULTS

| Chemical                 | Frequency<br>of Detection | Lowest<br>Concentration<br>Detected<br>(PPM) | Highest<br>Concentration<br>Detected<br>(PPM) | Location of<br>Highest<br>Concentration | Geometric<br>Mean<br>Concentration<br>(PPM) | Range of Detection<br>Limits for ND Samples<br>(PPM) |        |
|--------------------------|---------------------------|----------------------------------------------|-----------------------------------------------|-----------------------------------------|---------------------------------------------|------------------------------------------------------|--------|
|                          |                           |                                              |                                               |                                         |                                             | Highest                                              | Lowest |
| TETRACHLOROETHYLENE      | 100 / 419                 | 0.020                                        | 600                                           | CSB6                                    | 0.041                                       | 50                                                   | 0.0050 |
| TOLUENE                  | 169 / 424                 | 0.027                                        | 3100                                          | N195E150                                | 0.183                                       | 20                                                   | 0.0050 |
| TRANS-1,2-DICHLOROETHENE | 1 / 419                   | 0.034                                        | 0.034                                         | N200E230                                | 0.021                                       | 50                                                   | 0.0050 |
| TRICHLOROFLUOROMETHANE   | 14 / 419                  | 0.020                                        | 1.2                                           | N180E450                                | 0.023                                       | 50                                                   | 0.0050 |
| XYLENE                   | 110 / 425                 | 0.046                                        | 3600                                          | N210E210                                | 0.173                                       | 25                                                   | 0.0050 |
| ZINC                     | 96 / 96                   | 21                                           | 452                                           | MW-4(S)                                 | 65.130                                      | -                                                    | -      |



TABLE 3  
SUMMARY OF SURFACE WATER SAMPLING RESULTS

| Chemical                 | Frequency<br>of Detection | Lowest<br>Concentration<br>Detected<br>(PPM) | Highest<br>Concentration<br>Detected<br>(PPM) | Location of<br>Highest<br>Concentration | Geometric<br>Mean<br>Concentration<br>(PPM) | Range of Detection<br>Limits for ND Samples<br>(PPM) |        |
|--------------------------|---------------------------|----------------------------------------------|-----------------------------------------------|-----------------------------------------|---------------------------------------------|------------------------------------------------------|--------|
|                          |                           |                                              |                                               |                                         |                                             | Highest                                              | Lowest |
| 1,1,1-TRICHLOROETHANE    | 3 / 23                    | 0.0006                                       | 0.0270                                        | WT-1W                                   | 0.0003                                      | 0.0005                                               | 0.0005 |
| 1,1-DICHLOROETHANE       | 3 / 23                    | 0.0007                                       | 0.0160                                        | WT-1W                                   | 0.0003                                      | 0.0005                                               | 0.0005 |
| TRICHLOROETHYLENE        | 1 / 23                    | 0.0007                                       | 0.0007                                        | WT-1W                                   | 0.0003                                      | 0.0005                                               | 0.0005 |
| 1,2-DICHLOROETHYLENE-CIS | 4 / 23                    | 0.0007                                       | 0.0047                                        | WT-1W                                   | 0.0003                                      | 0.0005                                               | 0.0005 |
| ARSENIC                  | 1 / 23                    | 0.0100                                       | 0.0100                                        | CPW                                     | 0.0052                                      | 0.0100                                               | 0.0100 |
| FREON 113                | 3 / 11                    | 0.0006                                       | 0.0030                                        | WT-1W                                   | 0.0004                                      | 0.0005                                               | 0.0005 |
| LEAD                     | 1 / 23                    | 0.0110                                       | 0.0110                                        | NWC                                     | 0.0027                                      | 0.0050                                               | 0.0050 |
| METHYLENE CHLORIDE       | 2 / 23                    | 0.0016                                       | 0.0021                                        | CPW                                     | 0.0003                                      | 0.0005                                               | 0.0005 |
| TETRACHLOROETHYLENE      | 1 / 23                    | 0.0011                                       | 0.0011                                        | WT-1W                                   | 0.0003                                      | 0.0005                                               | 0.0005 |
| ZINC                     | 3 / 30                    | 0.0210                                       | 0.0600                                        | NWC                                     | 0.0255                                      | 0.0500                                               | 0.0200 |

TABLE 5

SUMMARY OF FACILITY SAMPLING RESULTS  
UNION CHEMICAL SITE

| Chemical Residue             | Frequency<br>of<br>Detection | Range of<br>Detected<br>Concentrations<br>(ppm) | Geometric<br>Mean<br>Concentration<br>(ppm) |
|------------------------------|------------------------------|-------------------------------------------------|---------------------------------------------|
| <u>Incinerator Equipment</u> |                              |                                                 |                                             |
| 2,3,7,8-TCDD                 | 0 / 6                        | -                                               | 0.0000145                                   |
| Other TCDD                   | 2 / 6                        | 0.00081 - 0.0017                                | 0.000106                                    |
| 2,3,7,8-TCDF                 | 5 / 6                        | 0.000012 - 0.0028                               | 0.000130                                    |
| Other TCDF                   | 4 / 6                        | 0.00057 - 0.0129                                | 0.000376                                    |
| 1,2,3,7,8-PeCDD              | 2 / 6                        | 0.00012 - 0.0016                                | 0.000066                                    |
| Other PeCDD                  | 3 / 6                        | 0.00019 - 0.0218                                | 0.000420                                    |
| 1,2,3,7,8-PeCDF              | 5 / 6                        | 0.0004 - 0.0159                                 | 0.000395                                    |
| Other PeCDF                  | 5 / 6                        | 0.0016 - 0.0785                                 | 0.001280                                    |
| XX2,3,7,8-HxCDD              | 3 / 6                        | 0.0001 - 0.0059                                 | 0.000136                                    |
| Other HxCDD                  | 4 / 6                        | 0.0011-0.0188                                   | 0.000802                                    |
| XX 2,3,7,8-HxCDF             | 5 / 6                        | 0.0011-0.052                                    | 0.000950                                    |
| Other HxCDF                  | 5 / 6                        | 0.000024-0.0708                                 | 0.001700                                    |
| 1,2,3,4,6,7,8-HpCDD          | 5 / 6                        | 0.00034 - 0.0163                                | 0.000572                                    |
| Other HpCDD                  | 5 / 6                        | 0.00027 - 0.0148                                | 0.000683                                    |
| 1,2,3,4,6,7,8-HpCDF          | 5 / 6                        | 0.00013 - 0.0966                                | 0.002030                                    |
| Other HpCDF                  | 5 / 6                        | 0.000035 - 0.123                                | 0.002718                                    |
| OCDD                         | 4 / 6                        | 0.00087-0.0259                                  | 0.001190                                    |
| OCDF                         | 5 / 6                        | 0.00075-0.0782                                  | 0.003093                                    |
| Antimony                     | 2 / 4                        | 21 - 44                                         | 8.72                                        |
| Arsenic                      | 1 / 4                        | 8.3                                             | 3.37                                        |
| Benzo(A) Anthracene          | 1 / 4                        | 8.2                                             | 3.48                                        |
| Benzo(B) Fluoranthene        | 1 / 4                        | 8.1                                             | 3.47                                        |
| Cadmium                      | 3 / 4                        | 4.9 - 40                                        | 5.73                                        |
| Chromium                     | 4 / 4                        | 13 - 810                                        | 210.66                                      |
| Chrysene                     | 1 / 4                        | 12                                              | 3.83                                        |
| Copper                       | 3 / 4                        | 40 - 4850                                       | 109.65                                      |
| Dimethylphthalate            | 1 / 4                        | 1100                                            | 6.67                                        |
| Ethylbenzene                 | 1 / 2                        | 19                                              | 0.22                                        |
| Flouranthene                 | 1 / 4                        | 10                                              | 3.66                                        |
| Lead                         | 3 / 4                        | 155 - 9200                                      | 199.35                                      |
| Mercury                      | 1 / 4                        | 0.24                                            | 0.12                                        |
| Methylene chloride           | 1 / 2                        | 61                                              | 0.39                                        |
| Nickel                       | 3 / 4                        | 64 - 712                                        | 90.58                                       |



TABLE 5

SUMMARY OF FACILITY SAMPLING RESULTS  
UNION CHEMICAL SITE

| Chemical Residue            | Frequency<br>of<br>Detection | Range of<br>Detected<br>Concentrations<br>(ppm) | Geometric<br>Mean<br>Concentration<br>(ppm) |
|-----------------------------|------------------------------|-------------------------------------------------|---------------------------------------------|
| Phenanthrene                | 1 / 4                        | 9.1                                             | 3.58                                        |
| Pyrene                      | 1 / 4                        | 16                                              | 4.12                                        |
| Styrene                     | 1 / 1                        | 326                                             | 326.00                                      |
| Zinc                        | 4 / 4                        | 9.5 - 1010                                      | 152.29                                      |
| <u>Still Building Area</u>  |                              |                                                 |                                             |
| 1,1,1-Trichloroethane       | 6 / 9                        | 0.087 - 19                                      | 0.88                                        |
| Trichloroethylene           | 3 / 9                        | 0.034 - 33                                      | 0.13                                        |
| Acetone                     | 1 / 3                        | 0.29                                            | 0.18                                        |
| Antimony                    | 4 / 5                        | 9.4 - 22                                        | 10.5                                        |
| Arsenic                     | 4 / 5                        | 10 - 19                                         | 9.56                                        |
| Bis(2-ethyl-hexyl)phthalate | 2 / 3                        | 160 - 1800                                      | 98.32                                       |
| Butyl benzyl phthalate      | 1 / 3                        | 25                                              | 5.14                                        |
| Cadmium                     | 5 / 5                        | 8 - 35                                          | 17.7                                        |
| Chromium                    | 5 / 5                        | 219 - 1170                                      | 557.7                                       |
| Copper                      | 5 / 5                        | 607 - 1910                                      | 843                                         |
| Cyanide                     | 5 / 5                        | 1.0 - 27                                        | 6.39                                        |
| Dimethylphthalate           | 1 / 3                        | 6.4                                             | 4.14                                        |
| Ethylbenzene                | 3 / 9                        | 0.062 - 38                                      | 0.51                                        |
| Isophorone                  | 1 / 3                        | 14                                              | 5.37                                        |
| Lead                        | 5 / 5                        | 1360 - 4010                                     | 2365                                        |
| Mercury                     | 5 / 5                        | 1.3 - 20                                        | 2.77                                        |
| Nickel                      | 5 / 5                        | 137 - 814                                       | 263                                         |
| Selenium                    | 2 / 5                        | 1.2 - 1.4                                       | 0.73                                        |
| Silver                      | 4 / 5                        | 5.3 - 13                                        | 6.47                                        |
| Tetrachloroethylene         | 6 / 9                        | 0.031 - 920                                     | 0.54                                        |
| Toluene                     | 3 / 9                        | 1.7 - 28                                        | 1.12                                        |
| Trichlorofluoromethane      | 1 / 9                        | 0.0089                                          | 0.08                                        |
| Xylene                      | 4 / 9                        | 0.029 - 270                                     | 1.16                                        |
| Zinc                        | 5 / 5                        | 890 - 5450                                      | 1923                                        |

APPENDIX C  
POTENTIALLY APPLICABLE REMEDIAL  
TECHNOLOGIES

D  
R  
A  
F  
T



## TABLE OF CONTENTS

|                                        | <u>PAGE</u> |
|----------------------------------------|-------------|
| 1.0 INTRODUCTION                       | C-1         |
| 2.0 CONTAINMENT OPTIONS                | C-2         |
| 2.1 Capping                            | C-2         |
| 2.1.1 Clay Cap                         | C-2         |
| 2.1.2 Synthetic Membranes              | C-2         |
| 2.1.3 Multimedia Cap                   | C-2         |
| 2.2 Vertical Barriers                  | C-3         |
| 2.2.1 Slurry Wall                      | C-3         |
| 2.2.2 Sheet Piling                     | C-3         |
| 2.2.3 Grout Curtains                   | C-3         |
| 2.3 Horizontal Barriers                | C-4         |
| 2.3.1 Liners                           | C-4         |
| 2.3.2 Bottom Sealing by Grouting       | C-4         |
| 2.4 Surface Controls                   | C-5         |
| 2.4.1 Diversion/Collection             | C-5         |
| 2.4.2 Grading                          | C-5         |
| 2.5 Dust Controls                      | C-5         |
| 2.5.1 Revegetation                     | C-5         |
| 2.5.2 Capping                          | C-6         |
| 2.5.3 Dust Suppressants                | C-6         |
| 3.0 REMOVAL OPTIONS                    | C-7         |
| 3.1 Ground Water Collection/Extraction | C-7         |
| 3.1.1 Recovery Wells                   | C-7         |
| 3.1.2 Interceptor Trenches             | C-8         |

TABLE OF CONTENTS  
(Continued)

|                                          | <u>PAGE</u> |
|------------------------------------------|-------------|
| 3.2 Soil Excavation                      | C-8         |
| 3.2.1 Partial Soil Excavation            | C-8         |
| 3.2.2 Complete Soil Excavation           | C-9         |
| 3.3 Bulk Sludge Removal                  | C-9         |
| 3.4 Structures Demolition                | C-9         |
| 4.0 TREATMENT OPTIONS                    | C-10        |
| 4.1 Physical Treatment                   | C-10        |
| 4.1.1 Ground Water                       | C-10        |
| 4.1.1.1 Sedimentation                    | C-10        |
| 4.1.1.2 Flocculation                     | C-10        |
| 4.1.1.3 Filtration/Ultrafiltration       | C-11        |
| 4.1.1.4 Reverse Osmosis                  | C-11        |
| 4.1.1.5 Evaporation                      | C-11        |
| 4.1.1.6 Air Stripping/Steam Stripping    | C-12        |
| 4.1.1.7 Distillation                     | C-12        |
| 4.1.1.8 Carbon Adsorption                | C-13        |
| 4.1.1.9 Ion Exchange                     | C-14        |
| 4.1.1.10 Dissolved Air Flotation         | C-14        |
| 4.1.1.11 Liquid-Liquid Extraction        | C-14        |
| 4.1.1.12 Electrodialysis                 | C-15        |
| 4.1.2 Soil                               | C-15        |
| 4.1.2.1 Liquified Gas Solvent Extraction | C-15        |
| 4.1.2.2 Ambient Temperature Aeration     | C-16        |
| 4.1.2.3 Water/Solvent Leaching           | C-17        |



TABLE OF CONTENTS  
(Continued)

|                                          | <u>PAGE</u> |
|------------------------------------------|-------------|
| 4.1.3 Sludge                             | C-17        |
| 4.1.3.1 Freeze Crystallization           | C-17        |
| 4.2 Chemical Treatment                   | C-17        |
| 4.2.1 Ground Water                       | C-17        |
| 4.2.1.1 Neutralization                   | C-17        |
| 4.2.1.2 Chemical Precipitation           | C-18        |
| 4.2.1.3 Chemical Oxidation               | C-18        |
| 4.2.1.4 Alkaline Chlorination            | C-18        |
| 4.2.1.5 Catalytic Dehydrohalogenation    | C-19        |
| 4.2.1.6 Electrochemical Operation        | C-19        |
| 4.2.1.7 Chelation                        | C-19        |
| 4.2.2 Soil                               | C-19        |
| 4.2.2.1 Lime Neutralization              | C-19        |
| 4.2.3 Sludge                             | C-20        |
| 4.2.3.1 Oxidation/Reduction              | C-20        |
| 4.3 Thermal Treatment                    | C-20        |
| 4.3.1 Ground Water                       | C-20        |
| 4.3.1.1 Wet Air Oxidation                | C-20        |
| 4.3.2 Soil                               | C-20        |
| 4.3.2.1 Incineration                     | C-20        |
| 4.3.2.2 Pyrolysis                        | C-21        |
| 4.3.2.3 Low Temperature Thermal Aeration | C-21        |

TABLE OF CONTENTS  
(Continued)

|                                                 | <u>PAGE</u> |
|-------------------------------------------------|-------------|
| 4.4 Biological Treatment                        | C-22        |
| 4.4.1 Ground Water                              | C-22        |
| 4.4.1.1 Trickling Filters                       | C-22        |
| 4.4.1.2 Rotating Biological Contactors          | C-23        |
| 4.4.1.3 Activated Sludge                        | C-23        |
| 4.4.1.4 Sequencing Batch Reactors               | C-24        |
| 4.4.1.5 Submerged Fixed Film Bioreactor         | C-25        |
| 4.4.1.6 Land Treatment                          | C-26        |
| 4.4.1.7 Enzymatic Degradation                   | C-27        |
| 4.4.1.8 AlgaSORB™                               | C-27        |
| 4.4.2 Soil                                      | C-28        |
| 4.4.2.1 Composting                              | C-28        |
| 4.5 In-Situ Treatment                           | C-29        |
| 4.5.1 Ground Water                              | C-29        |
| 4.5.1.1 Aerobic Biodegradation                  | C-29        |
| 4.5.2 Soil                                      | C-29        |
| 4.5.2.1 Enhanced Aerobic Biodegradation         | C-29        |
| 4.5.2.2 Flushing (With Surfactants)             | C-30        |
| 4.5.2.3 In-Situ Vacuum Extraction/Soil Aeration | C-31        |
| 4.5.2.4 Radio Frequency Heating                 | C-31        |
| 4.5.2.5 Steam Flushing                          | C-32        |
| 4.5.2.6 Thermal Stripping                       | C-32        |
| 4.5.2.7 Adsorbents                              | C-33        |



TABLE OF CONTENTS  
(Continued)

|                                                                                 | <u>PAGE</u> |
|---------------------------------------------------------------------------------|-------------|
| 4.5.2.8 Vitrification                                                           | C-33        |
| 4.5.2.9 Polymerization                                                          | C-34        |
| 4.6 Solification/Stabilization                                                  | C-34        |
| 4.7 Solids Processing/Treatment                                                 | C-35        |
| 5.0 DISPOSAL OPTIONS                                                            | C-36        |
| 5.1 Ground Water                                                                | C-36        |
| 5.1.1 Off-Site Disposal                                                         | C-36        |
| 5.1.2 Discharge to Publicly Owned Treatment Works                               | C-36        |
| 5.1.3 Discharge to Surface Water After Treatment                                | C-36        |
| 5.1.4 On-Site Reinjection of Treated Ground Water                               | C-36        |
| 5.1.5 On-Site Spray Irrigation After Treatment                                  | C-37        |
| 5.2 Ground Water Treatment Residuals                                            | C-37        |
| 5.2.1 On-Site Disposal and Off-Site Treatment/Disposal                          | C-37        |
| 5.3 Soil                                                                        | C-37        |
| 5.3.1 On-Site and Off-Site Disposal of Contaminated Soils in a RCRA Landfill    | C-37        |
| 5.3.2 On-Site Disposal of Treated Soils as Backfill                             | C-38        |
| 5.3.3 On-Site Storage of Soils                                                  | C-38        |
| 5.4 Sludge                                                                      | C-39        |
| 5.4.1 On-Site Disposal of Solidified Sludge                                     | C-39        |
| 5.4.2 Off-Site Disposal of Contaminated or Biological Sludge in a RCRA Landfill | C-39        |
| 6.0 DECONTAMINATION OPTIONS                                                     | C-40        |
| 6.1 Dusting/Vacuuming/Wiping                                                    | C-40        |
| 6.2 Gritblasting                                                                | C-40        |

TABLE OF CONTENTS  
(Continued)

|                      | <u>PAGE</u> |
|----------------------|-------------|
| 6.3 Hydroblasting    | C-40        |
| 6.4 Painting/Coating | C-41        |
| 6.5 Scarification    | C-41        |
| 6.6 RadKleen®        | C-41        |
| 6.7 Solvent Washing  | C-42        |
| 6.8 Steam Cleaning   | C-42        |

D  
R  
A  
F  
T



APPENDIX C  
POTENTIALLY APPLICABLE REMEDIAL TECHNOLOGIES

1.0 INTRODUCTION

This appendix provides a brief description of the process options considered potentially applicable for site remediation. There are five general response actions for the site. They include Containment Options (Section 2.0), Removal Options (Section 3.0), Treatment Options (Section 4.0), Disposal Options (Section 5.0), and Decontamination Options (Section 6.0). For each general response action, the applicable technology types and associated specific process options are discussed.

D  
R  
A  
F  
T

## 2.0 CONTAINMENT OPTIONS

Five technology types have been considered which could potentially provide containment of the constituents at the Union Chemical Site. The technology types include the following: capping, vertical barriers, horizontal barriers, surface controls, and dust controls.

### 2.1 Capping

#### 2.1.1 Clay Cap

A clay cap is a layer of compacted clay placed over waste or impacted soils to prevent the percolation of rainfall or surface water through the waste. By preventing percolation through the waste, the chemical residues remain in place and do not impact the ground water system. The clay cover could range from three to four feet in thickness. Note that such a design would not comply with Resource Conservation and Recovery Act (RCRA) requirements for new sites, as RCRA requires a multimedia cap (described in Section 2.1.3).

#### 2.1.2 Synthetic Membranes

Synthetic membranes, or flexible membrane caps, may also be used to reduce surface water infiltration. Generally, they must be used in conjunction with low permeability clay as described in Section 2.1.3.

#### 2.1.3 Multimedia Cap

Multimedia caps make use of both synthetic membranes and clay. Approximately two feet of clay underlies the membrane and an equivalent amount of topsoil covers it allowing for the growth of vegetation indigenous to the area.



Site-specific conditions may require additional layers which provide for more efficient drainage or deter burrowing animals from tearing the synthetic membrane. As with all caps, multimedia caps are used to prevent percolation through the waste and deter migration of chemical residues.

## 2.2 Vertical Barriers

### 2.2.1 Slurry Wall

A slurry wall is one of several types of subsurface cut-off walls that prevent additional ground water contamination by redirecting upgradient ground water away from a contaminated area. A slurry wall is constructed by filling a trench with a slurry such as bentonite or bentonite-soil-cement during excavation. The backfilled trench has a low permeability, and thus creates a barrier to ground water flow. Generally, slurry walls must be keyed at their base into an impermeable soil layer (clay).

### 2.2.2 Sheet Piling

Sheet piling can be used to form a continuous ground water barrier. The piling can reduce ground water contamination by redirecting upgradient ground water away from the area containing chemical residues. Although sheet piles can also be made of wood or precast concrete, steel is the most effective in terms of cutting off ground water and ease of installation. The construction of a steel sheet piling cut-off wall involves driving interlocking piles into the ground using a pneumatic or steam-driven pile driver. In some cases, the piles are pushed into pre-dug trenches. Piles are commonly 4 to 40 feet long and 15 to 20 inches wide. Because of corrosion and leaky joints usually present between piles, this method is often considered a temporary stop-gap measure.

### 2.2.3 Grout Curtains

Generally, grouting is the injection under pressure of one of a variety of special fluids into a rock or soil body to seal and strengthen that body.