Attachment A

List of Acronyms

ABBREVIATIONS

%R	Spike Recovery Control Limits
Aerojet	Aerojet-General Corporation
AOCs	Areas of Concern
API	Armor Piercing Incendiary
BTEX	Benzene, Toluene, Ethylbenzene, Xylenes
CAPCOA	California Air Pollution Control Officers Association
CCR	Current Conditions Report
CEQA	California Environmental Quality Act
CERCLA	Comprehensive Environmental Response Compensation and Liability Act
CMS	Corrective Measures Study
CMW	Corrective Measures Workplan
Consent Agreement	Corrective Action Administrative Agreement on Consent
CPT	Cone Penetrometer Test
CS	o-chlorobenzylidene malononitrile or "tear gas"
DHS	Department of Health Services
DOD	Department of Defense
DOT	Department of Transportation
DQOs	Data Quality Objectives
DTSC	Department of Toxic Substances Control
DU	Depleted Uranium
EOD	Explosive Ordnance Disposal
OEW	Ordnance Explosive Waste
EPI	Environmental Priorities Initiative
Facility	Aerojet Chino Hills Facility
ft	Feet
GPR	Ground Penetrating Radar
HASP	Health and Safety Plan
HBSSLs	Health- Based Soil Screening Levels
HBCLs	Health-Based Cleanup Levels
HEI	High Explosive Incendiary
HMX	Cyclotetramethylenetetranitramine or Octahydro-1,3,5,7-trinitro-1,3,5,7-tetrazocine
HSDB	National Library of Medicine Computerized Hazardous Substance Data Bank
LCS	Laboratory Control Samples
LTTD	Low Temperature Thermal Desorption
MCLs	Maximum Contaminant Levels
meq/l	milliequivalent per liter
MRI	Midwest Research Institute
msl	mean sea level
MS/MSD	Matrix Spike/Matrix Spike Duplicate
OB/OD	Open Burn/Open Detonation

ABBREVIATIONS
(cont.)

OSW	Office of Solid Waste
PA	Preliminary Assessment
PCBs	Polychlorinated Biphenyls
PCE	Tetrachloroethene
PID	Photoionization Detector
PIP	Public Involvement Plan
ppb	Parts Per Billion
PPE	Personal Protective Equipment
ppm	Parts Per Million
PQLs	Practical Quantitation Limits
PRG	Preliminary Remediation Goals
QA/QC	Quality Assurance/Quality Control
RA	Risk Assessment
RBCA	Risk-Based Corrective Action
RCRA	Resource Conservation and Recovery Act
RDX	Cyclotrimethylenetrinitramine or Hexahydro-1,3,5-trinitro-1,3,5-triazine
RfD	Reference Dose
RFI	RCRA Facility Investigation
RP	Relative Percent
RPD	Relative Percent Difference
RWQCB	Regional Water Quality Control Board
SCPHT	Sample Collection, Preservation and Holding Time
SOP	Standard Operating Procedures
SOW	Scope of Work
STLC	Soluble Threshold Limit Concentration
SVOCs	Semi-Volatile Organic Compounds
SWMUs	Solid Waste Management Units
TCE	Trichloroethylene
TCL	Target Compound List
TDS	Total Dissolved Solid
TLVs	Threshold Limit Values
1,3,5-TNB	1,3,5-Trinitrobenzene
TNT	Trinitrotoluene
TP	Target Practice Rounds
TPH	Total Petroleum Hydrocarbons
TPH-d	Total Petroleum Hydrocarbons as Diesel
TPH-g	Total Petroleum Hydrocarbons as Gasoline
TPH-mo	Total Petroleum Hydrocarbons as Motor Oil
TRPH	Total Recoverable Petroleum Hydrocarbons

ABBREVIATIONS
(cont.)

TTLC	Total Threshold Limit Concentration
UCL	Upper Confidence Level
USAEC	United States Army Environmental Center
USEPA	United States Environmental Protection Agency
UST	Underground Storage Tank
UXO	Unexploded Ordnance
VX	o-ethyl-s-(2-diisopropyl aminoethyl) methylphosphonothiolate
VOCs	Volatile Organic Compounds
WIP	Well Investigation Program
Workplan	RCRA Facility Investigation Workplan

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Attachment B

Conditions of Approval
For
Corrective Measures

Additional Work Required
Under
Section X of the Consent Agreement

DEPARTMENT OF TOXIC SUBSTANCES CONTROL
GEOLOGY AND CORRECTIVE ACTION BRANCH

CONDITIONS OF APPROVAL FOR CORRECTIVE MEASURES

AEROJET ORDNANCE – CHINO HILLS FACILITY
END OF WOODVIEW ROAD
CHINO HILLS, CALIFORNIA
EPA ID NO. CAD981457302

As a result of public comments received and changes in DTSC internal policy, the following conditions of approval are being added to the Corrective Measures:

1. The authority to detonate ordnance items found during ordnance sweeps will now be designated in the Consent Agreement as modified. An emergency permit will not need to be issued. This condition is being added to be consistent with current DTSC policy.

2. Air monitoring for dust shall be conducted downwind of excavation activities for excavation of soil contaminated with explosive chemicals or CS-containing material, and sifting of soil for ordnance. This condition is being added to address community concerns regarding air emissions and to be consistent with standard Health and Safety practices.

3. The soil contaminated with RDX (above health-based cleanup levels) that will be hauled off site as part of the Corrective Measures will be tested using a fish toxicity test pursuant to 66261.24 of Title 22 of the California Code of Regulations to determine whether or not it is a hazardous waste. The soil will be determined to be hazardous or non-hazardous waste The soil shall be transported off site in accordance with all appropriate requirements of the California Vehicle Code and Department of Transportation Regulations for either hazardous or non-hazardous waste. Notwithstanding these requirements and the classification of the soil as hazardous or non-hazardous, at a minimum, the soil will be transported off site in trucks with tarps. Trucks with "rollover" tarps shall be used for hauling this soil, and the tarping must fully enclose the truck bed. Aerojet must also decontaminate the trucks by dry brushing and shall inspect the trucks before they leave the site to ensure that the tarps are secure and decontamination has been adequately conducted. Trucks must follow the truck route established in the Initial Study: east on Woodview Road to Pipeline, south on Pipeline to Soquel Canyon Drive, and east on Soquel Canyon Drive to the 71 freeway. This condition is being added to address community concerns regarding escape of soil from trucks as the trucks travel from the site to the 71 freeway. Section 23114 of the California Vehicle Code states that tarped trucks carrying contaminated soil may not have holes, cracks or openings through which dirt can escape. If the soil is found to be a hazardous waste, the soil will be handled in accordance with the transportation requirements for hazardous waste (i.e. placed in sealed containers), and trucks with tarps will not be used

4. Aerojet shall notify DTSC in advance and the community in advance via an advertisement in a local newspaper (the Chino Hills Champion and/or Daily Bulletin) regarding the time frame for truck activity carrying contaminated soil/materials from the facility and regarding detonations.

5. Aerojet shall be required to notify the California Department of Parks and Recreation (CDPR) office, Los Lagos District, in the event of a brush fire on the property. The phone number is (909) 657-0676. This requirement is being added in response to comments made by CDPR.

6. Once the Corrective Measures have been implemented, surface water both on site and off site shall be resampled for explosive chemicals (via EPA method 8330) and perchlorate. This sampling shall be conducted at a time when surface water is present at the facility.

7. Aerojet shall be required to submit a community education plan at the time the Corrective Measures Completion Report is submitted. The purpose of this plan shall be to establish a dialogue with the community to develop information that the community wishes to know about ordnance in order for them to feel comfortable and be safe using the site in the future. This plan will include setting up a committee consisting of interested community members to discuss the needs of the community regarding ordnance.

8. Long term Operation and Maintenance Requirements

   As a requirement for termination of Corrective Action, Aerojet shall be required to submit a Long Term Operation and Maintenance Plan (O&M Plan) to ensure ongoing protection of human health and the environment with respect to ordnance. If, at the time of termination of Corrective Action, groundwater exists at the facility above health based levels, the long term operation and maintenance requirements will include groundwater monitoring over seasonal cycles to address migration issues and provisions to prevent future users of the site from being exposed to the water.

   For ordnance, these requirements will include construction support (requirements regarding grading including the placing of 10 feet of fill over ordnance impact areas, and the requirement for the availability of an Explosive Ordnance Disposal (EOD) Specialist during grading), deed notification (informing future property owners regarding ordnance) and the community ordnance education program mentioned above.

   These Long Term Operation and Maintenance Requirements will be described in more detail by Aerojet at the termination of Corrective Action at the facility and the O&M Plan will be reviewed and approved by DTSC.

9. Aerojet shall conduct a periodic (at least every 5 years) review of the effectiveness and reliability of the technology used to detect the presence of unexploded ordnance and evaluate the effectiveness of the Community Education Plan, and determine whether modifications to the Remedy and/or Community Education Plan are necessary.

DEPARTMENT OF TOXIC SUBSTANCES CONTROL
GEOLOGY AND CORRECTIVE ACTION BRANCH

ADDITIONAL WORK REQUIRED
UNDER
SECTION X OF THE CONSENT AGREEMENT

AEROJET ORDNANCE – CHINO HILLS FACILITY
END OF WOODVIEW ROAD
CHINO HILLS, CALIFORNIA
EPA ID NO. CAD981457302

As a result of public comments received and changes in DTSC internal policy, Aerojet is required to perform the following work:

1. Aerojet shall submit a surface water and groundwater sampling plan to address nitrates at the facility. This requirement is being added to address community concerns regarding nitrates.

2. Aerojet shall conduct confirmation sampling for explosive chemicals and Title 22 metals at all impact areas of the test ranges where such sampling has not been conducted to date to ensure that these constituents of concern are below health based cleanup levels for explosive chemicals and background levels for metals. Confirmation sampling for Title 22 metals shall also be conducted at SWMU #10A, Dragon Tooth Mine Test Area, and Test Area 20. This requirement is being added as part of the continuing ordnance investigation

3. Aerojet shall install a monitoring well in the perched groundwater zone at 58 feet at the former Redwater Pond, and the pumpability of the groundwater in this zone shall be evaluated to determine whether or not it can be removed. This work shall be conducted at a time when shallow subsurface water is likely to be present on the facility. This requirement is being added to evaluate whether pump-and-treat can be a remedy option at this area, and to address community concerns regarding whether or not this groundwater can be removed from the subsurface.

4. Aerojet shall conduct additional groundwater sampling to better define the extent of perchlorate contamination in the Upper A-12 Test Area, and to verify that this contamination is not migrating. A monitoring well shall be installed at the location of boring SW-15-31 at 35-40 feet (or other DTSC-approved location), and the pumpability of the groundwater shall be evaluated to determine whether or not it can be removed. This work shall be conducted at a time when shallow subsurface water is likely to be present on the facility. This requirement is being added to evaluate whether pump-and-treat can be a remedy option at this area, and to address community concerns regarding whether or not this groundwater can be removed from the subsurface

5. Aerojet shall propose and submit to DTSC cleanup levels for the following chemicals of concern detected in groundwater: RDX, HMX, 1,3,5-trinitrobenzene, 1,3-dinitrobenzene, 4-amino-2,6-dinitrotoluene, 2-amino-4,6-dinitrotoluene, and perchlorate. These levels shall be established by a Health Risk Assessment conducted by Aerojet using confirmation sampling data collected at the former Redwater Pond and Upper A-12 Test Area during implementation of the Corrective Measures.

6. Aerojet shall conduct soil and groundwater sampling in the area beneath the Former Landfill (SWMU #2) to determine whether or not perchlorate has impacted the subsurface. This investigation should be conducted upon completion of the Corrective Measures excavation of the landfill material. This work shall be conducted at a time when shallow subsurface water is likely to be present on the facility. This requirement is being added in response to evidence that the Former Landfill is the source of perchlorate detected in surface water samples from Soquel Canyon Creek and to address community concerns regarding contaminated groundwater and surface water at the facility.

7. Aerojet shall conduct confirmation sampling for Title 22 metals, semivolatile organic compounds, explosive chemicals and perchlorate at Area 5 mentioned in the 1991 Jaykim report titled "Excerpts from Draft Property Assessment of Aerojet Ordnance Chino Facility". This requirement is being added to confirm that levels of these chemicals are below levels of concern as stated in the ordnance sweep report documenting the results of ordnance sweeps for the former test areas at the site.

8. Aerojet shall submit copies of the report documenting the building decommissioning activities for DTSC's review. This requirement is being added to ensure that soil sampling data collected during these activities show no contamination above levels of concern.

9. Aerojet shall conduct an inspection for ordnance at the area along Soquel Canyon Creek, extending 1/4 to 1/2 mile beyond the gate at the southwest exit of the facility (Area of Concern). This requirement is being added to address community concerns

10. Aerojet shall be required to drill a boring below the excavation of the former underground storage tank to determine if shallow subsurface water is present. This boring shall be drilled 40-60 feet deep, below all unconsolidated material and into bedrock. If shallow subsurface water is encountered, it shall be tested for contaminants of concern from the tank, i.e. BTEX (benzene, toluene, ethylbenzene, xylene) and MTBE. This boring shall be drilled at a time when shallow groundwater is likely to be present at the facility.

11. Aerojet shall be required to submit data documenting the existing levels of uranium at the facility, and to conduct sampling of surface water and groundwater at the Facility for uranium. This requirement is being added to ensure that existing levels of uranium are protective of human health and the environment for a future residential land use scenario.

Attachment C

Information on Health Effects Of Constituents of Concern

TOXICOLOGICAL PROFILE FOR RDX

Prepared by:

Research Triangle Institute
Under Contract No. 205-93-0606

Prepared for:

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry

June 1995

C-1

1. PUBLIC HEALTH STATEMENT

This statement was prepared to give you information about RDX and to emphasize the human health effects that may result from exposure to it. The Environmental Protection Agency (EPA) has identified 1,397 hazardous waste sites as the most serious in the nation. These sites make up the National Priorities List (NPL) and are the sites targeted for long-term federal clean-up activities. RDX has been found in at least 16 of the sites on the NPL. However, the number of NPL sites evaluated for RDX is not known. As EPA evaluates more sites, the number of sites at which RDX is found may increase. This information is important because exposure to RDX may cause harmful health effects and because these sites are potential or actual sources of human exposure to RDX.

When a substance is released from a large area, such as an industrial plant, or from a container, such as a drum or bottle, it enters the environment. This release does not always lead to exposure. You can be exposed to a substance only when you come in contact with it. You may be exposed by breathing, eating, or drinking substances containing the substance or by skin contact with it.

If you are exposed to a substance such as RDX, many factors will determine whether harmful health effects will occur and what the type and severity of those health effects will be. These factors include the dose (how much), the duration (how long), the route or pathway by which you are exposed (breathing, eating, drinking, or skin contact), the other chemicals to which you are exposed, and your individual characteristics such as age, sex, nutritional status, family traits, lifestyle, and state of health.

1.1 WHAT IS RDX?

RDX stands for Royal Demolition Explosive. It is also known as cyclonite or hexogen. The chemical name for RDX is 1,3,5-trinitro-1,3,5-triazine. It is a white powder and is very explosive. It is used as an explosive and is also used in combination with other ingredients in

explosives. Its odor and taste are unknown. It is a synthetic product that does not occur naturally in the environment. It creates fumes when it is burned with other substances. For more information, see Chapters 3 and 4.

1.2 WHAT HAPPENS TO RDX WHEN IT ENTERS THE ENVIRONMENT?

RDX particles can enter the air when it is disposed of by burning. RDX can enter the water from disposal of waste water from Army ammunition plants, and can enter water or soil from spills or leaks from improper disposal at these plants or at hazardous waste sites. RDX dissolves very slowly and to a limited extent in water, and it also evaporates very slowly from water. It does not cling to soil very strongly and can get into the groundwater from soil. RDX can be broken down in air and water in a few hours, but it breaks down more slowly in soil. RDX does not build up in fish or in people. See Chapters 4 and 5 for more information on RDX in the environment

1.3 HOW MIGHT I BE EXPOSED TO RDX?

Few people will be exposed to RDX. Less than 500 people are known to work with RDX, but these people can breathe dust with RDX in it or get RDX on their skin. You may be exposed to RDX by drinking contaminated water or by touching contaminated soil if you live near factories that produce RDX. RDX has been found in water and soil at some ammunition plants. Surface water samples contained from nondetectable to 36.9 parts of RDX per 1 million parts (ppm) of water. Groundwater samples had levels of 0.001–14.1 ppm. RDX is present at higher levels in soil, with concentrations ranging from less than 5 ppm to 602 ppm. You may be exposed to RDX in the water or soil if it is disposed of improperly. We do not know how much might be in food or drinking water or how much is in the air. See Chapter 5 for more information on exposure to RDX.

1.4 HOW CAN RDX ENTER AND LEAVE MY BODY?

RDX can get into your lungs if you breathe in the fumes of burning RDX or breathe in the dust from powdered RDX It can also enter your body if it is in water that you drink. Soldiers have accidentally eaten it when they used it as cooking fuel and it got on their food. It may also pass through the skin into the bloodstream or enter through cuts or breaks in the skin. If you consume RDX, it enters your bloodstream very slowly. We do not know how much can enter through the lungs or skin The most likely route of exposure at or near hazardous waste sites is contaminated drinking water. We know that it changes into other chemicals in your body, but we do not know which chemicals it changes to. Some of these other chemicals may be hazardous to your health RDX will leave your body in the breath and urine within a few days. For more information, see Chapter 2.

1.5 HOW CAN RDX AFFECT MY HEALTH?

RDX can cause seizures (a problem of the nervous system) in humans and animals when large amounts are inhaled or eaten We do not know the effects of long-term, low-level exposure on the nervous system. No other significant health effects have been seen in humans Rats and mice have had decreased body weights and slight liver and kidney damage from eating RDX for 3 months or more We do not know if RDX causes cancer in people, but it did cause liver tumors in mice. We do not know whether RDX causes birth defects in humans; it did not cause birth defects in rabbits, but it did result in smaller offspring in rats. We also do not know whether RDX affects reproduction in people. For more information, see Chapter 2.

1.6 IS THERE A MEDICAL TEST TO DETERMINE WHETHER I HAVE BEEN EXPOSED TO RDX?

Medical tests are available to determine whether you have been exposed to RDX. These tests measure RDX levels in your blood or urine However, these tests can only be used if you have come in contact with RDX in the last few days. These tests can determine if you have

been exposed to RDX, but they cannot be used to determine how much RDX entered your body. The tests are not routinely available in the doctor's office, but may be ordered by the doctor. They cannot be used to determine long-term health effects from RDX. The usual immediate health effects are seizures, muscle twitching, or vomiting from very high exposures. These would probably occur before you had the blood or urine test.

1.7 WHAT RECOMMENDATIONS HAS THE FEDERAL GOVERNMENT MADE TO PROTECT HUMAN HEALTH?

The government has developed regulations and guidelines for RDX to protect the public from potential harmful health effects of the chemical. The Department of Transportation has many regulations on the transportation of explosives, and the Environmental Protection Agency (EPA) has recommended a drinking water guideline of 2 micrograms per liter (μg/L) for RDX.

The Occupational Safety and Health Administration (OSHA) regulates levels of RDX in the workplace. The maximum allowable amount of RDX in workroom air during an 8-hour workday, 40-hour workweek, is 1.5 milligrams per cubic meter (mg/m^3). People's health will probably not be affected by being exposed to this amount of RDX. The National Institute of Occupational Safety and Health (NIOSH) recommends guidelines for RDX in the workplace. The NIOSH recommended exposure limit (REL) for RDX during an 8-hour workday, 40-hour workweek is 1.5 mg/m^3. The NIOSH short-term exposure limit (STEL), which is the highest level of RDX that they recommend workers be exposed to for 15 minutes, is 3.0 mg/m^3. See Chapter 7 for more information on these and other regulations and guidelines concerning RDX.

1.8 WHERE CAN I GET MORE INFORMATION?

If you have any more questions or concerns, please contact your community or state health or environmental quality department or:

Agency for Toxic Substances and Disease Registry
Division of Toxicology
1600 Clifton Road NE, E-29
Atlanta, Georgia 30333

This agency can also provide you with information on the location of the nearest occupational and environmental health clinic. These clinics specialize in the recognition, evaluation, and treatment of illnesses resulting from exposure to hazardous substances.

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TOXICOLOGICAL PROFILE FOR 1,3-DINITROBENZENE AND 1,3,5-TRINITROBENZENE

Prepared by:

Research Triangle Institute
Under Contract No. 205-93-0606

Prepared for:

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry

June 1995

C-7

1. PUBLIC HEALTH STATEMENT

This statement was prepared to give you information about 1,3-dinitrobenzene (1,3-DNB) and 1,3,5-trinitrobenzene (1,3,5-TNB) and to emphasize the human health effects that may result from exposure to them. The Environmental Protection Agency (EPA) has identified 1,397 waste sites as the most serious in the nation. These sites make up the National Priorities List (NPL) and are the sites targeted for long-term federal clean-up activities. 1,3-DNB and 1,3,5-TNB have been found in at least 19 of the sites on the NPL. However, the number of NPL sites evaluated for 1,3-DNB and 1,3,5-TNB is not known. As EPA evaluates more sites, the number of sites at which 1,3-DNB and 1,3,5-TNB are found may increase. This information is important because exposure to 1,3-DNB and 1,3,5-TNB may cause harmful health effects and because these sites are potential or actual sources of human exposure to 1,3-DNB and 1,3,5-TNB.

When a chemical is released from a large area, such as an industrial plant, or from a container, such as a drum or bottle, it enters the environment as a chemical emission. This emission, which is also called a release, does not always lead to exposure. You can be exposed to a chemical only when you come into contact with the chemical. You may be exposed to it in the environment by breathing, eating, or drinking substances containing the chemical or from skin contact with it.

If you are exposed to a hazardous chemical such as 1,3-DNB or 1,3,5-TNB, several factors will determine whether harmful health effects will occur and what the type and severity of those health effects will be. These factors include the dose (how much), the duration (how long), the route or pathway by which you are exposed (breathing, eating, drinking, or skin contact), the other chemicals to which you are exposed, and your individual characteristics such as age, sex, nutritional status, family traits, lifestyle, and state of health.

1.1 WHAT ARE 1,3-DNB and 1,3,5-TNB?

1,3-DNB and 1,3,5-TNB are synthetic substances that are used in explosives. In making 1,3,5-TNB, 1,3-DNB is often made first. Both 1,3-DNB and 1,3,5-TNB are formed as by-products when another explosive, trinitrotoluene (TNT), is made. 1,3-DNB is also used to make certain dyes, as an intermediate in the synthesis of organic chemicals, and in the plastics manufacturing industry. 1,3,5-TNB is used in making rubber. Other names for 1,3-DNB include *m*-dinitrobenzene, 1,3-dinitrobenzol, 2,4-dinitrobenzene, binitrobenzene, and *m*-DNB. Other names for 1,3,5-TNB include benzite, *s*-trinitrobenzene, *sym*-trinitrobenzene, symmetric trinitrobenzene, *syn*-trinitrobenzene, and TNB. Both 1,3-DNB and 1,3,5-TNB are yellow, crystal-like solids at room temperature. They may exist in the air in very small amounts as a dust or a vapor and can dissolve in certain liquids. If either compound is put under very high heat, it will explode. These compounds have no odor or taste.

In this profile, 1,3-DNB and 1,3,5-TNB are discussed together because they have very similar structures. Since the two compounds are similar in structure, their toxic effects may not be very different. More information on the chemical and physical properties of 1,3-DNB and 1,3,5-TNB is found in Chapter 3. More information on the production and use of 1,3-DNB and 1,3,5-TNB is in Chapter 4.

1.2 WHAT HAPPENS TO 1,3-DNB or 1,3,5-TNB WHEN IT ENTERS THE ENVIRONMENT?

Waste discharges from Army ammunition plants or other chemical manufacturers are the primary sources for the releases of both compounds to air, water, and soil. They can also enter the environment from their use as explosives and from spills or improper disposal. It is unlikely that either compound would normally be found in the air. However, under some industrial use conditions, some 1,3-DNB and 1,3,5-TNB may enter the air in the form of dust. We have very little information about what happens to 1,3-DNB and 1,3,5-TNB in the air. The small amounts of 1,3,5-TNB that may enter the air are likely to break down very slowly. It might persist for many years in the air. 1,3-DNB is also likely to break down in the air;

however, we do not know how long this would take. Both compounds are slightly soluble in water. 1,3-DNB evaporates slowly from water; 1,3,5-TNB does not evaporate from water. Neither compound sticks strongly to soil; therefore, both can move through soil into groundwater. 1,3-DNB breaks down slowly in water and soil. It stays for days to months in water. Although 1,3,5-TNB probably breaks down in water and soil, we do not know how long this takes. Neither compound is likely to build up in fish or humans. See Chapters 4 and 5 for more information on 1,3-DNB and 1,3,5-TNB in the environment.

1.3 HOW MIGHT I BE EXPOSED TO 1,3-DNB OR 1,3,5-TNB?

Most of the population will not be exposed to 1,3-DNB or 1,3,5-TNB. If you live or work near an Army ammunition plant or other chemical manufacturer, you may be exposed to these compounds by contaminated drinking water, food, air, or soil. At this time, it is not known how much of these compounds you might consume or how much might be in the air. We also do not know how many workers are exposed to the compounds. Both 1,3-DNB and 1,3,5-TNB have been found in water and soil at some Army ammunition plants. Groundwater samples had levels of 1,3-DNB ranging from 0.0012 to 0.195 parts per one million parts of water (ppm). 1,3-DNB was present at higher levels in soil, with concentrations ranging from 0.77 to 1.5 ppm. 1,3,5-TNB was also present in groundwater samples at concentrations up to 8 ppm. 1,3,5-TNB was present at higher levels in soil, with concentrations ranging from 368 to 3,920 ppm. See Chapter 5 for more information on exposure to 1,3-DNB and 1,3,5-TNB.

1.4 HOW CAN 1,3-DNB AND 1,3,5-TNB ENTER AND LEAVE MY BODY?

1,3-DNB can enter your bloodstream if you breathe it in the air or get it on your skin. There is no information on how 1,3,5-TNB can enter or exit your body. Exposure of the general population to 1,3-DNB or 1,3,5-TNB is not likely, so most people exposed to 1,3-DNB have come in contact with it in their work place. Results of studies in people and animals show that 1,3-DNB enters the body very quickly through the skin or lungs. Once 1,3-DNB is inside your body, it breaks down quickly. 1,3-DNB and its related breakdown products also exit the body very quickly in the urine. Some breakdown products of 1,3-DNB may also

leave in the feces. Results of studies in people and animals show that most of the 1,3-DNB exits the body within 2 to 3 weeks after exposure. Chapter 2 has more information on how 1,3-DNB can enter and leave the body.

1.5 HOW CAN 1,3-DNB AND 1,3,5-TNB AFFECT MY HEALTH?

1,3-DNB and 1,3,5-TNB are suspected to cause similar health effects. Exposure to high concentrations of 1,3-DNB can reduce the ability of blood to carry oxygen and can cause your skin to become bluish in color. If you are exposed to 1,3-DNB for a long time, you can develop a reduction (or loss) in the number of red blood cells (anemia). Other symptoms of 1,3-DNB exposure include headache, nausea, and dizziness. We do not know if there are any long-term health effects of exposure to 1,3-DNB or 1,3,5-TNB in people. We also do not know if 1,3-DNB or 1,3,5-TNB causes birth defects or cancer in people.

Results of studies in animals show that effects of 1,3-DNB and 1,3,5-TNB on the blood are similar to the effects seen in people. Results from animal studies also show some other effects of 1,3-DNB exposure, such as behavioral changes, damaged sperm production, and male reproductive damage. We do not know if these other effects could occur in people. Animal studies also show that, in certain cases, a large enough single oral dose of 1,3-DNB can cause death. Neither 1,3-DNB or 1,3,5-TNB have been tested to see whether or not they cause cancer in animals.

The Environmental Protection Agency has determined that 1,3-DNB is not classifiable as to its human carcinogenicity and has not classified the carcinogenicity of 1,3,5-TNB.

More information on the health effects of 1,3-DNB and 1,3,5-TNB is in Chapter 2.

1.6 IS THERE A MEDICAL TEST TO DETERMINE WHETHER I HAVE BEEN EXPOSED TO 1,3-DNB OR 1,3,5-TNB?

No tests are available commercially to determine if you have been exposed to 1,3-DNB or 1,3,5-TNB. There are tests to detect 1,3-DNB and its breakdown products in the blood and urine of exposed animals, but these tests have not been used for people. Refer to Chapters 2 and 6 for more information on these tests for animals

1.7 WHAT RECOMMENDATIONS HAS THE FEDERAL GOVERNMENT MADE TO PROTECT HUMAN HEALTH?

The government has developed regulations and guidelines for 1,3-DNB and 1,3,5-TNB These are designed to protect the public from the harmful health effects of the chemicals. EPA has classified 1,3-DNB and 1,3,5-TNB as hazardous wastes that must meet certain disposal requirements The Department of Transportation has many regulations on the transportation of explosives including 1,3-DNB and 1,3,5-TNB.

The Occupational Safety and Health Administration (OSHA) regulates levels of 1,3-DNB in the workplace. The maximum allowable amount of 1,3-DNB in workroom air during an 8-hour workday, 40-hour workweek, is 1 0 milligram per cubic meter (mg/m^3)

See Chapter 7 for more information on regulations and guidelines on 1,3-DNB and 1,3,5-TNB.

1.8 WHERE CAN I GET MORE INFORMATION?

If you have any more questions or concerns, please contact your community or state health or environmental quality department or:

Agency for Toxic Substances and Disease Registry
Division of Toxicology
1600 Clifton Road NE, Mailstop E-29
Atlanta, Georgia 30333
(404) 639-6000

This agency can also tell you where to find the nearest occupational and environmental health clinic. These clinics specialize in the recognition, evaluation, and treatment of illness resulting from exposure to hazardous substances.

TOXICOLOGICAL PROFILE FOR LEAD

Prepared by:

Research Triangle Institute
Under Contract No. 205-93-0606

Prepared for:

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry

July 1999

C-14

1. PUBLIC HEALTH STATEMENT

This public health statement tells you about lead and the effects of exposure

The Environmental Protection Agency (EPA) identifies the most serious hazardous waste sites in the nation. These sites make up the National Priorities List (NPL) and are the sites targeted for long-term federal cleanup activities. Lead has been found in at least 1,026 of the 1,467 current or former NPL sites. However, the total number of NPL sites evaluated for this substance is not known. As more sites are evaluated, the sites at which lead is found may increase. This information is important because exposure to this substance may harm you and because these sites may be sources of exposure.

When a substance is released from a large area, such as an industrial plant, or from a container, such as a drum or bottle, it enters the environment. This release does not always result in exposure. You are exposed to a substance only when you come in contact with it. You may be exposed by breathing, eating, or drinking the substance or by skin contact.

If you are exposed to lead, many factors determine whether you'll be harmed. These factors include the dose (how much), the duration (how long), and how you come in contact with it. You must also consider the other chemicals you're exposed to and your age, sex, diet, family traits, lifestyle, and state of health.

1.1 WHAT IS LEAD?

Lead is a naturally occurring bluish-gray metal found in small amounts in the earth's crust. It has no characteristic taste or smell. Metallic lead does not dissolve in water and does not burn. Lead can combine with other chemicals to form what are usually known as lead compounds or lead salts. Some lead salts dissolve in water better than others. Some natural and manufactured substances contain lead but do not look like lead in its metallic form. Some of these substances can burn—for example, organic lead compounds in some gasolines.

Lead has many different uses. Its most important use is in the production of some types of batteries. It is also used in the production of ammunition, in some kinds of metal products (such as sheet lead, solder, some brass and bronze products, and pipes), and in ceramic glazes. Some chemicals containing lead, such as tetraethyl lead and tetramethyl lead, were once used as gasoline additives to increase octane rating. However, their use was phased out in the 1980s, and lead was banned for use in gasoline for transportation beginning January 1, 1996. Other chemicals containing lead are used in paint. The amount of lead added to paints and ceramic products, caulking, gasoline, and solder has also been reduced in recent years to minimize lead's harmful effects on people and animals. Lead used in ammunition, which is the largest non-battery end-use, has remained fairly constant in recent years. Lead is used in a large variety of medical equipment (radiation shields for protection against X-rays, electronic ceramic parts of ultrasound machines, intravenous pumps, fetal monitors, and surgical equipment). Lead is also used in scientific equipment (circuit boards for computers and other electronic circuitry) and military equipment (jet turbine engine blades, military tracking systems).

Most lead used by industry comes from mined ores ("primary") or from recycled scrap metal or batteries ("secondary"). Human activities (such as the former use of "leaded" gasoline) have spread lead and substances that contain lead to all parts of the environment. For example, lead is in air, drinking water, rivers, lakes, oceans, dust, and soil. Lead is also in plants and animals that people may eat. See Chapter 3 for more information on the physical and chemical properties of lead. Chapter 4 contains more information on the production and use of lead.

1.2 WHAT HAPPENS TO LEAD WHEN IT ENTERS THE ENVIRONMENT?

Lead occurs naturally in the environment. However, most of the high levels found throughout the environment come from human activities. Before the use of leaded gasoline was banned, most of the lead released into the U.S. environment came from car exhaust. In 1979, cars released 94.6 million kilograms (kg; 1 kg equals 2.2 pounds) of lead into the air in the United States. In 1989, when the use of lead was limited but not banned, cars released only 2.2 million kg to the air. Since EPA banned the use of leaded gasoline for highway transportation in 1996, the amount of

lead released into the air has decreased further. Other sources of lead released to the air include burning fuel, such as coal or oil, industrial processes, and burning solid waste. Once lead goes into the atmosphere, it may travel thousands of miles if the lead particles are small or if the lead compounds easily evaporate. Lead is removed from the air by rain and by particles falling to the ground or into surface water.

The release of lead to air is now less than the release of lead to land. Most of the lead in inner city soils comes from old houses painted with paint containing lead and previous automotive exhaust emitted when gasoline contained lead. Landfills may contain waste from lead ore mining, ammunition manufacturing, or other industrial activities such as battery production.

Sources of lead in dust and soil include lead that falls to the ground from the air, and weathering and chipping of lead-based paint from buildings and other structures. Lead in dust may also come from windblown soil. Disposal of lead in municipal and hazardous waste dump sites may also add lead to soil. Mining wastes that have been used for sandlots, driveways, and roadbeds can also be sources of lead.

Higher levels of lead in soil can be measured near roadways. This accumulation came from car exhaust in the past. Once lead falls onto soil, it usually sticks to soil particles. Small amounts of lead may enter rivers, lakes, and streams when soil particles are moved by rainwater. Lead may remain stuck to soil particles in water for many years. Movement of lead from soil particles into underground water or drinking water is unlikely unless the water is acidic or "soft." Movement of lead from soil will also depend on the type of lead salt or compound and on the physical and chemical characteristics of the soil.

Sources of lead in surface water or sediment include deposits of lead-containing dust from the atmosphere, waste water from industries that handle lead (primarily iron and steel industries and lead producers), urban runoff, and mining piles.

Some of the chemicals that contain lead are broken down by sunlight, air, and water to other forms of lead. Lead compounds in water may combine with different chemicals depending on the acidity and temperature of the water. Lead itself cannot be broken down.

The levels of lead may build up in plants and animals from areas where air, water, or soil are contaminated with lead. If animals eat contaminated plants or animals, most of the lead that they eat will pass through their bodies. Chapters 4 and 5 contain more information about what happens to lead in the environment.

1.3 HOW MIGHT I BE EXPOSED TO LEAD?

People living near hazardous waste sites may be exposed to lead and chemicals that contain lead by breathing air, drinking water, eating foods, or swallowing or touching dust or dirt that contains lead. For people who do not live near hazardous waste sites, exposure to lead may occur in several ways: (1) by eating foods or drinking water that contain lead, (2) by spending time in areas where leaded paints have been used and are deteriorating, (3) by working in jobs where lead is used, (4) by using health-care products or folk remedies that contain lead, and (5) by having hobbies in which lead may be used such as sculpturing (lead solder) and staining glass.

Foods such as fruits, vegetables, meats, grains, seafood, soft drinks, and wine may have lead in them. Cigarette smoke also contains small amounts of lead. Lead gets into food from water during cooking and into foods and beverages from dust that contains lead falling onto crops, from plants absorbing lead that is in the soil, and from dust that contains lead falling onto food during processing. Lead may also enter foods if they are put into improperly glazed pottery or ceramic dishes and from leaded-crystal glassware. Illegal whiskey made using stills that contain lead-soldered parts (such as truck radiators) may also contain lead. The amount of lead found in canned foods decreased 87% from 1980 to 1988, which indicates that the chance of exposure to lead in canned food from lead-soldered containers has been greatly reduced. Lead may also be released from soldered joints in kettles used to boil water for beverages.

In general, very little lead is found in lakes, rivers, or groundwater used to supply the public with drinking water. More than 99% of all publicly supplied drinking water contains less than 0.005 parts of lead per million parts of water (ppm). However, the amount of lead taken into your body through drinking water can be higher in communities with acidic water supplies. Acidic water makes it easier for the lead found in pipes, leaded solder, and brass faucets to enter water. Public water treatment systems are now required to use control measures to make water less acidic. Sources of lead in drinking water include lead that can come out of lead pipes, faucets, and leaded solder used in plumbing. Plumbing that contains lead may be found in public drinking water systems, and in houses, apartment buildings, and public buildings that are more than twenty years old.

Breathing in or swallowing airborne dust and dirt that have lead in them is another way you can be exposed. In 1984, burning leaded gasoline was the single largest source of lead emissions. Very little lead in the air comes from gasoline now because EPA has banned its use in gasoline. Other sources of lead in the air include releases to the air from industries involved in iron and steel production, lead-acid-battery manufacturing, and non-ferrous (brass and bronze) foundries. Lead released into air may also come from burning of solid lead-containing waste, windblown dust, volcanoes, exhaust from workroom air, burning or weathering of lead-painted surfaces, fumes from leaded gasoline, and cigarette smoke.

Skin contact with dust and dirt containing lead occurs every day. Some cosmetics and hair dyes contain lead compounds. However, not much lead can get into your body through your skin. Leaded gasoline contains a lead compound that may be quickly absorbed.

In the home, you or your children may be exposed to lead if you take some types of home remedy medicines that contain lead compounds. Lead compounds are in some non-Western cosmetics, such as surma and kohl. Some types of hair colorants and dyes contain lead acetate. Read the labels on hair coloring products, use them with caution, and keep them away from children.

People who are exposed at work are usually exposed by breathing in air that contains lead particles. Exposure to lead occurs in many jobs. People who work in lead smelting and refining industries, brass/bronze foundries, rubber products and plastics industries, soldering, steel welding and cutting operations, battery manufacturing plants, and lead compound manufacturing industries may be exposed to lead. Construction workers and people who work at municipal waste incinerators, pottery and ceramics industries, radiator repair shops, and other industries that use lead solder may also be exposed. Between 0.5 and 1.5 million workers are exposed to lead in the workplace. In California alone, more than 200,000 workers are exposed to lead. Families of workers may be exposed to higher levels of lead when workers bring home lead dust on their work clothes.

You may also be exposed to lead in the home if you work with stained glass as a hobby, make lead fishing weights or ammunition, or if you are involved in home renovation that involves the removal of old lead-based paint. Chapter 5 contains further information on sources of exposure to lead.

1.4 HOW CAN LEAD ENTER AND LEAVE MY BODY?

Some of the lead that enters your body comes from breathing in dust or chemicals that contain lead. Once this lead gets into your lungs, it goes quickly to other parts of the body in your blood.

You may swallow lead by eating food and drinking liquids that contain it, and also by swallowing large particles (diameter greater than 5 micrometers; 1 micrometer is one millionth of a meter). Most of the lead that enters your body comes through swallowing, even though very little of the amount you swallow actually enters your blood and other parts of your body. In addition to the lead that may be present in food and drink, accidental ingestion of lead may occur due to skin contamination while eating, drinking, smoking, or applying cosmetics (including lip balm). The amount that gets into your body from your stomach partially depends on when you ate your last meal. It also depends on how old you are and how well the lead particles you ate dissolved in your stomach juices. Experiments using adult volunteers showed that, for adults who had just

eaten, the amount of lead that got into the blood from the stomach was only about 6% of the total amount taken in. In adults who had not eaten for a day, about 60–80% of the lead from the stomach got into their blood. In general, if adults and children swallow the same amount of lead, a bigger proportion of the amount swallowed will enter the blood in children than in adults.

Dust and soil that contain lead may get on your skin, but only a small portion of the lead will pass through your skin and enter your blood if it is not washed off. More lead can pass through skin that has been damaged (for example by scrapes, scratches, and wounds). The only kinds of lead compounds that easily penetrate the skin are the additives in leaded gasoline, which is no longer sold to the general public. Therefore, the general public is not likely to encounter lead that can enter through the skin

Shortly after lead gets into your body, it travels in the blood to the "soft tissues" (such as the liver, kidneys, lungs, brain, spleen, muscles, and heart). After several weeks, most of the lead moves into your bones and teeth. In adults, about 94% of the total amount of lead in the body is contained in the bones and teeth. About 73% of the lead in children's bodies is stored in their bones. Some of the lead can stay in your bones for decades; however, some lead can leave your bones and reenter your blood and organs under certain circumstances, for example, during pregnancy and periods of breast feeding, after a bone is broken, and during advancing age

Your body does not change lead into any other form. Once it is taken in and distributed to your organs, the lead that is not stored in your bones leaves your body in your urine or your feces. About 99% of the amount of lead taken into the body of an adult will leave in the waste within a couple of weeks, but only about 32% of the lead taken into the body of a child will leave in the waste. Under conditions of continued exposure, not all the lead that enters the body will be eliminated, and this may result in accumulation of lead in body tissues, notably bone. For more information on how lead can enter and leave your body, please refer to Chapter 2.

1.5 HOW CAN LEAD AFFECT MY HEALTH?

The effects of lead are the same whether it enters the body through breathing or swallowing. The main target for lead toxicity is the nervous system, both in adults and in children. Long-term exposure of adults to lead at work has resulted in decreased performance in some tests that measure functions of the nervous system. Lead exposure may also cause weakness in fingers, wrists, or ankles. Some studies in humans have suggested that lead exposure may increase blood pressure, but the evidence is inconclusive. Lead exposure may also cause anemia, a low number of blood cells. The connection between the occurrence of some of these effects (e.g., increased blood pressure, altered function of the nervous system) and low levels of exposure to lead is not certain. At high levels of exposure, lead can severely damage the brain and kidneys in adults or children. In pregnant women, high levels of exposure to lead may cause miscarriage. High-level exposure in men can damage the organs responsible for sperm production.

To protect the public from the harmful effects of toxic chemicals and to find ways to treat people who have been harmed, scientists use many tests.

One way to see if a chemical will hurt people is to learn how the chemical is absorbed, used, and released by the body; for some chemicals, animal testing may be necessary. Animal testing may also be used to identify health effects such as cancer or birth defects. Without laboratory animals, scientists would lose a basic method to get information needed to make wise decisions to protect public health. Scientists have the responsibility to treat research animals with care and compassion. Laws today protect the welfare of research animals, and scientists must comply with strict animal care guidelines.

We have no proof that lead causes cancer in humans. Kidney tumors have developed in rats and mice given large doses of lead. The animal studies have been criticized because of the very high doses used, among other things. The results of high-dose studies should not be used to predict whether lead may cause cancer in humans. The Department of Health and Human Services (DHHS) has determined that lead acetate and lead phosphate may reasonably be expected to be

capable of causing cancer, based on sufficient evidence from animal studies, but there is inadequate evidence from human studies. See Chapter 2 for more information on the health effects of lead

1.6 HOW CAN LEAD AFFECT CHILDREN?

This section discusses potential health effects from exposures during the period from conception to maturity at 18 years of age in humans. Potential effects on children resulting from exposures of the parents are also considered.

Studies carried out by the Center for Disease Control and Prevention (CDC) show that the levels of lead in the blood of U.S. children have been getting lower and lower. This is because lead is banned from gasoline, residential paint, and solder that is used for food cans and water pipes. Still, about 900,000 U.S. children between the ages of 1 and 5 years are believed to have blood lead levels equal or greater than 10 μg/dL, the CDC level of concern.

Children are more vulnerable to lead poisoning than adults. Children are exposed to lead all through their lives. They can be exposed to lead in the womb if their mothers have lead in their bodies. Babies can swallow lead when they breast feed, or eat other foods and drink water that contains lead. Babies and children can swallow and breathe lead in dirt, dust, or sand while they play on the floor or ground. These activities make it easier for children to be exposed to lead than adults. The dirt or dust on their hands, toys, and other items may have lead particles in it. In some cases children swallow nonfood items such as paint chips; these may contain very large amounts of lead, particularly in and around older houses that were painted with lead-based paint. The paint in these houses often chips off and mixes with dust and dirt. Some old paint is 5–40% lead. Also, compared to adults, a bigger proportion of the amount of lead swallowed will enter the blood in children.

Children are more sensitive to the effects of lead than adults. Lead affects children in different ways depending how much lead a child swallows. A child who swallows large amounts of lead

may develop blood anemia, kidney damage, colic (severe "stomachache"), muscle weakness, and brain damage which can kill the child A large amount of lead might get into a child's body if the child ate small pieces of old paint that contained large amounts of lead. If a child swallows smaller amounts of lead, much less severe effects on blood and brain function may occur. In this case, recovery is likely once the child is removed from the source of lead exposure. In some cases, the amount of lead in the child's body can be lowered by giving the child certain drugs that help eliminate lead from the body. At still lower levels of exposure, lead can affect a child's mental and physical growth. Fetuses exposed to lead in the womb, because their mothers had a lot of lead in their bodies, may be born prematurely and have lower weights at birth. Exposure in the womb, in infancy, or in early childhood may also slow mental development and lower intelligence later in childhood. There is evidence that some effects may persist beyond childhood

Health workers can find out whether a child may have been exposed to harmful levels of lead by taking a blood sample. They can also find out how much lead is in a child's bones by taking a special type of X-ray of the finger, knee, or elbow. This, however, is not a routine type of test.

1.7 HOW CAN FAMILIES REDUCE THE RISK OF EXPOSURE TO LEAD?

If your doctor finds that you have been exposed to significant amounts of lead, ask your doctor if children may also be exposed. When necessary your doctor may need to ask your state public health department to investigate.

The most important way families can lower exposures to lead is to know about the sources of lead in their homes and avoid exposure to these sources. Some homes or day-care facilities may have more lead in them than others. Families who live in or visit these places may be exposed to higher amounts of lead. These include homes built before 1978 that may have been painted with paint that contains lead (lead-based paint) If you are buying a home that was built before 1978, you may want to know if it contains lead based paint. Federal government regulations require a person selling a home to tell the real estate agent or person buying the home of any known lead-based hazards on the property. Adding lead to paint is no longer allowed. If your house was built

before 1978, it may have been painted with lead-based paint. This lead may still be on walls, floors, ceilings, and window sills, or on the outside walls of the house. The paint may have been scraped off by a previous owner, and the paint chips and dust may still be in the yard soil. In some states, homeowners can have the paint in their homes tested for lead by their local health departments. Families can lower the possibility of children swallowing paint chips by not allowing their children to chew or mouth these painted surfaces and be sure they wash their hands often, especially before eating. Families can also have a professional lead paint removal expert remove and dispose of peeling or flaking paint or painted surfaces, and repaint the surface. Using heat guns or dry scrapping of old lead containing paint during home reconstruction and remodeling can be a substantial source of lead exposure to children. Surfaces should be tested before such activities, and professional home repair personnel should be consulted to make sure that safe procedures are used and removed materials and dust are contained in order to keep exposures to children to a minimum. These repairs should not be made by homeowners themselves, unless they consult with a professional to get the information they need to prevent the possibility of lead poisoning during or after the repairs.

Older homes that have plumbing with lead or lead solder may have higher amounts of lead in drinking water. You cannot see, taste, or smell lead in water, and boiling your water will not get rid of lead. Running your water for 15 to 30 seconds before drinking or cooking with it will get rid of lead that may leach out from the pipes, especially if you have not used your water for a while, for example, overnight. You can contact your local health department or water supplier to find out about testing your water for lead.

You can bring lead home in the dust on your hands or clothes if lead is used in the place where you work. Lead dust is likely to be found in places where lead is mined or smelted, where car batteries are made or recycled, where electric cable sheathing is made, where fine crystal glass is made, or where certain types of ceramic pottery are made. Pets can also bring lead into the home in dust or dirt on their fur or feet if they spend time in places that have high levels of lead in the soil.

Lead may be taken up in edible plants from the soil by the roots; therefore, home gardening may also contribute to exposure if the produce is grown in soils that have high lead concentrations. Certain hobbies and home or car repair activities like radiator repair can add lead to the home as well. These include soldering glass or metal, making bullets or slugs, or glazing pottery. Some non-Western "folk remedies" contain lead. Examples of these include greta and azarcon used to treat diarrhea.

Some types of paints and pigments that are used as facial make-up or hair coloring contain lead. Cosmetics that contain lead include surma and kohl, which are popular in certain Asian countries. Read the labels on hair coloring products, and keep hair dyes that contain lead acetate away from children. Do not allow children to touch hair that has been colored with lead-containing dyes or any surfaces that have come into contact with these dyes because lead compounds can rub off onto their hands and be transferred to their mouths.

Swallowing of lead in house dust or soil is a very important exposure pathway for children. This problem can be reduced in many ways. Regular hand and face washing to remove lead dusts and soil, especially before meals, can lower the possibility that lead on the skin is accidentally swallowed while eating. Families can lower exposures to lead by regularly cleaning the home of dust and tracked in soil. Door mats can help lower the amount of soil that is tracked into the home; removing your shoes before will also help. Planting grass and shrubs over bare soil areas in the yard can lower contact that children and pets may have with soil and the tracking of soil into the home.

Families whose members are exposed to lead dusts at work can keep these dusts out of reach of children by showering and changing clothes before leaving work, and bagging their work clothes before they are brought into the home for cleaning. Proper ventilation and cleaning—during and after hobby activities, home or auto repair activities, and hair coloring with products that contain lead—will decrease the possibility of exposure.

It is important that children have proper nutrition and eat a balanced diet of foods that supply adequate amounts of vitamins and minerals, especially calcium and iron. Good nutrition lowers the amount of swallowed lead that passes to the bloodstream and also may lower some of the toxic effects of lead.

You can find out whether your child may have been exposed to lead by having your doctor take a blood sample

1.8 IS THERE A MEDICAL TEST TO DETERMINE WHETHER I HAVE BEEN EXPOSED TO LEAD?

The amount of total lead in the blood can be measured to determine if exposure to lead has occurred. This test can tell if you have been recently exposed to lead. Lead can be measured lead in teeth or bones by X-ray techniques, but these methods are not widely available. These tests tell about long-term exposures to lead. Exposure to lead can be evaluated by measuring erythrocyte protoporphyrin (EP) in blood samples. EP is a part of red blood cells known to increase when the amount of lead in the blood is high. However, the EP level is not sensitive enough to identify children with elevated blood lead levels below about 25 micrograms per deciliter (μg/dL). For this reason, the primary screening method is measurement of blood lead. For more information on tests to measure lead in the body, see Chapters 2 and 6.

1.9 WHAT RECOMMENDATIONS HAS THE FEDERAL GOVERNMENT MADE TO PROTECT HUMAN HEALTH?

The federal government develops regulations and recommendations to protect public health. Regulations can be enforced by law. Federal agencies that develop regulations for toxic substances include the Environmental Protection Agency (EPA), the Occupational Safety and Health Administration (OSHA), and the Food and Drug Administration (FDA). Recommendations provide valuable guidelines to protect public health but cannot be enforced by law. Federal organizations that develop recommendations for toxic substances include the

Agency for Toxic Substances and Disease Registry (ATSDR) and the National Institute for Occupational Safety and Health (NIOSH).

Regulations and recommendations can be expressed in not-to-exceed levels in air, water, soil, or food that are usually based on levels that affect animals; then they are adjusted to help protect people. Sometimes these not-to-exceed levels differ among federal organizations because of different exposure times (an 8-hour workday or a 24-hour day), the use of different animal studies, or other factors.

Recommendations and regulations are also periodically updated as more information becomes available. For the most current information, check with the federal agency or organization that provides it. Some regulations and recommendations for lead include the following:

CDC recommends that states develop a plan to find children who may be exposed to lead and have their blood tested for lead. They make basic recommendations for states to follow. These include testing children at ages 1 and 2. Children who are 3 to 6 years old should be tested if they have never been tested for lead before and they receive services from public assistance programs for the poor such as Medicaid or the Supplemental Food Program for Women, Infants and Children (WIC); if they live in a building or frequently visit a house built before 1950; if they visit a home (house or apartment) built before 1978 that has been recently remodeled; or if they have a brother, sister, or playmate who has had lead poisoning.

CDC considers children to have an elevated level of lead if the amount of lead in the blood is at least 10 μg/dL. Medical evaluation and environmental investigation and remediation should be done for all children with blood lead levels equal or greater than 20 μg/dL. Medical treatment may be necessary in children if the lead concentration in blood is higher than 45 μg/dL.

EPA requires that the concentration of lead in air that the public breathes be no higher than 1.5 micrograms per cubic meter ($\mu g/m^3$) averaged over 3 months. EPA regulations no longer

allow lead in gasoline. The Clean Air Act Amendments (CAAA) of 1990 banned the sale of leaded gasoline as of December 31, 1995

EPA regulations also limit lead in drinking water to 0.015 milligrams per liter (mg/L). The 1988 Lead Contamination Control Act requires the Consumer Product Safety Commission (CPSC), EPA, and the states to recall or repair water coolers containing lead. This law also requires new coolers to be lead-free. In addition, drinking water in schools must be tested for lead, and the sources of lead in this water must be removed.

To help protect small children, CPSC requires that the concentration of lead in most paints available through normal consumer channels be not more than 0.06%. The Federal Hazardous Substance Act (FHSA) bans children's products containing hazardous amounts of lead

The Department of Housing and Urban Development (HUD) develops recommendations and regulations to prevent exposure to lead. HUD requires that federally funded housing and renovations, public housing, and Indian housing be tested for lead-based paint hazards and that such hazards be fixed by covering the paint or removing it. When determining whether lead-based paint applied to interior or exterior painted surfaces of dwellings should be removed, the standard used by EPA and HUD is that paint with a lead concentration equal to or greater than 1.0 milligram per square centimeter (mg/cm^2) of surface area should be removed or otherwise treated. HUD is carrying out demonstration projects to determine the best ways of covering or removing lead-based paint in housing.

EPA has developed standards for lead paint hazards, lead in dust, and lead in soil. To educate parents, homeowners, and tenants about lead hazards, lead poisoning prevention in the home, and the lead abatement process, EPA has published several general information pamphlets. Copies of these pamphlets can be obtained from the National Lead Information Center or from various Internet sites, including http://www.epa.gov/opptintr/lead.

OSHA regulations limit the concentration of lead in workroom air to 50 $\mu g/m^3$ for an 8-hour workday. If a worker has a blood lead level of 50 µg/dL, then OSHA requires that worker be removed from the workroom where lead exposure is occurring.

FDA includes lead on its list of poisonous and deleterious substances. FDA considers foods packaged in cans containing lead solders to be adulterated. Tin-coated lead foil has been used as a covering applied over the cork and neck areas of wine bottles for decorative purposes and to prevent insect infestations. Because it can be reasonably expected that lead could become a component of the wine, the use of these capsules is also a violation of the Federal Food, Drug, and Cosmetic Act. FDA has reviewed several direct human food ingredients and has determined them to be "generally recognized as safe" when used in accordance with current good manufacturing practices. Some of these ingredients contain allowable lead concentrations that range from 0.1 to 10 parts per million (ppm).

Please see Chapter 7 for more information on federal and state regulations and guidelines for lead.

1.10 WHERE CAN I GET MORE INFORMATION?

If you have any more questions or concerns, please contact your community or state health or environmental quality department or

Agency for Toxic Substances and Disease Registry
Division of Toxicology
1600 Clifton Road NE, Mailstop E-29
Atlanta, GA 30333

* Information line and technical assistance

Phone: 1-888-42-ATSDR (1-888-422-8737)
Fax: (404) 639-6315 or 6324

ATSDR can also tell you the location of occupational and environmental health clinics. These clinics specialize in recognizing, evaluating, and treating illnesses resulting from exposure to hazardous substances.

* To order toxicological profiles, contact

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Phone: (800) 553-6847 or (703) 605-6000

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TOXICOLOGICAL PROFILE FOR CHLORINATED DIBENZO-*p*-DIOXINS

Prepared by:

Research Triangle Institute
Under Contract No 205-93-0606

Prepared for:

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry

December 1998

C-32

1. PUBLIC HEALTH STATEMENT

This public health statement tells you about chlorinated dibenzo-*p*-dioxins (CDDs) and the effects of exposure

The Environmental Protection Agency (EPA) identifies the most serious hazardous waste sites in the nation These sites make up the National Priorities List (NPL) and are the sites targeted for long-term federal clean-up CDDs (all types) have been found in at least 126 of the 1,467 current or former NPL sites However, it's unknown how many NPL sites have been evaluated for these substances As more sites are evaluated, the number of sites with CDDs may increase This is important because exposure to these substances may harm you and because these sites may be sources of exposure

When a substance is released from a large area, such as an industrial plant, or from a container, such as a drum or bottle, it enters the environment This release does not always lead to exposure You can be exposed to a substance only when you come in contact with it You may be exposed by breathing, eating, or drinking the substance or by skin contact

If you are exposed to CDDs, many factors determine whether you'll be harmed These factors include the dose (how much), the duration (how long), and how you come in contact with it You must also consider the other chemicals you're exposed to and your age, sex, diet, family traits, lifestyle, and state of health

1.1 WHAT ARE CDDs?

CDDs are a family of 75 different compounds commonly referred to as polychlorinated dioxins These compounds have varying harmful effects The CDD family is divided into eight groups of chemicals based on the number of chlorine atoms in the compound The group with one chlorine atom is called the mono-chlorinated dioxin(s) The groups with two through eight chlorine atoms are called di-chlorinated dioxin (DCDD), tri-chlorinated dioxin (TrCDD), tetra-chlorinated dioxin (TCDD), penta-chlorinated dioxin (PeCDD), hexa-chlorinated dioxin (HxCDD), hepta-chlorinated dioxin (HpCDD), and octa-chlorinated dioxin (OCDD) The chlorine atoms can be attached to the

dioxin molecule at any one of eight positions. The name of each CDD indicates both the number and the positions of the chlorine atoms. For example, the CDD with four chlorine atoms at positions 2, 3, 7, and 8 on the dioxin molecule is called 2,3,7,8-tetrachlorodibenzo-*p*-dioxin or 2,3,7,8-TCDD. 2,3,7,8-TCDD is one of the most toxic of the CDDs to mammals and has received the most attention. Thus, 2,3,7,8-TCDD serves as a prototype for the CDDs. CDDs with toxic properties similar to 2,3,7,8-TCDD are called "dioxin-like" compounds.

In the pure form, CDDs are colorless solids or crystals. CDDs enter the environment as mixtures containing a variety of individual components and impurities. In the environment they tend to be associated with ash, soil, or any surface with a high organic content, such as plant leaves. In air and water, a portion of the CDDs may be found in the vapor or dissolved state, depending on the amount of particulate matter, temperature, and other environmental factors. 2,3,7,8-TCDD is odorless. The odors of the other CDDs are not known. CDDs are known to occur naturally, and are also produced by human activities. They are naturally produced from the incomplete combustion of organic material by forest fires or volcanic activity. CDDs are not intentionally manufactured by industry, except in small amounts for research purposes. They are unintentionally produced by industrial, municipal, and domestic incineration and combustion processes. Currently, it is believed that CDD emissions associated with human incineration and combustion activities are the predominant environmental source.

CDDs (mainly 2,3,7,8-TCDD) may be formed during the chlorine bleaching process used by pulp and paper mills. CDDs occur as a contaminant in the manufacturing process of certain chlorinated organic chemicals, such as chlorinated phenols. 2,3,7,8-TCDD is a by-product formed during the manufacture of 2,4,5-trichlorophenol (2,4,5-TCP). 2,4,5-TCP was used to produce hexachlorophene (used to kill bacteria) and the herbicide, 2,4,5-trichlorophenoxyacetic acid (2,4,5-T). Various formulations of 2,4,5-T have been used extensively for weed control on crops and range lands, and along roadways throughout the world. 2,4,5-T was a component of Agent Orange, which was used extensively by the U.S. military in the Vietnam War. In most industrialized countries the use of products contaminated with CDDs has been greatly reduced. Use of hexachlorophene and the herbicide 2,4,5-T is currently restricted in the United States. Other chlorinated chemicals, like pentachlorophenol (PCP), used to preserve wood, do contain some of the more highly chlorinated CDDs (those with more chlorine atoms), but 2,3,7,8-TCDD is not usually found. The use of PCP has been restricted to certain manufacturing applications.

Currently, CDDs are primarily released to the environment during combustion of fossil fuels (coal, oil, and natural gas) and wood, and during incineration processes (municipal and medical solid waste and hazardous waste incineration). While incineration may be the primary current source of release of CDDs into the environment, the levels of CDDs produced by incineration are extremely low CDDs are associated with ash generated in combustion and incineration processes. Emissions from incinerator sources vary greatly and depend on management practices and applied technologies CDDs also have been detected at low concentrations in cigarette smoke, home-heating systems, and exhaust from cars running on leaded gasoline or unleaded gasoline, and diesel fuel. Burning of many materials that may contain chlorine, such as plastics, wood treated with pentachlorophenol (PCP), pesticide-treated wastes, other polychlorinated chemicals (polychlorinated biphenyls or PCBs), and even bleached paper can produce CDDs

Although this public health statement will focus on CDDs, it is important to note that CDDs are found in the environment together with other structurally related chlorinated chemicals, such as chlorinated dibenzofurans (CDFs) and polychlorinated biphenyls (PCBs). Therefore, people are generally exposed to mixtures of CDDs and other classes of toxicologically and structurally similar compounds. 2,3,7,8-TCDD is one of the most toxic and extensively studied of the CDDs and serves as a prototype for the toxicologically relevant or "dioxin-like CDDs Based on results from animal studies, scientists have learned that they can express the toxicity of dioxin-like CDDs as a fraction of the toxicity attributed to 2,3,7,8-TCDD For example, the toxicity of dioxin-like CDDs can be half or one tenth or any fraction of that of 2,3,7,8-TCDD Scientists call that fraction a Toxic Equivalent Factor (TEF). More information on TEFs can be found in Section 2.5

For more information on CDDs, please refer to Chapters 3, 4, and 5.

1.2 WHAT HAPPENS TO CDDs WHEN THEY ENTER THE ENVIRONMENT?

CDDs are released into the air in emissions from municipal solid waste and industrial incinerators Exhaust from vehicles powered with leaded and unleaded gasoline and diesel fuel also release CDDs to the air. Other sources of CDDs in air include: emissions from oil- or coal-fired power plants, burning of chlorinated compounds such as PCBs, and cigarette smoke CDDs formed during combustion processes are associated with small particles in the air, such as ash The larger particles will be deposited close to the emission source, while very small particles may be

transported longer distances Some of the lower chlorinated CDDs (DCDD, TrCDD, and some of the TCDDs) may vaporize from the particles (and soil or water surfaces) and be transported long distances in the atmosphere, even around the globe It has been estimated that 20 to 60% of 2,3,7,8-TCDD in the air is in the vapor phase Sunlight and atmospheric chemicals will break down a very small portion of the CDDs, but most CDDs will be deposited on land or water.

CDDs occur as a contaminant in the manufacture of various chlorinated pesticides and herbicides, and releases to the environment have occurred during the use of these chemicals. Because CDDs remain in the environment for a long time, contamination from past pesticide and herbicide use may still be of concern. In addition, improper storage or disposal of these pesticides and waste generated during their production can lead to CDD contamination of soil and water.

CDDs are released in waste waters from pulp and paper mills that use chlorine or chlorine-containing chemicals in the bleaching process. Some of the CDDs deposited on or near the water surface will be broken down by sunlight. A very small portion of the total CDDs in water will evaporate to air. Because CDDs do not dissolve easily in water, most of the CDDs in water will attach strongly to small particles of soil or organic matter and eventually settle to the bottom. CDDs may also attach to microscopic plants and animals (plankton) which are eaten by larger animals, that are in turn eaten by even larger animals This is called a food chain. Concentrations of chemicals such as the most toxic, 2,3,7,8-chlorine substituted CDDs, which are difficult for the animals to break down, usually increase at each step in the food chain This process, called biomagnification, is the reason why undetectable levels of CDDs in water can result in measurable concentrations in aquatic animals. The food chain is the main route by which CDD concentrations build up in larger fish, although some fish may accumulate CDDs by eating particles containing CDDs directly off the bottom

CDDs deposited on land from combustion sources or from herbicide or pesticide applications bind strongly to the soil, and therefore are not likely to contaminate groundwater by moving deeper into the soil. However, the presence of other chemical pollutants in contaminated soils, such as those found at hazardous waste sites or associated with chemical spills (for example, oil spills), may dissolve CDDs, making it easier for CDDs to move through the soil The movement of chemical waste containing CDDs through soil has resulted in contamination of groundwater. Soil erosion

and surface runoff can also transport CDDs into surface waters. A very small amount of CDDs at the soil surface will evaporate into air. Certain types of soil bacteria and fungus can break CDDs down, but the process is very slow. In fact, CDDs can exist in soil for many years. Plants take up only very small amounts of CDDs by their roots. Most of the CDDs found on the parts of plants above the ground probably come from air and dust and/or previous use of CDD-containing pesticides or herbicides. Animals (such as cattle) feeding on the plants may accumulate CDDs in their body tissues (meat) and milk.

For more information on what happens to CDDs in the environment, see Chapter 5.

1.3 HOW MIGHT I BE EXPOSED TO CDDs?

CDDs are found at very low levels in the environment. These levels are measured in nanograms and picograms. One nanogram (ng) is one billionth of a gram, and one picogram (pg) is one trillionth of a gram. In some contaminated soils, concentrations of CDDs are reported as parts per billion. One part per billion (ppb) is one part CDD per billion parts of soil. The concentration of CDDs is often reported as parts per trillion, in samples of air, water, or soil. One part per trillion (ppt) is one part CDD per trillion parts of air, water, or soil. In some rural areas where CDD concentrations are very low in air or water, measurements are given in parts per quadrillion (ppq), which means one part CDD per quadrillion parts of air or water.

CDDs are found everywhere in the environment, and most people are exposed to very small background levels of CDDs when they breath air, consume food or milk, or have skin contact with materials contaminated with CDDs. For the general population, more than 90% of the daily intake of CDDs, CDFs, and other dioxin-like compounds comes from food, primarily meat, dairy products, and fish. CDDs may be present at much lower levels in fruits and vegetables. The actual intake of CDDs from food for any one person will depend on the amount and type of food consumed and the level of contamination. Higher levels may be found in foods from areas contaminated with chemicals, such as pesticides or herbicides, containing CDDs as impurities. CDDs have been measured in human milk, cow's milk, and infant formula, so infants are known to be exposed to CDDs.

Most surface water in the United States typically does not contain 2,3,7,8-TCDD and other CDDs at levels that are high enough to be measured (1 ppq or more). Municipal drinking water does not usually contain CDDs because the CDDs do not dissolve in water and primarily stick to particles, which are usually filtered out of treated drinking water. This means that using tap water to wash clothes or to bathe or shower, or swimming in pools or in uncontaminated lakes, rivers, or at ocean beaches will not expose people to significant levels of CDDs. Although CDDs are not usually found in filtered, treated drinking water, they have, on occasion, been detected in unfiltered groundwater from areas with known CDD contamination.

Exposure to CDDs can also occur through skin contact with chlorinated pesticides and herbicides, contaminated soils, or other materials such as PCP-treated wood and PCB transformer fluids. Background levels of CDDs in soil are higher than background levels in both air and water. Background levels of CDDs detected in uncontaminated soils in the United States are generally very low or not detectable. 2,3,7,8-TCDD is not usually found in rural soil, but is typically found in soil in industrialized areas at levels ranging from 0.001 to 0.01 ppb. However, higher levels of 2,3,7,8-TCDD may be found in areas where CDDs have contaminated the soil. For example, contaminated soil at Times Beach, Missouri, had levels of 2,3,7,8-TCDD ranging from 4.4–317 ppb.

If CDDs are present at all in outdoor air in rural areas, they are generally present at very low levels or at concentrations near the detection limits for testing equipment. In winter, because of the burning of wood and other fuels for home heating, CDD levels may be slightly higher than during other seasons. In general, the background air levels of CDDs in urban areas are higher than in rural areas. Typical levels of CDDs in outdoor air in urban areas and industrial areas averaged 2.3 picograms per meter cubed (pg/m^3). 2,3,7,8-TCDD is not usually found in rural or urban air, but it is found in air near urban waste incinerators and high-traffic areas. The air around people who are smoking cigarettes may also have CDDs at levels above background levels. Although breathing contaminated air is a minor route of exposure for most people, exposure may be greater in areas near these CDD sources.

CDDs have been found in all samples of adipose tissue and blood (serum lipids) from individuals with no known previous exposure. This indicates that all people are exposed to small amounts of CDDs. Levels of 2,3,7,8-TCDD in serum from the general population typically range from 3 to

7 ppt (on a lipid basis), and rarely exceed 10 ppt. Typically, lower levels of CDDs are found in less industrialized countries and in younger people.

The production, use, and disposal of pesticides and phenoxy herbicides, disposal of production waste containing 2,3,7,8-TCDD, industrial accidents involving 2,4,5-trichlorophenol (2,3,5-TCP), and the consumption of CDD-contaminated food, have all led to increased potential for excess exposure of some groups of people. 2,3,7,8-TCDD has been detected at 91 of the 126 hazardous waste sites on the NPL that have been reported to contain CDDs. People living around these sites may be exposed to above-background levels of 2,3,7,8-TCDD and other CDDs. Elevated levels of CDDs have been reported in fish, shellfish, birds, and mammals collected in areas surrounding various chemical production facilities, various hazardous waste sites, and pulp and paper mills using the chlorine bleaching process. Sometimes these findings have resulted in closure of these areas for the purpose of fishing. People who eat contaminated food from these contaminated areas are at risk of increased exposure to CDDs.

Occupational exposure to CDDs generally occurs through breathing contaminated air, or through skin contact with materials containing CDDs. Workers with the potential to be exposed to above-average levels of CDDs include those involved in the production or handling of certain chlorinated phenols (such as 2,4,5-TCP, PCP) or chlorinated pesticides or herbicides (such as 2,4,5-T, 2,4-D, hexachlorophene, Silvex®), and those involved in application of chlorinated pesticides containing CDDs as impurities. Workers whose jobs involve pressure treatment of wood with PCP and the handling of PCP-treated wood products, chlorination processes at pulp and paper mills, or operation of municipal solid waste or hazardous waste incinerators may have increased exposure to CDDs. Finally, workers involved in hazardous waste clean-up or clean-up of PCB transformer and/or capacitor fires including emergency service personnel like fire fighters and police who respond to such fires are also at additional risk of exposure to CDDs. Most of these occupational exposures have been significantly reduced in recent years.

In general, workers involved in the manufacture of 2,4,5-TCP and subsequent products were exposed to far greater levels of 2,3,7,8-TCDD than those involved in the handling and application of chlorinated pesticides containing CDDs. Current serum lipid levels of 2,3,7,8-TCDD in a small number of U.S. Air Force veterans who were directly involved in the aerial spraying of herbicides (Agent Orange contaminated with 2,3,7,8-TCDD) in Vietnam as part of Operation Ranch Hand,

are up to 3 times higher than the general population. However, while studies on blood or fatty tissue 2,3,7,8-TCDD levels in U S. Army ground combat Vietnam veterans also found some individuals with 2,3,7,8-TCDD levels higher than those of the general population, overall, most Vietnam veterans and Vietnamese living in Vietnam studied to dated have blood and fatty tissue 2,3,7,8-TCDD levels comparable to members of the general U.S. population

For more information on exposure to CDDs, see Chapter 5.

1.4 HOW CAN CDDs ENTER AND LEAVE MY BODY?

CDDs can enter your body when you breathe contaminated air, eat contaminated food, or have skin contact with contaminated soil or other materials. The most common way CDDs can enter your body is by eating food contaminated with CDDs

If you breathe air that contains CDDs, the CDDs can enter your body through your lungs and pass into the blood stream, but we do not know how fast or how much of the CDDs will enter the blood stream. If you swallow food or water containing CDDs, most of the CDDs will enter your body and pass from the intestines to the blood stream Smaller amounts of highly chlorinated CDDs will enter your body compared to the less chlorinated 2,3,7,8-TCDD. If you swallow soil containing CDDs, a small amount of the CDDs will pass through the intestines into the blood stream. If soil contaminated with CDDs comes into contact with your skin, some of the CDDs will enter the body but we do not know how fast they will enter the blood stream.

Once in your body, CDDs can be found in most tissues with the highest amounts found in the liver and body fat (adipose tissue). Body fat and possibly the liver can store CDDs for many years before eliminating them from the body CDDs with chlorine atoms in the 2, 3, 7, and 8 positions and highly chlorinated dioxins, such as OCDD, are generally found in higher concentrations in the fat than other CDDs

Little is known about CDDs breakdown in the human body Studies in animals show that some of the 2,3,7,8-TCDD from food is slowly broken down. There is evidence from animals suggesting that the break-down products are less harmful than the unchanged 2,3,7,8-TCDD.

For people, the average time it takes to remove one-half of the 2,3,7,8-TCDD from the body is highly variable and may take from 7 to 12 years. There is less information on the other CDDs, but what information exists suggests 5 to 15 years. CDDs are eliminated from the body primarily in the stool, and only a small amount leaves the body in the urine. Some CDDs will leave the body in the breast milk of nursing mothers.

Much less is known about how much other CDD compounds will enter the body, how much will be stored in the body and for how long, and how they are removed from the body.
For more information about how CDDs can enter and leave your body, see Chapter 2.

1.5 HOW CAN CDDs AFFECT MY HEALTH?

Many studies have looked at how CDDs can affect human health. Most of these studies examined workers exposed during the manufacture of chemicals and pesticides contaminated with 2,3,7,8-TCDD. Other studies have looked at American Vietnam veterans and Vietnamese populations exposed to Agent Orange and populations exposed to 2,3,7,8-TCDD as a result of an accident. The workers and Vietnam veterans were most likely exposed to 2,3,7,8-TCDD mainly through breathing and skin contact. People who were accidentally exposed to 2,3,7,8-TCDD in Seveso, Italy, or Times Beach, Missouri, were probably exposed through eating and drinking contaminated food and milk, breathing contaminated particles and dust, through skin contact with contaminated soil and through unintentional hand-to mouth activity. Epidemiology is an inexact science and many of the human studies have many shortcomings which make it difficult for scientists to establish an association between 2,3,7,8-TCDD exposure levels and health effects. A common problem with most of the human studies is that the people are exposed to a number of chemicals at the same time. In most human health studies, we do not know how much 2,3,7,8-TCDD people were exposed to or how long the exposure lasted. In other studies, the people were examined many years after they were exposed and some of the effects may have not have been present at the time of examination or the effects observed may not have been caused by 2,3,7,8-TCDD. Some of the more recent studies have measured 2,3,7,8-TCDD levels in the blood or fat tissue of exposed populations. The levels of 2,3,7,8-TCDD in the blood or fat tissue can be used to estimate the extent of past exposures.

A number of effects have been observed in people exposed to 2,3,7,8-TCDD levels which are at least 10 times higher than background levels. The most obvious health effect in people exposed to relatively large amounts of 2,3,7,8-TCDD is chloracne. Chloracne is a severe skin disease characterized by acne-like lesions. Chloracne generally occurs on the face and upper body, but may occur elsewhere on the body. Unlike common acne, severe chloracne is harder to cure and can be more disfiguring. In milder cases, the lesions heal several months after exposure ends. In more severe cases, the lesions may last for many years after exposure. Most of the chloracne cases have been attributed to accidental exposure to high doses of 2,3,7,8-TCDD. Other effects to the skin, such as erythematous or red skin rashes, discoloration, and excessive body hair, have been reported to occur in people following exposure to high concentrations of 2,3,7,8-TCDD. Changes in blood and urine that may indicate liver damage have been observed in people. Alterations in the ability of the liver to metabolize (or breakdown) hemoglobin, lipids, sugar, and protein have been reported in people exposed to relatively high concentrations of 2,3,7,8-TCDD. Most of the effects are considered mild and were reversible. However, in some people these effects may last for many years. Slight increases in the risk of diabetes and abnormal glucose tolerance have been observed in some studies of people exposed to 2,3,7,8-TCDD. We do not have enough information to know if exposure to 2,3,7,8-TCDD will result in reproductive or developmental effects in people, but animal studies suggest that this is a potential health concern. Several studies of workers exposed to high levels (with body burdens more than 50 times higher than background body burden levels) of 2,3,7,8-TCDD suggest that exposure to 2,3,7,8-TCDD may increase the risk of cancer in people.

The Department of Health and Human Services (DHHS) has determined that it is reasonable to expect that 2,3,7,8-TCDD may cause cancer. The International Agency for Research on Cancer (IARC) has determined that 2,3,7,8-TCDD can cause cancer in people, but that it is not possible to classify other CDDs as to their carcinogenicity to humans. The EPA has determined that 2,3,7,8-TCDD is a probable human carcinogen when considered alone and when considered in association with phenoxy herbicides and/or chlorophenols. The EPA has determined also that a mixture of CDDs with six chlorine atoms (4 of the 6 chlorine atoms at the 2, 3, 7, and 8 positions) is a probable human carcinogen.

To protect the public from the harmful effects of toxic chemicals and to find ways to treat people who have been harmed, scientists use many tests

One way to see if a chemical will hurt people is to learn how the chemical is absorbed, used, and released by the body; for some chemicals, animal testing may be necessary. Animal testing may also be used to identify health effects such as cancer or birth defects. Without laboratory animals, scientists would lose a basic method to get information needed to make wise decisions to protect public health. Scientists have the responsibility to treat research animals with care and compassion. Laws today protect the welfare of research animals, and scientists must comply with strict animal care guidelines.

The health effects of some CDDs have been extensively studied in animals. Some CDDs are much more toxic than others. 2,3,7,8-TCDD and, to a lesser extent, CDDs with five (penta) or six (hexa) chlorine atoms substituted in the 2, 3, 7, and 8 positions, are extremely toxic to animals. Other CDDs, which do not have chlorine atoms substituted in the 2, 3, 7, and 8 positions, are considered relatively less toxic compared to 2,3,7,8-TCDD.

2,3,7,8-TCDD has been the most extensively studied CDD and it has been shown to cause a large number of adverse health effects in animals. There are always going to be some difficulties in using animal data to quantify health risks in people. In general, the doses used in the animal studies result in body burdens that are at least 10 times higher than human background body burdens, often the animal studies use doses that are over 1,000 times higher than human background levels. Some animal species are much more acutely sensitive to 2,3,7,8-TCDD than others. For example, it takes several thousand times more 2,3,7,8-TCDD to kill a hamster than a guinea pig. The reason for the difference in sensitivity among species is currently being investigated. For other effects, such as reproductive toxicity, there is very little difference in sensitivity between hamsters and guinea pigs. Another consideration in using animal data to predict health effects in people exposed to CDDs in the environment is the design of the animal studies. In most of the animal studies, the animals were exposed to only 2,3,7,8-TCDD, the most toxic CDD. 2,3,7,8-TCDD is rarely the main CDD found in the environment and people are typically exposed to a number of CDDs and compounds with similar toxic actions. Until scientists learn more about possible differences between people and animals, levels recommended to be of little or no risk to human health are based on the more sensitive species and the assumption that effects in animals could occur in people. This approach is further justified on the basis that humans are likely to exhibit a wide range of sensitivities to various health effects and the need to protect the most susceptible individuals.

In certain animal species, 2,3,7,8-TCDD is especially harmful and can cause death after a single exposure to small amounts. Before death, animals may lose as much as 40% or more of their body weight following a single dose of 2,3,7,8-TCDD. Exposure to non-lethal levels added in their food can cause a variety of adverse effects in animals, such as weight loss, biochemical and degenerative changes in the liver. Some animals that were exposed to CDDs in their food had effects to the skin such as hair loss, swelling of the face, and moderate to severe chloracne. In many species of animals, the immune system appears to be extremely sensitive to 2,3,7,8-TCDD. At relatively low levels (approximately 10 times higher than human background body burdens), 2,3,7,8-TCDD weakens the immune system and causes a decrease in the system's ability to fight foreign substances such as bacteria and viruses.

Exposure to 2,3,7,8-TCDD can cause reproductive damage and birth defects in animals. Decreases in fertility, altered levels of sex hormones, reduced production of sperm, and increased rates of miscarriages were found in animals exposed to 2,3,7,8-TCDD in food. Rats and mice that were exposed to small amounts of 2,3,7,8-TCDD in food for a long time developed cancer of the liver and thyroid, and other types of cancer.

The results of the oral animal studies suggest that the most sensitive effects (effects that will occur at the lowest doses) are immune, endocrine, and developmental effects. It is reasonable to assume that these will also be the most sensitive effects in humans.

We know less about the ability of other CDDs to cause adverse health effects. However, it appears that all CDDs with chlorine in the 2, 3, 7, and 8 positions have similar effects to 2,3,7,8-TCDD but the effects occur at higher doses.

Relatively large amounts of 2,3,7,8-TCDD applied to the skin of some animal species have resulted in deaths. Smaller amounts have resulted in weight loss, acne-like sores on the skin, and biochemical and degenerative changes in the liver. In addition, mice that had 2,3,7,8-TCDD repeatedly applied to their skin developed skin cancer. Although effects in animals following exposure through the skin have not been as extensively studied as effects following exposure in food, they appear to be quite similar. The ability of other CDDs to cause adverse health effects in animals following exposure to the skin has not been well studied.

You can find out more information on the health effects of CDDs in Chapter 2.

1.6 HOW CAN CDDs AFFECT CHILDREN?

This section discusses potential health effects from exposures during the period from conception to maturity at 18 years of age in humans. Potential effects on children resulting from exposures of the parents are also considered.

Very few studies have looked at how CDDs can affect children's health. Chloracne has been observed in children exposed to much higher than current background levels of 2,3,7,8-TCDD. The children appeared to be more sensitive (effects occurred at a lower body burden) than adults. We do not know why children are more sensitive than adults to this effect. It is likely that children exposed to higher than background levels will have similar effects as adults.

We do not know if exposure to CDDs will result in birth defects or other developmental effects in people. Birth defects have been observed in animals exposed to higher than background levels of 2,3,7,8-TCDD. The developing animal is very sensitive to 2,3,7,8-TCDD. In some studies, effects were observed at body burdens 10 times higher than human background body burden levels. Offspring of animals exposed to 2,3,7,8-TCDD in food during pregnancy often had severe birth defects including bleeding, skeletal deformities, kidney defects, weakened immune responses, impaired development of the reproductive system, and learning and behavioral impairments. Exposure to other CDDs, such as 2,7-DCDD, 1,2,3,7,8-PeCDD, OCDD, and HxCDD, can also result in developmental effects in animals.

We have no information to suggest that there are any differences between children and adults in terms of how much CDDs will enter the body, where CDDs can be found in the body, and how fast CDDs will leave the body. CDDs from the mother can enter her unborn baby through the placenta. It can also be transferred from the mother to infant through breast milk. Because CDDs have been measured in human milk, cows milk, and infant formula, nursing infants are also exposed to CDDs. In most cases the beneficial aspects (biological and psychological) of breast-feeding outweigh any risks from exposure to CDDs from mother's milk.

1.7 HOW CAN FAMILIES REDUCE THE RISK OF EXPOSURE TO CDDs?

If your doctor finds that you have been exposed to significant amounts of CDDs, ask your doctor if children may also be exposed. When necessary your doctor may need to ask your state Department of Public Health to investigate.

Structural material used in building homes such as chemically treated lumber for decking and plastic PVC pipes used in water pipes and other conduits can release CDDS if they are burned as refuse during construction or if there is a structural fire in your home. To avoid exposures from some of these sources, construction refuse should not be burned near your home especially when children are out playing.

Children may be exposed to CDDs from ingestion of contaminated soil or by contact of contaminated soil with their skin. However, skin contact with contaminated soil will result in much less CDDs entering the blood stream than if they ingest contaminated soil. Also, the amount of CDDs that will pass to the blood stream after eating contaminated soil will depend on the type of soil and on how tight the CDDs are bound to the soil. Children should be restricted from playing near any known hazardous waste sites. Some children eat a lot of dirt. Discourage your children from eating dirt or from putting their toys or other foreign objects in their mouths that may be contaminated with soil. Make sure that your children wash their hands frequently, especially before eating. Discourage your children from putting their hands in their mouths or other hand-to-mouth activities.

Older children may be exposed to CDDs if they smoke cigarettes. Younger children and infants may be exposed by inhaling the second-hand smoke from their parents or other adult smokers. Parents should talk to their children about the dangers of smoking cigarettes.

You and your children are likely to be exposed to very low amounts of CDDs in the diet particularly when you consume meat, milk, other dairy products, and fish. This represents the major source of background exposure to CDDs in most people. Children and adults should eat a balanced diet preferably containing low to moderate amounts of animal fats including meat and dairy products, and fish that contain higher amounts of CDDs and eat larger amounts of fruits, vegetables and grains.

You or your children may be exposed to CDDs by eating certain types of fish or wildlife caught in certain locations. A number of states have advisories for CDDs in fish and shellfish species; and one state has a wildlife advisory in effect for wood ducks. Each state, Native American tribe, or U.S. Territory sets its own criteria for issuing fish and wildlife advisories. A fish advisory will specify which waterbodies have restrictions, and a wildlife advisory will specify which hunting areas have restrictions. The advisory will tell you what types and sizes of fish or game are of concern. The advisory may completely ban eating fish or game or recommend that you limit the number of meals you eat of a certain species. For example, an advisory may tell you to eat a certain type of fish no more than once a month. The advisory may also tell you only to eat certain parts of the fish or game animal and how to prepare or cook the fish or game to decrease your exposure to CDDs. Fish and wildlife advisories are often stricter for pregnant women, nursing mothers, and young children. To reduce your children's exposure to CDDs, obey all fish and wildlife advisories. Information on Fish and Wildlife Advisories in your state is available from your state Public Health Department, or state Natural Resources Department and signs may be posted in certain fishing and hunting areas.

1.8 IS THERE A MEDICAL TEST TO DETERMINE WHETHER I HAVE BEEN EXPOSED TO CDDs?

Specific tests exist to measure CDD levels in samples of body fat, blood, and breast milk, but these tests are not routinely available. All people now have some levels of CDDs in their body fat and blood. Levels of 2,3,7,8-TCDD on a lipid basis are generally below 10 pg/g of lipid (ppt) in the blood and fatty tissue of the general population of the United States, and usually range from 3 to 7 ppt. Levels higher than these indicate past exposure to above-normal levels of 2,3,7,8-TCDD. Although CDDs stay in the body fat for a long time (see Section 1.4), tests are not used to determine when exposure occurred, but can be used to estimate dose of the exposure if the time of exposure is known.

Although exposure to 2,3,7,8-TCDD has been associated with adverse health effects in people, no one effect is specifically related to exposure to CDDs. There are laboratory tests which can indicate whether you have been exposed to CDDs, but these are costly and take weeks to perform and they cannot be used to predict whether you will develop harmful health effects.

1.9 WHAT RECOMMENDATIONS HAS THE FEDERAL GOVERNMENT MADE TO PROTECT HUMAN HEALTH?

The federal government develops regulations and recommendations to protect public health Regulations can be enforced by law. Federal agencies that develop regulations for toxic substances include the Environmental Protection Agency (EPA), the Occupational Safety and Health Administration (OSHA), and the Food and Drug Administration (FDA) Recommendations provide valuable guidelines to protect public health but cannot be enforced by law. Federal organizations that develop recommendations for toxic substances include the Agency for Toxic Substances and Disease Registry (ATSDR) and the National Institute for Occupational Safety and Health (NIOSH)

Regulations and recommendations can be expressed in not-to-exceed levels in air, water, soil, or food that are usually based on levels that affect animals, then they are adjusted to help protect people Sometimes these not-to-exceed levels differ among federal organizations because of different exposure times (an 8-hour workday or a 24-hour day), the use of different animal studies, or other factors

Recommendations and regulations are also periodically updated as more information becomes available. For the most current information, check with the federal agency or organization that provides it Some regulations and recommendations for CDDs include the following:

The government has developed regulations and guidelines for 2,3,7,8-TCDD. These are designed to protect the public from the potential adverse health effects of the chemical. The Food and Drug Administration (FDA) recommends against consuming fish and shellfish with 2,3,7,8-TCDD levels greater than 50 ppt. Such levels have resulted in the closing of several commercial fishing areas. In addition, EPA has issued guidance to states on how to evaluate health risks to recreational and subsistence fishers, and how to issue fish consumption advisories when concentrations of CDDs in fish and shellfish pose a risk to these populations Currently, 66 health advisories have been issued by 21 states restricting consumption of fish and wildlife contaminated with CDDs EPA also has recommended limits on how much 2,3,7,8-TCDD can be present in drinking water. EPA advises that children should not have more than 1 nanogram 2,3,7,8-TCDD per liter of water (ng/L) (ppt)

in 1 day, or more than 0.01 ng/L per day for long-term exposure For long-term exposure in adults, EPA recommends that there should not be more than 0 04 ng/L (ppt) in drinking water.

Human milk can contain higher levels of CDDs than cow's milk Therefore, breast-fed infants can be exposed to higher levels of CDDs on a body weight basis than adults The World Health Organization (WHO) has concluded that this risk to infants does not outweigh the positive biological and psychological benefits of breast-feeding at general population levels of dioxins However, the specific concentration at which CDD levels in human milk would lead to harmful health effects in infants has not yet been determined

Regulation of many of the sources of CDDs appears to have been successful in reducing the amount of CDDs entering the ecosystem and in decreasing the potential for human exposure. EPA and ATSDR listed 2,3,7,8-TCDD as hazardous substance Many regulations govern its destruction and disposal. See Chapter 7 for more information on regulations and guidelines

1.10 WHERE CAN I GET MORE INFORMATION?

If you have any more questions or concerns, please contact your community or state health or environmental quality department or

Agency for Toxic Substances and Disease Registry
Division of Toxicology
1600 Clifton Road NE, Mailstop E-29
Atlanta, GA 30333

* Information line and technical assistance

Phone: 1-800-44701544
Fax: (404) 639-6359

ATSDR can also tell you the location of occupational and environmental health clinics These clinics specialize in recognizing, evaluating, and treating illnesses resulting from exposure to hazardous substances.

* To order toxicological profiles, contact:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Phone: (800) 553-6847 or (703) 487-4650

TOXICOLOGICAL PROFILE FOR URANIUM

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Public Health Service
Agency for Toxic Substances and Disease Registry

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C-51

1. PUBLIC HEALTH STATEMENT

This public health statement tells you about uranium and the effects of exposure.

The Environmental Protection Agency (EPA) identifies the most serious hazardous waste sites in the nation. These sites make up the National Priorities List (NPL) and are the sites targeted for long-term federal cleanup activities. Elevated uranium levels have been found in at least 54 of the 1,517 current or former NPL sites. However, the total number of NPL sites evaluated for this substance is not known. As more sites are evaluated, the sites at which uranium is found may increase. This information is important because exposure to this substance may harm you and because these sites may be sources of exposure.

When a substance is released from a large area, such as an industrial plant, or from a container, such as a drum or bottle, it enters the environment. This release does not always lead to exposure. You are normally exposed to a substance only when you come in contact with it. You may be exposed by breathing, eating, or drinking the substance or by skin contact. However, since uranium is radioactive, you can also be exposed to its radiation if you are near it.

If you are exposed to uranium, many factors determine whether you'll be harmed. These factors include the dose (how much), the duration (how long), and how you come in contact with it. You must also consider the other chemicals you're exposed to and your age, sex, diet, family traits, lifestyle, and state of health.

1.1 WHAT IS URANIUM?

Uranium is a natural and commonly occurring radioactive element. It is found in very small amounts in nature in the form of minerals, but may be processed into a silver-colored metal. Rocks, soil, surface and underground water, air, and plants and animals all contain varying amounts of uranium. Typical concentrations in most materials are a few parts per million (ppm). This corresponds to around 4 tons of uranium in 1 square mile of soil 1 foot deep, or about half a

teaspoon of uranium in a typical 8-cubic yard dump truck load of soil. Some rocks and soils may also contain greater amounts of uranium. If the amount is great enough, the uranium may be present in commercial quantities and can be mined. After the uranium is extracted, it is converted into uranium dioxide or other chemical forms by a series of chemical processes known as milling. The residue remaining after the uranium has been extracted is called mill tailings. Mill tailings contain a small amount of uranium, as well as other naturally radioactive waste products such as radium and thorium.

Natural uranium is a mixture of three types (or isotopes) of uranium, written as ^{234}U, ^{235}U, and ^{238}U, or as U-234, U-235, and U-238, and read as uranium two thirty-four, etc. All three isotopes behave the same chemically, so any combination of the three would have the same chemical effect on your body. But they are different radioactive materials with different radioactive properties. That is why we must look at the actual percentages of the three isotopes in a sample of uranium to determine how radioactive the uranium is. For uranium that has been locked inside the earth for millions of years, we know the percentage of each isotope by weight and by radioactivity. By weight, natural uranium is about 0.01% ^{234}U, 0.72% ^{235}U, and 99.27% ^{238}U. About 48.9% of the radioactivity is associated with ^{234}U, 2.2% is associated with ^{235}U, and 48.9% is associated with ^{238}U.

The weight and radioactivity percentages are different because each isotope has a different physical half-life. Radioactive isotopes are constantly changing into different isotopes by giving off radiation. The half-life is the time it takes for half of that uranium isotope to give off its radiation and change into a different element. The half-lives of uranium isotopes are very long (244 thousand years for ^{234}U, 710 million years for ^{235}U, and 4½ billion years for ^{238}U). The shorter half-life makes ^{234}U the most radioactive, and the longer half-life makes ^{238}U the least radioactive. If you have one gram of each isotope side by side, the ^{234}U will be about 20 thousand times more radioactive and the ^{235}U will be 6 times more radioactive than the ^{238}U.

Uranium is measured in units of mass (grams) or radioactivity (curies or becquerels), depending on the type of equipment available or the level that needs to be measured. The becquerel (Bq) is a

new international unit, and the curie (Ci) is a traditional unit; both are currently used. A Bq is the amount of radioactive material in which 1 billion atoms transform every second, and a Ci is the amount of radioactive material in which 37 billion atoms transform every second. The mass and activity ratios given in the previous paragraph are those found in rocks inside the earth's crust, where 1.5 gram of uranium is equivalent to 1 millionth of a Ci (μCi). Although this ratio can vary in air, soil, and water, the conversions made in this profile use the 1.5-to-1 ratio unless the actual isotope ratios are known. When both mass and radioactivity units are shown, the first is normally the one reported in the literature. Some of the values may be rounded to make the text easier to read.

The uranium isotopes in the earth were present when the earth was formed. Both ^{235}U and ^{238}U have such long half-lives that part of the uranium originally on earth is still here, waiting to give off its radiation. The original ^{234}U would have decayed away by now, but new ^{234}U is constantly being made from the decay of ^{238}U. When ^{238}U gives off its radiation, it changes or decays through a series of different radioactive materials, including ^{234}U. This series, or decay chain, ends when a stable, non-radioactive substance is made. This element is lead. This toxicological profile deals with the uranium isotopes and not with the other radioactive decay products, like radium, thorium, and radon.

For uranium that has been in contact with water, the natural weight and radioactivity percentages can vary slightly from the percentages mentioned in the previous paragraphs. We don't fully understand why that happens in nature, but measurements show us that it does. The processing of uranium for industrial and governmental use can also change the ratios. We give these ratios special names if they were changed by human activities. If the fraction of ^{235}U is increased, we call it enriched uranium. However, if the portion of ^{235}U is decreased, we call it depleted uranium. The differences between the weight and radioactivity ratios matter when we want to convert between radioactivity and mass, and when we talk about how toxic uranium might be. Depleted uranium is less radioactive than natural uranium, and enriched uranium is more radioactive than natural uranium. This profile focuses on natural and depleted uranium, which are more likely to be chemical hazards than radiation hazards. The profile also discusses enriched uranium, which can be both a chemical and a radiation hazard.

The industrial process called enrichment is used to increase the amount of ^{234}U and ^{235}U and decrease the amount of ^{238}U in natural uranium. The product of this process is enriched uranium, and the leftover is depleted uranium. Enriched uranium is more radioactive than natural uranium, and natural uranium is more radioactive than depleted uranium. When enriched uranium is 97.5% pure ^{235}U, the same weight of enriched uranium has about 75 times the radioactivity as natural uranium. This is because enriched uranium also contains ^{234}U, which is even more radioactive than ^{235}U. The ^{235}U is responsible for most of the radioactivity in enriched uranium. Natural uranium is typically about two times more radioactive than depleted uranium. Other isotopes of uranium called ^{232}U and ^{233}U are produced by industrial processes. These are also much more radioactive than natural uranium.

The total amount of natural uranium on earth stays almost the same because of the very long half-lives of the uranium isotopes. The natural uranium can be moved from place to place by nature or by people, and some uranium is removed from the earth by mining. When rocks are broken up by water or wind, uranium becomes a part of the soil. When it rains, the soil containing uranium can be carried into rivers and lakes. Wind can blow dust that contains uranium into the air.

Natural uranium is radioactive but poses little radioactive danger because it gives off very small amounts of radiation. Uranium transforms into another element and gives off radiation. In this way uranium transforms into thorium and gives off a particle called an alpha particle or alpha radiation. Uranium is called the parent, and thorium is called the transformation product. When the transformation product is radioactive, it keeps transforming until a stable product is formed. During these decay processes, the parent uranium, its decay products, and their subsequent decay products each release radiation. Radon and radium are two of these products. Unlike other kinds of radiation, the alpha radiation ordinarily given off by uranium cannot pass through solid objects, such as paper or human skin. For more information on radiation, see Appendix D and the glossary at the end of this profile or the ASTDR *Toxicological Profile for Ionizing Radiation*.

The main civilian use of uranium is in nuclear power plants and on helicopters and airplanes. It is also used by the armed forces as shielding to protect Army tanks, parts of bullets and missiles to

help them go through enemy armored vehicles, as a source of power, and in nuclear weapons. Very small amounts are used to make some ceramic ornament glazes, light bulbs, photographic chemicals, and household products. Some fertilizers contain slightly higher amounts of natural uranium. For more information about the properties and uses of uranium, see Chapters 3, 4, and 5.

1.2 WHAT HAPPENS TO URANIUM WHEN IT ENTERS THE ENVIRONMENT?

Uranium is a naturally occurring radioactive material that is present to some degree in almost everything in our environment, including soil, rocks, water, and air. It is a reactive metal, so it is not found as free uranium in the environment. In addition to the uranium naturally found in minerals, the uranium metal and compounds that are left after humans mine and process the minerals can also be released back to the environment in mill tailings. This uranium can combine with other chemicals in the environment to form other uranium compounds. Each of these uranium compounds dissolves to its own special extent in water, ranging from not soluble to very soluble. This helps determine how easily the compound can move through the environment, as well as how toxic it might be.

The amount of uranium that has been measured in air in different parts of the United States by EPA ranges from 0.011 to 0.3 femtocuries (0.00002 to 0.00045 micrograms) per cubic meter (m^3). (One femtocurie is equal to 1 picocurie [pCi] divided by 1,000. A picocurie [pCi] is 1 one-trillionth of a curie and a microgram [μg] is one millionth of a gram. Even at the higher concentration, there is so little uranium in a cubic meter of air that less than one atom transforms each day.

In the air, uranium exists as dust. Very small dust-like particles of uranium in the air fall out of the air onto surface water, plant surfaces, and soil either by themselves or when rain falls. These particles of uranium eventually end up back in the soil or in the bottoms of lakes, rivers, and ponds, where they stay and mix with the natural uranium that is already there.

Uranium in water comes from different sources. Most of it comes from dissolving uranium out of rocks and soil that water runs over and through. Only a very small part is from the settling of uranium dust out of the air. Some of the uranium is simply suspended in water, like muddy water. The amount of uranium that has been measured in drinking water in different parts of the United States by EPA is generally less than 1.5 μg (1 pCi) for every liter of water. EPA has found that the levels of uranium in water in different parts of the United States are extremely low in most cases, and that water containing normal amounts of uranium is usually safe to drink. Because of the nature of uranium, not much of it gets into fish or vegetables, and most of that which gets into livestock is eliminated quickly in urine and feces.

Uranium is found naturally in soil in amounts that vary over a wide range, but the typical concentration is 3 μg (2 pCi) per gram of soil. Additional uranium can be added by industrial activities. Soluble uranium compounds can combine with other substances in the environment to form other uranium compounds. Uranium compounds may stay in the soil for thousands of years without moving downward into groundwater. When large amounts of natural uranium are found in soil, it is usually soil with phosphate deposits. The amount of uranium that has been measured in the phosphate-rich soils of north and central Florida ranges from 4.5 to 83.4 pCi of uranium in every gram of soil. In areas like New Mexico, where uranium is mined and processed, the amount of uranium per gram of soil ranges between 0.07 and 3.4 pCi (0.1–5.1 micrograms [μg]) of uranium per gram soil). The amount of uranium in soil near a uranium fuel fabrication facility in the state of Washington ranges from 0.51 to 3.1 pCi/gram (0.8–4.6 μg uranium/gram soil), with an average value of 1.2 pCi/gram (1.7 μg uranium/gram soil). These levels must be carefully compared with the levels in uncontaminated soil in that area, since they are within the normal ranges for uncontaminated soil.

Plants can absorb uranium from the soil onto their roots without absorbing it into the body of the plant. Therefore, root vegetables like potatoes and radishes that are grown in uranium-contaminated soil may contain more uranium than if the soil contained levels of uranium that were natural for the area. Washing the vegetable or removing its skin often removes most or all of the uranium. For more information about what happens to uranium in the environment, see Chapter 5.

1.3 HOW MIGHT I BE EXPOSED TO URANIUM?

Since uranium is found everywhere in small amounts, you always take it into your body from the air, water, food, and soil. Food and water have small amounts of natural uranium in them. People eat about 1–2 micrograms (0.6–1.0 picocuries) of natural uranium every day with their food and take in about 1.5 micrograms (0.8 picocuries) of natural uranium for every liter of water they drink, but they breathe in much lower amounts. Root vegetables, such as beets and potatoes, tend to have a bit more uranium than other foods. In a few places, there tends to be more natural uranium in the water than in the food. People in these areas naturally take in more uranium from their drinking water than from their foods. It is possible that you may eat and drink more uranium if you live in an area with naturally higher amounts of uranium in the soil or water or if you live near a uranium-contaminated hazardous waste site. You can also take in (or ingest) more uranium if you eat food grown in contaminated soil, or drink water that has unusually high levels of uranium. Normally, very little of the uranium in lakes, rivers, or oceans gets into the fish or seafood we eat. The amounts in the air are usually so small that they can be safely ignored. People who are artists, art or craft teachers, ceramic hobbyists, or glass workers who still use certain banned uranium-containing glazes or enamels may also be near to higher levels of uranium, but they will not necessarily take any into their bodies. People who work at factories that process uranium, work with phosphate fertilizers, or live near uranium mines have a chance of taking in more uranium than most other people. People who work on gyroscopes, helicopter rotor counterbalances, or control surfaces of airplanes may work with painted uranium metal, but the coating normally will keep them from taking in any uranium. People who work with armor-piercing weapons that contain uranium will be exposed to low levels of radiation while close to these weapons, but are not likely to take in any uranium. Those who fire uranium weapons, work with weapons with damaged uranium, or on equipment which has been bombarded with these weapons can be exposed to uranium and may wear protective clothes and masks to limit their intake. Larger-than-normal amounts of uranium might also enter the environment from erosion of tailings from mines and mills for uranium and other metals. Accidental discharges from uranium processing plants are possible, but these compounds spread out quickly into the air. For more information about how you may be exposed to uranium, see Chapter 5.

1.4 HOW CAN URANIUM ENTER AND LEAVE MY BODY?

We take uranium into our bodies in the food we eat, water we drink, and air we breathe. What we take in from industrial activities is in addition to what we take in from natural sources.

When you breathe uranium dust, some of it is exhaled and some stays in your lungs. The size of the uranium dust particles and how easily they dissolve determines where in the body the uranium goes and how it leaves your body. Uranium dust may consist of small, fine particles and coarse, big particles. The big particles are caught in the nose, sinuses, and upper part of your lungs where they are blown out or pushed to the throat and swallowed. The small particles are inhaled down to the lower part of your lungs. If they do not dissolve easily, they stay there for years and cause most of the radiation dose to the lungs from uranium. They may gradually dissolve and go into your blood. If the particles do dissolve easily, they go into your blood more quickly. A small part of the uranium you swallow will also go into your blood. The blood carries uranium throughout your body. Most of it leaves in your urine in a few days, but a little stays in your kidneys and bones.

When you eat foods and drink liquids containing uranium, most of it leaves within a few days in your feces and never enters your blood. A small portion will get into your blood and will leave your body through your urine within a few days. The rest can stay in your bones, kidneys, or other soft tissues. A small amount goes to your bones and may stay there for years. Most people have a very small amounts of uranium, about 1/5,000th of the weight of an aspirin tablet, in their bodies, mainly in their bones.

Although uranium is weakly radioactive, most of the radiation it gives off cannot travel far from its source. If the uranium is outside your body, such as in soil, most of its radiation cannot penetrate your skin and enter your body. To be exposed to radiation from uranium, you have to eat, drink, or breathe it, or get it on your skin. If uranium transformation products are also present, you can be exposed to their radiation at a distance. For more information about how uranium can leave your body, see Chapter 2.

1.5 HOW CAN URANIUM AFFECT MY HEALTH?

To protect the public from the harmful effects of toxic chemicals and to find ways to treat people who have been harmed, scientists must determine what the harmful effects are, how to test for them, how much of the chemical is required to produce each of the harmful effects, how we recognize an overexposure, and how to treat it.

One way to see if a chemical will hurt people is to learn how the chemical is absorbed, used, and released by the body; for some chemicals, animal testing may be necessary. Animal testing may also be used to identify health effects such as kidney or liver damage, cancer, or birth defects. Without laboratory animals, scientists would lose a basic method to get information needed to make wise decisions to protect public health. Scientists have the responsibility to treat research animals with care and compassion. Laws today protect the welfare of research animals, and scientists must comply with strict animal care guidelines.

Uranium is a chemical substance that is also radioactive. Scientists have never detected harmful radiation effects from low levels of natural uranium, although some may be possible. However, scientists have seen chemical effects. A few people have developed signs of kidney disease after intake of large amounts of uranium. Animals have also developed kidney disease after they have been treated with large amounts of uranium, so it is possible that intake of a large amount of uranium might damage your kidneys. There is also a chance of getting cancer from any radioactive material like uranium. Natural and depleted uranium are only weakly radioactive and are not likely to cause you to get cancer from their radiation. No human cancer of any type has ever been seen as a result of exposure to natural or depleted uranium. Uranium can decay into other radionuclides, which can cause cancer if you are exposed to enough of them for a long enough period. Doctors that studied lung and other cancers in uranium miners did not think that uranium radiation caused these cancers. The miners smoked cigarettes and were exposed to other substances that we know cause cancer, and the observed lung cancers were attributed to large exposures to radon and its radioactive transformation products.

The chance of getting cancer is greater if you are exposed to enriched uranium, because it is more radioactive than natural uranium. Cancer may not become apparent until many years after a person is exposed to a radioactive material (from swallowing or breathing it). Just being near uranium is not dangerous to your health because uranium gives off very little of the penetrating gamma radiation. However, uranium is normally accompanied by the other transformation products in its decay chain, so you would be exposed to their radiation as well.

The Committee on the Biological Effects of Ionizing Radiation (BEIR IV) reported that eating food or drinking water that has normal amounts of uranium will most likely not cause cancer or other health problems in most people. The Committee used data from animal studies to estimate that a small number of people who steadily eat food or drink water that has larger-than-normal quantities of uranium in it could get a kind of bone cancer called a sarcoma. The Committee reported calculations showing that if people steadily eat food or drink water containing about 1 pCi of uranium every day of their lives, bone sarcomas would be expected to occur in about 1 to 2 of every million people after 70 years, based on the radiation dose alone. However, we do not know this for certain because people normally ingest only slightly more than this amount each day, and people who have been exposed to larger amounts have not been found to get cancer.

We do not know if exposure to uranium causes reproductive effects in people. Very high doses of uranium have caused reproductive problems (reduced sperm counts) in some experiments with laboratory animals. Most studies show no effects. For more information about how uranium can affect your health, see Chapter 2.

1.6 HOW CAN URANIUM AFFECT CHILDREN?

This section discusses potential health effects from exposures during the period from conception to maturity at 18 years of age in humans. Potential effects on children resulting from exposures of the parents are also considered.

Like adults, children are exposed to small amounts of uranium in air, food, and drinking water. However, no cases have been reported where exposure to uranium is known to have caused health effects in children. It is possible that if children were exposed to very high amounts of uranium they might have damage to their kidneys like that seen in adults. We do not know whether children differ from adults in their susceptibility to health effects from uranium exposure.

It is not known if exposure to uranium has effects on the development of the human fetus. Very high doses of uranium in drinking water can affect the development of the fetus in laboratory animals. One study reported birth defects and another reported an increase in fetal deaths. However, we do not believe that uranium can cause these problems in pregnant women who take in normal amounts of uranium from food and water, or who breathe the air around a hazardous waste site that contains uranium.

Very young animals absorb more uranium into their blood than adults when they are fed uranium. We do not know if this happens in children.

Measurements of uranium have not been made in pregnant women, so we do not know if uranium can cross the placenta and enter the fetus. In an experiment with pregnant animals, only a very small amount (0.03%) of the injected uranium reached the fetus. Even less uranium is likely to reach the fetus in mothers exposed by inhaling, swallowing, or touching uranium. No measurements have been made of uranium in breast milk. Because of the chemical properties of uranium, it is unlikely that it would concentrate in breast milk.

1.7 HOW CAN FAMILIES REDUCE THE RISK OF EXPOSURE TO URANIUM?

If your doctor finds that you have been exposed to significant amounts of uranium, ask whether your children might also be exposed. Your doctor might need to ask your state health department to investigate.

It is possible that higher-than-normal levels of uranium may be in the soil at a hazardous waste site. Some children eat a lot of dirt. You should prevent your children from eating dirt. Make sure they wash their hands frequently, and before eating. If you live near hazardous waste site, discourage your children from putting their hands in their mouths or from engaging in other hand-to-mouth activities.

1.8 IS THERE A MEDICAL TEST TO DETERMINE WHETHER I HAVE BEEN EXPOSED TO URANIUM?

Yes, there are medical tests that can determine whether you have been exposed by measuring the amount of uranium in your urine, blood, and hair. Urine analysis is the standard test. If you take into your body a larger-than-normal amount of uranium over a short period, the amount of uranium in your urine may be increased for a short time. Because most uranium leaves the body within a few days, normally the amount in the urine only shows whether you have been exposed to a larger-than-normal amount within the last week or so. If the intake is large or higher-than-normal levels are taken in over a long period, the urine levels may be high for a longer period of time. Many factors can affect the detection of uranium after exposure. These factors include the type of uranium you were exposed to, the amount you took into your body, and the sensitivity of the detection method. Also, the amount in your urine does not always accurately show how much uranium you have been exposed to. If you think you have been exposed to elevated levels of uranium and want to have your urine tested, you should do so promptly while the levels may still be high. In addition to uranium, the urine could be tested for evidence of kidney damage, by looking for protein, glucose, and nonprotein nitrogen, which are some of the chemicals that can appear in your urine because of kidney damage. Testing for these chemicals could determine whether you have kidney damage. However, since kidney damage is also caused by several common diseases, such as diabetes, it would not tell you if the damage was caused by the presence of uranium in your body.

A radioactivity counter can tell if your skin is contaminated with uranium, because uranium is radioactive. If you inhale large amounts of uranium, it may be possible to measure the amount of

radioactivity in your body with special radiation measurement instruments. See Chapters 2 and 6 for more information.

1.9 WHAT RECOMMENDATIONS HAS THE FEDERAL GOVERNMENT MADE TO PROTECT HUMAN HEALTH?

International and national organizations like the International Commission on Radiological Protection (ICRP) and the National Council on Radiation Protection and Measurements (NCRP) provide recommendations for protecting people from materials, like uranium, that give off ionizing radiation. The federal government considers these recommendations and develops regulations and guidelines to protect public health. Regulations can be enforced by law. Federal agencies that develop regulations for toxic substances include the EPA, the Nuclear Regulatory Commission (NRC), the Occupational Safety and Health Administration (OSHA), and the Food and Drug Administration (FDA). Recommendations provide valuable guidelines to protect public health but cannot be enforced by law. Federal organizations that develop recommendations for toxic substances include the Agency for Toxic Substances and Disease Registry (ATSDR) and the National Institute for Occupational Safety and Health (NIOSH).

Regulations and recommendations can be expressed as levels that are not to be exceeded in air, water, soil, or food that are usually based on levels that affect animals. Then they are adjusted with appropriate safety factors to help protect people. Sometimes these not-to-exceed levels differ among federal organizations because of different exposure times (an 8-hour workday or a 24-hour day), the use of different animal studies, or other factors.

Recommendations and regulations are also periodically updated as more information becomes available. For the most current information, check with the federal agency or organization that provides it. Some regulations and recommendations for uranium are discussed below.

EPA has not set a limit for uranium in air, but it has set a goal of no uranium in drinking water. EPA calls this the Maximum Contaminant Level Goal (MCLG), but recognizes that, currently, there is no practical way to meet this goal. Because of this, EPA proposed in 1991 to allow up to

20 μg of uranium per liter (20 μg/L) in drinking water, and states began regulating to achieve this level. EPA calls this the Maximum Contaminant Level (MCL) The MCL for uranium is based on calculations that if 150,000 people drink water that contains 20 μg/L of uranium for a lifetime, there is a chance that one of them may develop cancer from the uranium in the drinking water. In 1994, EPA considered changing the MCL to 80 μg per liter based on newer human intake and uptake values and the high cost of reducing uranium levels in drinking water supplies In 1998, EPA temporarily dropped its 1991 limit, but is currently working to develop an appropriate limit based on a broader range of human and animal health studies. ATSDR, other federal agencies, Canada, and other professionals are advising EPA regarding a new MCL. Canada is currently developing its own national guideline value because that country has the richest known uranium ore deposits in the world and high uranium concentrations in some of its well water

EPA has also decided that any accidental uranium waste containing 0 1 curies of radioactivity (150 kilograms) must be cleaned up EPA calls this the Reportable Quantity Accidental Release EPA also has established a standard for uranium mill tailings. In the workplace, NIOSH/OSHA has set a Recommended Exposure Limit (REL) and a Permissible Exposure Limit (PEL) of 0.05 mg/m^3 (34 pCi/m^3) for uranium dust, while the NRC has an occupational limit of 0.2 mg/m^3 (130 pCi/m^3). The NRC has set uranium release limits at 0 06 pCi/m^3 (0 09 μg/m^3) of air and 300 pCi/liter (450 μg/liter) of water. NRC and OSHA expect that the public will normally be exposed to much lower concentrations. For more information about recommendations the federal government has made to protect your health, see Chapter 7.

1.10 WHERE CAN I GET MORE INFORMATION?

If you have any more questions or concerns, please contact your community or state health or environmental quality department or

Agency for Toxic Substances and Disease Registry
Division of Toxicology
1600 Clifton Road NE, Mailstop E-29
Atlanta, GA 30333

* Information line and technical assistance

Phone: 1-888-42-ATSDR (1-888-422-8737)
Fax: (404) 639-6315 or 6324

ATSDR can also tell you the location of occupational and environmental health clinics. These clinics specialize in recognizing, evaluating, and treating illnesses resulting from exposure to hazardous substances.

* To order toxicological profiles, contact

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Phone: (800) 553-6847 or (703) 605-6000

TOXICOLOGICAL PROFILE FOR 2,4,6-TRINITROTOLUENE

Prepared by:

Sciences International, Inc.
Under Subcontract to:

Research Triangle Institute
Under Contract No. 205-93-0606

Prepared for:

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry

June 1995

C-67

1. PUBLIC HEALTH STATEMENT

This Statement was prepared to give you information about 2,4,6-trinitrotoluene and to emphasize the human health effects that may result from exposure to it. The Environmental Protection Agency (EPA) has identified 1,397 sites on its National Priorities List (NPL). 2,4,6-Trinitrotoluene has been found in at least 20 of these sites. However, we do not know how many of the 1,397 NPL sites have been evaluated for 2,4,6-trinitrotoluene. As EPA evaluates more sites, the number of sites at which 2,4,6-trinitrotoluene is found may change. This information is important for you to know because 2,4,6-trinitrotoluene may cause harmful health effects and because these sites are potential or actual sources of human exposure to 2,4,6-trinitrotoluene.

When a chemical is released from a large area, such as an industrial plant, or from a container, such as a drum or bottle, it enters the environment as a chemical emission. This emission, which is also called a release, does not always lead to exposure. You can be exposed to a chemical only when you come into contact with the chemical. You may be exposed to it in the environment by breathing, eating, or drinking substances containing the chemical or from skin contact with it.

If you are exposed to a hazardous chemical such as 2,4,6-trinitrotoluene, several factors will determine whether harmful health effects will occur and what the type and severity of those health effects will be. These factors include the dose (how much), the duration (how long), the route or pathway by which you are exposed (breathing, eating, drinking, or skin contact), the other chemicals to which you are exposed, and your individual characteristics such as age, sex, nutritional status, family traits, life-style, and state of health.

1.0 PUBLIC HEALTH STATEMENT

1.1 WHAT IS 2,4,6-TRINITROTOLUENE?

2,4,6-Trinitrotoluene is a yellow, odorless, solid manufactured compound that does not occur naturally in the environment. It is made by combining toluene with a mixture of nitric acid and sulfuric acid. 2,4,6-Trinitrotoluene is also known by other names such as sym-trinitrotoluene, TNT, and 1-methyl-2,4,6-trinitrobenzene. 2,4,6-Trinitrotoluene is produced in the United States only at military arsenals. It is not produced commercially. 2,4,6-Trinitrotoluene is an explosive used in military shells, bombs, and grenades, in industrial uses, and in underwater blasting. For more information on the chemical and physical properties of 2,4,6-trinitrotoluene, see Chapter 3. For more information on its production and use, see Chapter 4.

1.2 WHAT HAPPENS TO 2,4,6-TRINITROTOLUENE WHEN IT ENTERS THE ENVIRONMENT?

2,4,6-Trinitrotoluene enters the environment in waste waters and solid wastes resulting from the manufacture of the compound, the processing and destruction of bombs and grenades, and the recycling of explosives. The compound moves in surface water and through soils to groundwater. In surface water, 2,4,6-trinitrotoluene is rapidly broken down into other chemical compounds by sunlight. Microorganisms in water and sediment break down the compound more slowly. Small amounts of 2,4,6-trinitrotoluene can accumulate in fish and plants. For more information on what happens to 2,4,6-trinitrotoluene when it enters the environment, see Chapter 5.

1.3 HOW MIGHT I BE EXPOSED TO 2,4,6-TRINITROTOLUENE?

You may be exposed to 2,4,6-trinitrotoluene as a result of its movement from chemical waste disposal sites to drinking water. Children may also be exposed through eating contaminated soil. Most exposure would result from drinking contaminated water, breathing contaminated

air, or eating contaminated foods such as fruits and vegetables. 2,4,6-Trinitrotoluene has been measured at waste disposal sites in groundwater at 0.32 parts of 2,4,6-trinitrotoluene per million parts of water (ppm) and in soil at up to 13,000 ppm. We have no data on levels in air or foods. 2,4,6-Trinitrotoluene can be taken up by plants from contaminated soil and is probably present in the air as a result of disposal by burning at military sites. Therefore, intake of air and homegrown fruits and vegetables by people living near military sites may also be sources of exposure to 2,4,6-trinitrotoluene.

Worker exposure to 2,4,6-trinitrotoluene is possible as a result of its use in the production of bombs and grenades. Most workplace exposure results from breathing in 2,4,6-trinitrotoluene dust or vapor and contact with dust on the skin. For additional information on how you can be exposed to 2,4,6-trinitrotoluene, see Chapter 5.

1.4 HOW CAN 2,4,6-TRINITROTOLUENE ENTER AND LEAVE MY BODY?

2,4,6-Trinitrotoluene rapidly and completely enters your body when you breathe in air or drink water that is contaminated with this chemical. We have no information on how much 2,4,6-trinitrotoluene enters your body when it gets on your skin. We do know that it enters your body more slowly through the skin than when it is taken into your mouth. 2,4,6-Trinitrotoluene in your blood travels throughout your body to all of your organs. When 2,4,6-trinitrotoluene reaches your liver, it breaks down and changes into several different substances. Not all of these substances have been identified, and we do not know whether they are harmful or not. Most of these substances travel in your blood until they reach your kidneys and then leave your body in your urine. Studies in animals show that almost all of the 2,4,6-trinitrotoluene that enters the body breaks down and leaves the body in the urine within 24 hours. Chapter 2 contains more information on how 2,4,6-trinitrotoluene enters and leaves your body.

1.5 HOW CAN 2,4,6-TRINITROTOLUENE AFFECT MY HEALTH?

Workers involved in the production of high explosives experienced many harmful health effects as a result of exposure to 2,4,6-trinitrotoluene at their jobs. These effects included disorders of the blood, such as anemia, and abnormal liver function. However, the levels of 2,4,6-trinitrotoluene in the workplace air at the time these effects were seen ranged from less than 0.01 to 1.49 milligrams of 2,4,6-trinitrotoluene per cubic meter of air (mg/m^3). Some of the concentrations measured are higher than the level currently allowed in the workplace (0.5 mg/m^3) Similar effects on the blood and the liver have been observed in animals that either breathed or were fed 2,4,6-trinitrotoluene. In addition, studies show that animals force-fed 2,4,6-trinitrotoluene for an intermediate-duration (from 15–364 days) may have enlargement of the spleen and other harmful effects on the immune system. When people have prolonged skin contact with 2,4,6-trinitrotoluene, they may develop an allergic reaction of the skin to this chemical, such as itching and irritation. In addition, long-term exposure to 2,4,6-trinitrotoluene has been associated with the development of cataracts in people.

No information is available to indicate whether 2,4,6-trinitrotoluene causes birth defects. However, studies in animals that were treated with high doses of 2,4,6-trinitrotoluene have shown that it can cause serious effects on the male reproductive system. The available information for determining whether 2,4,6-trinitrotoluene causes cancer in humans is inadequate. However, rats that ate 2,4,6-trinitrotoluene for long periods developed tumors of the urinary bladder. Based on this study with rats, EPA has classified 2,4,6-trinitrotoluene in Group C, a possible human carcinogen

1.6 IS THERE A MEDICAL TEST TO DETERMINE WHETHER I HAVE BEEN EXPOSED TO 2,4,6-TRINITROTOLUENE?

There are tests to determine if you have been exposed to 2,4,6-trinitrotoluene. These tests measure 2,4,6-trinitrotoluene or its breakdown products in your blood and urine and have been used to test exposed workers. Detection of the breakdown products in your urine is a clear indication that you have been exposed. The complex and expensive equipment needed to perform these tests is generally available only at specialized laboratories. Another simpler, but less specific, test of 2,4,6-trinitrotoluene exposure is a change in the color of your urine to amber or deep red. This change results from the presence of breakdown products and may indicate that you have been exposed to 2,4,6-trinitrotoluene. None of these tests can predict whether a person exposed to 2,4,6-trinitrotoluene will experience any health effects related to the exposure. For more information on tests for exposure, see Chapters 2 and 6.

1.7 WHAT RECOMMENDATIONS HAS THE FEDERAL GOVERNMENT MADE TO PROTECT HUMAN HEALTH?

The government has developed regulations and guidelines for 2,4,6-trinitrotoluene. These are designed to protect the public and workers exposed to 2,4,6-trinitrotoluene from potential harmful health effects of the chemical. Since 2,4,6-trinitrotoluene is explosive, flammable, and toxic, EPA has designated it as a hazardous waste. The Department of Transportation (DOT) regulates the transport of 2,4,6-trinitrotoluene because it is a hazardous material. DOT specifies that when 2,4,6-trinitrotoluene is shipped, it must be wet with at least 10% water (by weight) and it must be clearly labeled as a flammable solid (HSDB 1994).

The Occupational Safety and Health Administration (OSHA) regulates levels of hazardous materials in the workplace. The maximum allowable amount of 2,4,6-trinitrotoluene in workroom air during an 8-hour workday, 40-hour workweek, is 0.5 mg/m^3. The National Institute for Occupational Safety and Health (NIOSH) recommends that the concentration in

workroom air be limited to 0.5 mg/m^3 for up to a 10-hour workday during a 40-hour workweek (NIOSH 1992) For more information on federal regulations about 2,4,6-trinitrotoluene, see Chapter 7.

1.8 WHERE CAN I GET MORE INFORMATION?

If you have any more questions or concerns, please contact your community or state health or environmental quality department or:

Agency for Toxic Substances and Disease Registry
Division of Toxicology
1600 Clifton Road NE, Mailstop E-29
Atlanta, Georgia 30333

This agency can also tell you where to find the nearest occupational and environmental health clinic These clinics specialize in the recognition, evaluation, and treatment of illnesses resulting from exposure to hazardous substances.

TOXICOLOGICAL PROFILE FOR HMX

Prepared by:

Sciences International, Inc.
Under Subcontract to:

Research Triangle Institute
Under Contract No. 205-93-0606

Prepared for:

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry

September 1997

C-74

1. PUBLIC HEALTH STATEMENT

This Statement was prepared to give you information about HMX and to emphasize the human health effects that may result from exposure to it The Environmental Protection Agency (EPA) has identified 1,416 hazardous waste sites as the most serious in the nation These sites make up the National Priorities List (NPL) and are the sites targeted for long-term federal cleanup activities. HMX has been found in at least 10 of the sites on the NPL However, the number of NPL sites evaluated for HMX is not known. As EPA evaluates more sites, the number of sites at which HMX is found may increase This information is important because exposure to HMX may cause harmful health effects and because these sites are potential or actual sources of human exposure to HMX

When a substance is released from a large area, such as an industrial plant, or from a container, such as a drum or bottle, it enters the environment. This release does not always lead to exposure. You can be exposed to a substance only when you come in contact with it You may be exposed by breathing, eating, or drinking substances containing the substance or by skin contact with it.

If you are exposed to a substance such as HMX, many factors will determine whether harmful health effects will occur and what the type and severity of those health effects will be. These factors include the dose (how much), the duration (how long), the route or pathway by which you are exposed (breathing, eating, drinking, or skin contact), the other chemicals to which you are exposed, and your individual characteristics such as age, gender, nutritional status, family traits, life-style, and state of health.

1.1 WHAT IS HMX?

HMX, an acronym for High Melting eXplosive, is also known as octogen and cyclotetramethylene-tetranitramine, as well as by other names It is a colorless solid that dissolves slightly in water. Only a very small amount of HMX will evaporate into the air; however, it can occur in air attached to suspended particles or dust The taste and smell of HMX are not known

HMX is a manmade chemical and does not occur naturally in the environment It is made from other chemicals known as hexamine, ammonium nitrate, nitric acid, and acetic acid HMX explodes

violently at high temperatures (534°F and above). Because of this property, HMX is used in nuclear devices, plastic explosives, rocket fuels, and burster chargers. A small amount of HMX is also formed in making cyclotrimethylene-trinitramine (RDX), another explosive similar in structure to HMX. The amount of HMX made and used in the United States at present is not known, but it is believed to be greater than 30 million pounds per year.

More information about the chemical names, properties, and uses of HMX is in Chapters 3 and 4.

1.2 WHAT HAPPENS TO HMX WHEN IT ENTERS THE ENVIRONMENT?

Most of the HMX that enters the environment is released into waste water from places that make or use HMX. A small amount of HMX can be released to the air as dust or ash from facilities that burn waste contaminated with HMX. Some HMX may be released to soil as a result of accidental spills, the settling of HMX-containing dust particles from the air, or the disposal of waste that contains HMX in landfills.

Dust particles containing HMX may be carried by the wind for some distance. The distance depends on a number of factors, including particle size, wind velocity, and weather conditions. Eventually, these particles settle to the earth, depositing on soil and surface waters. The length of time that HMX remains in the air is not known.

In surface water, HMX does not evaporate or bind to sediments to any large extent. Sunlight breaks down most of the HMX in surface water into other compounds, usually in a matter of days to weeks. The amount of time HMX remains in surface water depends on how much light-absorbing material is present. A small amount of HMX may also be broken down by bacteria in the water. Some of the breakdown products of HMX (nitrite, nitrate, formaldehyde, 1,1-dimethylhydrazine) are also harmful to your health, although the amounts you may be exposed to as a result of HMX in your drinking water are not expected to be above trace levels.

Laboratory studies show that HMX is likely to move from soil into groundwater, particularly in sandy soils. For most soils, however, the movement of HMX into groundwater is expected to be slow. Bacteria in the soil are not expected to break down HMX to any large extent. Exactly how long HMX

will remain in the environment is not known; however, HMX in soil and groundwater is expected to stay there for a long time.

It is not known if plants, fish, or animals living in areas contaminated with HMX build up high levels of the chemical in their tissues.

More information on what happens to HMX when it enters the environment is in Chapters 4 and 5

1.3 HOW MIGHT I BE EXPOSED TO HMX?

There is no information on how often you might be exposed to HMX in the environment or to how much. Most people, however, probably won't be exposed to HMX from the environment. People who work at facilities that make or use HMX or RDX, such as military personnel, may be exposed. These workers may be exposed by inhaling dusts that contain HMX or by getting HMX-containing liquids on their skin. People who live near facilities that make or use HMX, or near hazardous waste sites that contain HMX, may also be exposed. For these residents, exposure (if any) is most likely to occur from contaminated groundwater. However, exposures to small amounts of HMX from contaminated surface water, soil, and air are also possible.

More information on how you can be exposed to HMX is in Chapter 5

1.4 HOW CAN HMX ENTER AND LEAVE MY BODY?

HMX can enter your body if you breathe contaminated air, swallow contaminated water or soil, or get substances that contain HMX on your skin. Very little is known about how much and how fast HMX enters your body after you are exposed.

Limited information from laboratory studies in animals suggests that if you swallow HMX, only a small amount (less than 5 percent) will be absorbed into your blood. The rest of the HMX that is not absorbed leaves your body in your feces, usually within a day or two after you are exposed. Your blood carries the small amount of absorbed HMX to your tissues. Animal studies suggest that the

resulting concentrations of HMX in your lungs, liver, heart, and kidneys may be slightly higher than the concentrations in other tissues

HMX does not remain in any of your tissues for very long Information from animal studies suggests that your body can transform HMX into other compounds called metabolites. At present, the identity and toxicity of these metabolites are not known Most of these metabolites leave your body in your urine, usually within a few days after you are exposed Smaller amounts of these metabolites may be released in your feces or in the air you breathe out

More information on how HMX enters and leaves your body is in Chapter 2

1.5 HOW CAN HMX AFFECT MY HEALTH?

Information on the adverse health effects of HMX is limited In one human study, no adverse effects were reported in workers exposed to HMX in air However, the concentrations of HMX in the workplace air were not reported in this study, and only a small number of workers and effects were investigated.

Studies in rats, mice, and rabbits indicate that HMX may be harmful to your liver and central nervous system if it is swallowed or gets on your skin. The lowest dose producing any effects in animals was 100 milligrams per kilogram of body weight per day (mg/kg/day) orally and 165 mg/kg/day on the skin Limited evidence suggests that even a single exposure to these dose levels harmed rabbits The mechanism by which HMX causes adverse effects on the liver and nervous system is not understood.

The reproductive and developmental effects of HMX have not been well studied in humans or animals At present, the information needed to determine if HMX causes cancer is insufficient Due to the lack of information, EPA has determined that HMX is not classifiable as to its human carcinogenicity

More information on how HMX can affect your health is in Chapter 2.

1.6 IS THERE A MEDICAL TEST TO DETERMINE WHETHER I HAVE BEEN EXPOSED TO HMX?

You can find out if you have been exposed to HMX by having your blood, urine, or feces tested for HMX Since HMX is poorly absorbed after it is swallowed, the levels of HMX in your blood and urine are likely to be lower than those in your feces For best results, tests for HMX should be done within a few days after you are exposed These tests cannot be used to tell how much HMX you have been exposed to or to predict whether or not you will experience adverse health effects These tests are not usually done in a doctor's office, but require that the samples be sent to a laboratory for testing

More information on medical tests to determine whether you have been exposed to HMX is in Chapters 2 and 6

1.7 WHAT RECOMMENDATIONS HAS THE FEDERAL GOVERNMENT MADE TO PROTECT HUMAN HEALTH?

The federal government has made several regulations and guidelines to protect human health EPA recommends that the concentration of HMX in an adult's drinking water be less than 0 40 milligrams per liter (mg/L) for a lifetime exposure. EPA regulates waste containing HMX as hazardous and has set restrictions on its disposal in landfills The Department of State regulates the exportation of HMX, and the Department of Transportation regulates its transportation The Bureau of Alcohol, Tobacco, and Firearms regulates the importation, manufacture, distribution, and storage of HMX.

More information on government regulations and guidelines for HMX is in Chapter 7

1.8 WHERE CAN I GET MORE INFORMATION?

If you have any more questions or concerns, please contact your community or state health or environmental quality department or:

Agency for Toxic Substances and Disease Registry
Division of Toxicology
1600 Clifton Road NE, E-29
Atlanta, Georgia 30333
(404) 639-6000

This agency can also provide you with information on the location of occupational and environmental health clinics. These clinics specialize in the recognition, evaluation, and treatment of illness resulting from exposure to hazardous substances

EPA United States Environmental Protection Agency
Office of Water

Office of Ground Water and Drinking Water

PERCHLORATE

HEALTH EFFECTS/TOXICOLOGY

Introduction

A significant portion of the expedited research underway to address perchlorate contamination in the environment has been dedicated to obtaining a reliable and comprehensive data base on the health effects and toxicology of perchlorate. Such robust data are necessary to develop a health risk assessment that includes an estimate called a reference dose (RfD) which can be used to evaluate the potential risk of human exposures. The RfD can also be used in risk management programs to help guide the range where analytical methods must be effective and to target treatment technologies. The health effects data serve as the lynchpin in the overall integrated approach to addressing the emerging issues of perchlorate contamination.

Background

The currently available database on the health effects and toxicology of perchlorate or its salts is very limited. The majority of human data are clinical reports of patients treated with potassium perchlorate for hyperthyroidism resulting from an autoimmune condition known as Graves' disease. Potassium perchlorate is still used diagnostically to test thyroid hormone [thyroid stimulating hormone (TSH), triiodothyronine (T3), and thyroxine (T4)] production in some clinical settings. The basis for the effect on thyroid hormone function is the competitive inhibition of iodide anion uptake into the thyroid gland by perchlorate anion (ClO_4^-) which then results in reduced thyroid hormone production.

It is difficult to establish a dose-response for the effects on thyroid function from daily or repeated exposures in normal humans from the data on patients with Graves' disease because of a variety of confounding factors, including: the effect of the disease, that often only a single exposure and not repeated exposures were tested, that only one or two doses were employed, and that often the only effect monitored was iodine release from the thyroid or control of the hyperthyroid state. There are limited data in normal human subjects and laboratory animals that support the effect of perchlorate on thyroid hormones, but the majority of these additional studies suffer from the same limitations with respect to the number of doses and exposures. These limitations prevent establishment of a quantitative dose-response estimate for the effects on thyroid hormones after long-term repeated exposures to perchlorate in

C-81

healthy human subjects.

The typical objective of a health risk assessment is to evaluate a comprehensive array of testing endpoints that represent various life stages in which potential effects could occur, e.g., the developing fetus through adult and for effects on reproductive capability. Thyroid hormone deficiencies, such as those induced by perchlorate, can affect normal metabolism, growth and development. No robust data exist to evaluate other potential target tissues or effects. There are no data to evaluate the effects of perchlorate in potentially susceptible population such as developing fetuses, nor are there data on the effects of perchlorate on reproductive capacity of male or female laboratory animals.

Benign tumors have been reported in the thyroids of male Wistar rats and female BALB/c mice treated with repeated, high dose exposures (2 years at 1,339 and 46 weeks at 2,147 mg/Kg-day, respectively) of potassium perchlorate in drinking water. Benign tumors in the thyroid have been established to be the result of a series of progressive changes that occur in the thyroid in response to interference with thyroid-pituitary homeostasis (i.e., perturbation of the normal stable state of the hormones and functions shared between these two related glands). This progression is similar regardless of the cause of the thyroid hormone interference (Hill et al., 1989; Capen, 1997; Hurley et al., submitted). The EPA has adopted the policy that an assumption of a threshold based on these precursor lesions along the progression is appropriate for the dose-response of chemicals which cause this type of disruption in the thyroid when they do not have genotoxic activity, i.e., cause damage to DNA or show other genetic disruption (U.S. EPA, 1998). Therefore, a dose-response estimate established using the no-observed-adverse-effect level for the precursor lesions should be an estimate also protective for potential benign tumor development. Existing shorter-term studies indicate that perchlorate causes changes in the thyroid typical of the progression described and genotoxic studies are underway to establish that perchlorate does not have any activity relevant to carcinogenicity.

Provisional Health Risk Assessment

The EPA Superfund Technical Support Center issued a provisional reference dose (RfD) in 1992 and a revised provisional RfD in 1995. An RfD is calculated as an estimate of a daily oral human exposure that will result in no deleterious noncancer effects over a lifetime. Ideally, an RfD is based on a database that evaluates an array of endpoints that address potential toxicity during various critical lifestages, from developing fetus through adult and reproductive stages. The provisional RfD values (1992 and 1995) were based on an acute study in which single doses of potassium perchlorate caused the release of iodide from the thyroids of patients with Graves' Disease. The no-observed-adverse-effect-level (NOAEL) was determined to be 0.14 mg/Kg-day based on release of iodine in the thyroid followed by incomplete inhibition of iodine uptake. Uncertainty factors that ranged from 300 to 1000 were applied to account for data missing on additional endpoints and extrapolations required to calculate a lifetime human exposure level. Standard assumptions for ingestion rate and body weight were then applied to the RfD to calculate the reported range in the ground water cleanup guidance levels of 4 -18 parts per billion (ppb). The California Department of Health Services (CA DHS) EXIT EPA adopted 18 ppb as its provisional action level.

The provisional RfD values issued are listed by the EPA only as provisional because they did not undergo the internal Agency and external peer review required of estimates available on the EPA's Integrated Risk Information System (IRIS). The outcome of an external peer review convened in March 1997 of an analogous RfD derivation by an independent organization, Toxicology Excellence for Risk

Assessment (TERA) EXIT EPA, was the determination that the health effects and toxicity data were insufficient for a credible quantitative risk analysis. The external peer review panel concluded that the data were not sufficient to rule out effects of perchlorate on other organs, so that it could not be determined unequivocally that the effects on the thyroid were the critical effect. In particular, the reviewers were concerned that developmental toxicity, notably neurological development due to hypothyroidism during pregnancy, could be a critical effect of perchlorate that has not been adequately examined in studies to date.

New Health Effects / Toxicology Studies Underway

In response to the March 1997 external peer review of the provisional RfD value, a subsequent external peer review of experts was convened in May 1997 to recommend and prioritize a set of studies to address the key data gaps and reduce uncertainties in various extrapolations. The objective of the new studies is to provide a comprehensive database that provides for development of a robust RfD estimate that reduces the uncertainties inherent in the provisional values. Funding for the studies was procured and obligated through a variety of sources, principally the USAF and the Perchlorate Study Group (PSG).(1)

The protocols for the studies were reviewed by external peer reviewers from the EPA, California EPA, academia, industry, private institutes and Health Canada. The timeframe for the development of these new data has been precedent setting and has been a direct result of a unique partnering initiative. Typical research and development mechanisms would have required a number of years to accomplish these same studies.

Eight new studies were recommended in order to provide a comprehensive array of endpoints. These are described below along with their anticipated role in informing the revised health risk assessment.

(1) 90-Day Subchronic Oral Bioassay Study. This study is considered the minimum data requirement for derivation of an oral RfD. The study will identify other target tissues, test young adult rats, and also provide data on the effect of repeated exposure to perchlorate on thyroid hormone levels. These data may also allow reduction of the uncertainty factor applied for database deficiencies.

(2) Neurobehavioral Developmental Study. This study will evaluate the potential for developmental neurotoxicity of perchlorate by assessing functional and morphological endpoints in offspring from mother exposed during pregnancy and lactation. Neurotoxicity endpoints may be a critical effect and the developing organism a sensitive subpopulation. These data may allow reduction of the uncertainty factors applied for intrahuman variability and database deficiencies.

(3) Segment II Developmental Study. This study will evaluate the potential for perchlorate to cause birth defects in rabbits and will identify a potentially critical effect and subpopulation. This study will also provide data on the thyroid hormone effects in a second species (in addition to rats). These data may allow reduction of the uncertainty factor applied for database deficiencies.

(4) Two-Generation Reproductive Toxicity Study. This study will evaluate the potential for perchlorate to cause deficits in reproductive performance in adult rats and for toxicity in the young offspring. This study may identify a potentially critical effect and allow for reduction of the uncertainty factor applied for database deficiencies.

C-83

(5) ADME (Absorption, Distribution, Metabolism, and Elimination) Studies. These studies will be performed to understand the pharmacokinetics (how perchlorate is absorbed, distributed, metabolized and excreted) of perchlorate in test animals and humans. These data will provide information that will allow construction of quantitative extrapolation of dose across species (e.g., rat to human).

(6) Perchlorate Mechanism Studies. These studies will be conducted by a comparison of the existing literature and of new *in vitro* and *in vivo* data that evaluate the effects of perchlorate on the iodide uptake mechanism across species to aid in the quantitative extrapolation of dose.

(7) Genotoxicity Assays. These studies will evaluate the potential for carcinogenicity by evaluating mutations and toxic effects on DNA. These data will be useful to evaluate whether the benign thyroid tumors are likely to be a result of the proposed threshold pathogenesis process.

(8) Immunotoxicity Studies. These studies will evaluate the potential for perchlorate to disrupt immune function and identify a potentially critical effect. These data may help to reduce the uncertainty factor applied for database deficiencies.

Additional work may be required to mathematically model the dosimetry (pharmacokinetics) and toxic effects in order to increase the accuracy of a health risk determination, but this will need to be evaluated as the new data become available. An epidemiological study has been proposed to look at infant thyroid hormone data from mothers who were exposed in their drinking water supplies. The analysis would rely on the dose reconstruction data to the level of either a city or census block and will assume either that all women who lived in that area were exposed to that level of perchlorate or impose standard assumptions from other such studies (e.g., 20% of women drink bottled water). The dose reconstruction of what was in the water would have to be constructed on occurrence data once the hydrology in the aquifers and transport and transformation processes can be worked out. Both of these studies are considered refinements to the revision of the RfD that will likely result from the new studies.

EPA Plans for Revised Health Assessment and Peer Review

Revised Health Risk Assessment

The National Center for Environmental Assessment (NCEA) in the Office of Research and Development (ORD) of the EPA plans to evaluate the health effects and toxicology data fromthese new studies and then issue a new assessment at the end of September 1998. The new assessment, all the new data, and the study protocols will then be subjected to an external peer review in November 1998 before the assessment is finalized. The assessment, data, and protocols will be available to the public at the time of release to external peer review.

Once finalized, this new peer-reviewed health assessment and new oral RfD will serve as a more robust health effects estimate than the existing provisional values with which to evaluate exposure estimates in order to characterize potential risk from perchlorate contamination or with which to develop guidance levels for cleanup and to target treatment technologies.

External Peer Review of Revised Assessment

Independent, external peer review of the study protocols, toxicity studies, and revised reference dose and health assessment for perchlorate will be critical to ensuring that future decisions based on the RfD will be protective of human health. EPA's Office of

Solid Waste and Emergency Response (OSWER) will task a qualified contractor to manage peer review of technical issues related to the development of the reference dose, including study design, conduct of toxicity studies, statistical treatment of data, selection of critical effect, selection of uncertainty factors and risk characterization. The peer review will be conducted by a panel of technical experts in developmental toxicology, reproductive toxicology, genetic toxicology, general toxicology, pathology, biostatistics, dose-response modeling and risk assessment. Peer reviewers will be selected from a pool of candidates nominated by stakeholders in the perchlorate issues. The RfD assessment package, supporting studies, and study protocols for the new data will be distributed to the peer review panel in advance of the peer review meeting. Peer reviewers will independently review the RfD assessment package and supporting studies, and will submit their written comments to OSWER's contractor prior to the peer review meeting. The peer reviewer's comments will be compiled by OSWER's contractor and will be distributed to all of the peer reviewers and the public in advance of the meeting. The peer reviewers will gather for a two day meeting in a location selected based on accessibility to stakeholders and the peer reviewers. The public will be invited to attend and observe the peer review meeting. Following the peer review meeting, the peer review panel will generate a report detailing their comments on the reference dose package and supporting studies. EPA NCEA will generate a responsiveness summary report which will discuss in detail how they will address the comments raised by the peer reviewers. The provisional reference dose will subsequently be issued by EPA.

For more information on this topic, please refer to speaker's presentations *from the Perchlorate Stakeholder's Forum, held May 19-21, 1998*

ECOLOGICAL EFFECTS

Background

Perchlorate salts are quite soluble in water. The resultant anion (ClO_4^-) is exceedingly mobile in aqueous systems and can persist for many decades under typical groundwater and surface water conditions, due to kinetic barriers to its reactivity with other available constituents. This mobility and persistence may pose a threat to ecological receptors and whole ecosystems, either by direct harm to organisms, or it may indirectly affect their ability to survive and reproduce.

Currently, there are no data to evaluate the effects of perchlorate on ecological systems nor is there data about the possible uptake of perchlorate into agricultural products through irrigation of the food crops. Analytical tests have been derived to detect perchlorate in water, but little is known about testing food crops for perchlorate.

This fact sheet will describe historical studies of perchlorate on non-human receptors. Next, it will present tests proposed by the U.S. Environmental Protection Agency (EPA) and the U.S. Air Force (USAF) to address the current gaps in knowledge. The information gained from these screening-level tests will be used to support recommendations for further studies. Lastly, this fact sheet will outline the effort by the USAF to determine fate and transport of ammonium perchlorate in the environment.

Historical Studies

Searches of available databases have revealed minimal information on the ecological effects of ammonium perchlorate or any of its other salts. Little data exist to describe its effects on various soil, sediment or aquatic receptors including: aquatic

C-85

vertebrates, aquatic or sediment invertebrates, bacteria or plants. The data that is available suggest effects on thyroid-hormone mediated development in the South African clawed frog, *Xenopus laevis* in the range of 50-100 parts per million (ppm); and 1000 ppm in recent studies has been shown to completely block the metamorphosis of tadpoles. Effects on development and population growth have also been indicated in the freshwater sea lamprey at 100 ppm and the freshwater hydra at 350 ppm. Mortality was observed in cold water trout (6000-7000 ppm) and *Daphnia magna* (670 ppm). Effects on seed germination and growth of agricultural plants were reported at 10 ppm.

Proposed Activities

The USAF/Detachment 1, Human Systems Center, Brooks AFB, in conjunction with EPA, has developed a proposal for a battery of screening level bioassays in laboratory-reared organisms representative of ecological receptors across soil, sediment, and water column receptors to evaluate dose-response relationships. The identified tests focus on identifying gross (direct) toxicity tests whose endpoints can include mortality, growth, and reproductive success. Dose response relationships can be evaluated.

In general, the tools used to evaluate chemical effects on soil and benthic invertebrates, plants, and fish include benchmark values, toxicity tests, bioaccumulation estimates, and field studies. In the absence of accepted benchmark values, a tiered approach to a toxicity assessment of effects on ecological receptors is suggested. The purpose of a tiered approach is to do necessary and sufficient amount of work to characterize risk to an ecological receptor with an acceptable degree of uncertainty. In this approach to describe ecological impact of perchlorate, Tier 1 included the literature search described under Historical Studies. Tier 2 will include the tests shown below. If significant toxicity is demonstrated in a suite of bioassays more sophisticated assessments can be implemented. Bioassays with standard protocols and general regulatory acceptance were chosen.

Proposed tests include:

Test Organism	Matrix
Daphnia magna	Sediment invertebrate
Lactuca sativa (lettuce)	Vascular plant
Pimephales promelas Fathead minnow	Aquatic vertebrate
Eisenia foetida Earthworm	Soil invertebrate

This battery of tests has been reduced from the original list presented at the Perchlorate Stakeholders Forum in Henderson, Nevada, May 19-21, 1998. Initially, seven tests were suggested, including the vascular plant Lemna minor (duckweed). However, based on stakeholder input and the need for a more focused battery of tests, the above four tests have been selected for the first round of testing. Lettuce was substituted for the duckweed because of Tribal concerns regarding the sizable lettuce crop al ong the Colorado River

Although these are screening level tests and only give us an idea of gross toxicity, they will provide needed dose-response information to make decisions on the need for the next tier of tests (Tier 3) to be completed as required (e.g., bioavailability, bioaccumulation, histopathology, etc.).

Transport and Transformation:

The USAF has begun to determine the transport and transformation (also called fate and transport) of ammonium perchlorate in the environment. This information can be used to predict the flow of perchlorate in the subsurface. Currently, a literature search has been completed which describes fate and transport of ammonium perchlorate in the subsurface. The study identifies and assesses factors such as solubility, adsorption, biodegradation, chemical reactions, dispersion, diffusion, and other processes affecting fate and transport of perchlorate.

The literature shows perchlorate to be non-volatile, so inhalation of perchlorate vapor is not expected. However, perchlorate salts do exhibit high solubility in water, which leads to high mobility in surface water and groundwater. Its density is nearly twice that of water, so it will sink in water. Concentrated solutions are also more dense than water. Because perchlorate salts are so soluble, perchlorate ion will predominate in solution. However, potassium is less soluble than ammonium, so it is possible that potassium perchlorate may precipitate ("salt-out") of solution, decreasing migration

Perchlorate is a kinetically stable ion, which means that reduction of the chlorine atom from a +7 oxidation state in perchlorate to a -1 oxidation state as a chloride ion does not occur spontaneously--it would require a input of energy (e.g., heat or light) or the presence of a catalyst to help the reaction occur.

Dilution and precipitation reactions are presumed to have the most significant effect on perchlorate migration. Through dilution, concentrations would be expected to be significantly less away from the source. Precipitation, can help decrease mobility of perchlorate, but the salt can then re-dissolve, be transported, and precipitate repeatedly. Sorption is not expected to attenuate perchlorate since it absorbs weakly to most soil minerals. Since perchlorate in chemically stable, natural chemical reduction in the environment is not expected to be significant. The treatment technology subcommittee of the Interagency Perchlorate Steering Committee (IPSC) is examining biological reduction of perchlorate.

Based on the information gathered in this literature review, recommendations have been made for a second phase to fill many of the gaps in the current understanding of perchlorate transport and transformation. This will help develop models to predict and describe perchlorate migration in the subsurface

For more information on this topic, please refer to speaker's presentations*from the Perchlorate Stakeholder's Forum, held May 19-21, 1998*

EPA Region 9 Perchlorate Update

U.S. ENVIRONMENTAL PROTECTION AGENCY • REGION 9 • 75 HAWTHORNE STREET • SAN FRANCISCO, CA • JUNE 1999

The U.S. Environmental Protection Agency (EPA) has been working in partnership with states, federal agencies, tribes, water suppliers and the private sector to address a recently discovered threat to water supplies from a component of solid rocket fuel and other sources. The Interagency Perchlorate Steering Committee (IPSC) is co-chaired by the EPA and the Department of Defense (DoD) and is comprised of representatives from 19 state, federal, and tribal agencies.

Background

Perchlorate originates as a contaminant in the environment from the solid salts of ammonium, potassium, or sodium perchlorate. The perchlorate part of the salts are quite soluble in water. The resultant anion (ClO_4^-) is very mobile in aqueous systems. It can persist for many decades under typical groundwater and surface water conditions, because of its resistance to react with other available constituents.

Ammonium perchlorate is manufactured for use as the oxidizer component and primary ingredient in solid propellant for rockets, missiles, and fireworks.

Large-scale production began in the United States in the mid-1940s. Because of its shelf life, it must be periodically washed out of the country's missile and rocket inventory and replaced with a fresh supply. Thus, large volumes of the compound have been disposed of since the 1940s in Nevada, California, Utah, and likely other states. Perchlorate salts are used on a large scale as a component of air bag inflators. Ammonium perchlorate is used in the manufacture of matches and in analytical chemistry.

Other uses of perchlorate salts include their use in nuclear reactors and electronic tubes, as additives in lubricating oils, in tanning and finishing leather, as a fixer for fabrics and dyes, in electroplating, in aluminum refining, in rubber manufacture, and in the production of paints and enamels. Chemical fertilizer also has been reported to be a potential source of perchlorate contamination.

The EPA had established a provisional reference dose (RfD) range based on assessments of existing information in 1992 and revised in 1995. By applying the standard default body weight (70 kg) and water consumption level (2 L/day), the resulting provisional cleanup or action levels would range from 4-18 parts per billion (ppb).

Prior to April 1997, perchlorate could not be detected at concentrations below 100 ppb. Many uncertainties remained about its toxicity, about how to remove it from water, or how extensive a problem perchlorate might pose to water supplies. In April 1997, the California Department of Health Services (CA DHS) developed a new analytical method to detect low levels of perchlorate (4ppb) in water. Within the last two years, this chemical has been found in the water supplies of over 15 million people in CA, NV and AZ and in surface or groundwater throughout the United States (AR, IA, IN, KS, MD, NM, NY, PA, TX, UT, WV).

Perchlorate is of concern because of: 1) Potential health effects at low concentrations; 2) the possibility that perchlorate may be widespread in the environment; 3) the expense of removing perchlorate from water and soil; and 4) the effects that perchlorate may have on ecosystems.

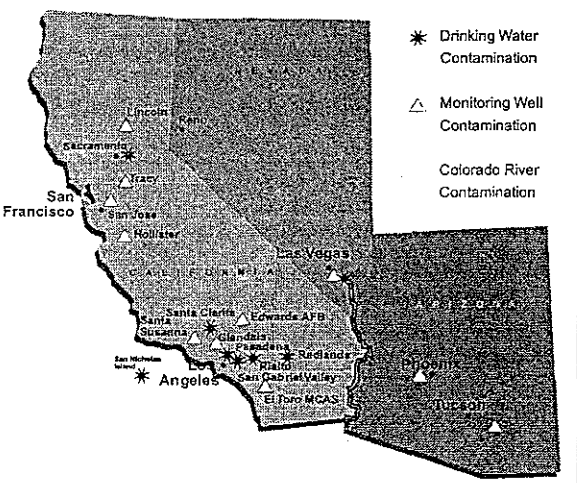
Research has been carried out at an accelerated pace to better understand the human health effects of perchlorate, examine possible ecological impacts, refine analytical methods, develop treatment technologies, and increase occurrence data, while keeping stakeholders informed and involved.

Toxicology

The EPA held an external peer review of the document entitled 'Perchlorate Environmental Contamination: Toxicology Review and Risk Characterization" on February 10-11, 1999 in San Bernardino, CA which was open to the public. The external review document (ERD), was developed by the EPA's Office of Research and Development, National Center for Environmental Assessment (ORD/NCEA). The ERD presented an updated human health risk assessment as well as a screening-level ecological assessment of newly performed studies on the toxicity of perchlorate. The updated human health risk assessment model harmonizes noncancer and cancer approaches to derive a single oral risk benchmark for perchlorate. The proposed revised oral human health risk benchmark is 0.0009mg/kg-day. The proposed revised oral risk benchmark is an estimate of the amount of perchlorate, which when ingested daily over a lifetime is anticipated to be without adverse health effects (both noncancer and cancer) to humans, including sensitive subpopulations. Finalizing the oral risk benchmark requires completion of additional toxicology studies and further evaluation of toxicology results.

The EPA has committed to another external peer review as part of the process to more completely and accurately characterize the human and ecotoxicological risks associated with perchlorate contamination. In the next assessment, NCEA will address comments

Figure 1: Perchlorate Occurrences in EPA Region 9



C-88

made in the external peer review report, as well as review and incorporate data from additional studies that were either nearing completion or recommended at that time. The purpose of the next external peer review will be to evaluate these additional data and to review the final draft NCEA assessment on perchlorate. All of the perchlorate testing and study activities, whether underway, in review, or planned, are being timed to support the goal of the next external peer review in early 2000.

Because new analyses and data are to be considered, the human and ecotoxicology benchmarks are likely to change. The new estimates will reflect greater accuracy and may be either higher or lower than the harmonized benchmark proposed in the ERD. The Office of Research and Development has recommended that the EPA's risk assessors and risk managers continue to use the standing provisional reference dose (RfD) range of 0.0001 to 0.0005 mg/kg-day because of continued uncertainty with respect to the impact of the pending data and analyses. This recommendation helps to ensure that the EPA bases its risk management decisions on the best available peer reviewed science and is in keeping with the full and open participatory process of the series of external peer review workshops. The standing provisional RfD range is the more conservative of the estimates available at this time and, therefore, more likely to be protective of public health. This is also consistent with the EPA's practice that existing toxicity estimates remain in effect until the review process to revise them is completed.

Regulatory/Federal

There is currently no federal National Primary Drinking Water Regulation for perchlorate. It is on the EPA's Safe Drinking Water Act's Contaminant Candidate List, but before a determination to regulate can be made, data gaps must be filled regarding occurrence, health effects, treatment technologies, and analytical methods. Finding these answers for perchlorate is a very high priority.

Following the establishment of a final harmonized oral human health risk benchmark for perchlorate, the EPA will develop a drinking water Health Advisory. Based on the current proposed revised oral risk benchmark, and standard default body weight (70 kg) and water consumption (2 L/day) values, a drinking water equivalent level (DWEL) would be calculated at 31.5 ppb. It is important to recognize that the DWEL is a level that assumes all perchlorate exposure comes from drinking water and does not take into account the contribution of perchlorate from other sources, which will be considered in developing a Health Advisory.

Regulatory/States

In 1997, California established an action level of 18 ppb for perchlorate in public water supplies. Legislative action to establish a state drinking water standard for perchlorate was passed in 1998 (CA Senate Bill 1033) but was vetoed by the governor. In January 1999, CA DHS adopted a regulation identifying perchlorate as an unregulated chemical for which monitoring is required. Certain drinking water systems will need to sample their drinking water sources for perchlorate.

In August 1997, the Nevada Division of Environmental Protection (NDEP) selected 18 ppb as the recommended action level for cleanup pending a more current risk assessment.

In March 1999, the Arizona Department of Health Services set a provisional Health Based Guidance Level of 31 ppb.

Texas has decided to use 22 ppb as an "interim" action level for perchlorate in drinking water.

No other state is known to have adopted action levels for perchlorate.

Figure 2: States With Identified Perchlorate Manufacturers or Users

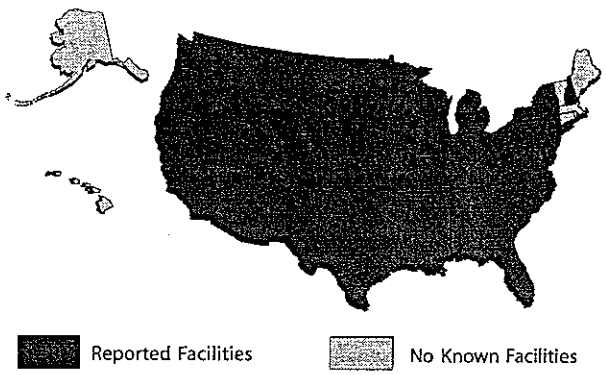
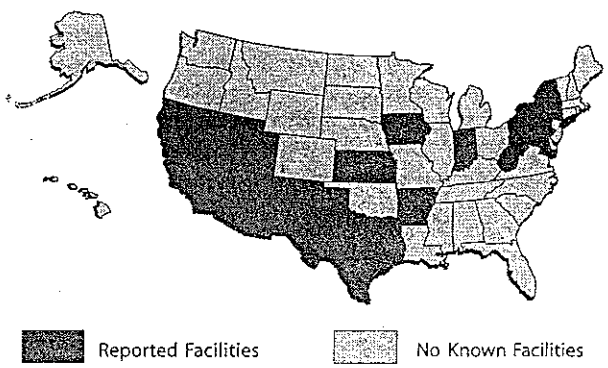


Figure 3: States with Environmental Releases of Perchlorate



Colorado River

Perchlorate concentrations at the Metropolitan Water District's (MWD) water intake at Lake Havasu, CA have averaged 6 ppb for the last two years (range 5 to 9 ppb). Arizona's Central Arizona Project (CAP) also takes water from Lake Havasu. Perchlorate concentrations in Lake Mead, at the water intake for the city of Las Vegas, have varied from less than 4 ppb to 16 ppb. The EPA is working with the NDEP to clean up the source of the perchlorate in Henderson, NV, and is monitoring the river for perchlorate in collaboration with the U.S. Geological Survey, adjacent states and other agencies.

Groundwater

In California, 140 public water supply wells have reported perchlorate above 4 ppb. Water suppliers have shut down wells or blended water so that they are providing water which does not exceed the California action level of 18ppb. In EPA Region 9, we know of 19 separate releases of perchlorate to the environment affecting 3 states, 11 tribes and perhaps Mexico.

Treatment Technologies

In the two years since perchlorate was discovered in water supplies in California, Nevada, and Arizona, much progress has been made in developing treatment methods capable of removing perchlorate from water. Most of the attention has been directed at two technologies: biological treatment and ion exchange.

Biological Treatment

In the biological treatment process, microbes destroy perchlorate by converting the perchlorate ion to oxygen and chloride. In most cases,

nutrients must be added to sustain the microbes. A six month pilot-scale study of a biological process has been completed for the San Gabriel Valley Superfund Sites, demonstrating the reduction of perchlorate from approximately 75 ppb to below detectable levels. The same process is being used in a recently-constructed full-scale system at the Aerojet Superfund Site in Northern California, where perchlorate concentrations exceed 1,000 ppb. A biological process has also been used to treat perchlorate-contaminated wastewaters resulting from the manufacture and maintenance of rocket motors, where perchlorate concentrations may exceed 500,000 ppb.

Biological treatment methods are believed to be capable of producing potable water, but additional testing must be completed to determine whether a biological process can reliably and cost-effectively produce drinking water quality water. The necessary tests are planned for later this year, when a 500 gallon per minute biological treatment system designed to produce potable water for use in the San Gabriel Valley should be in operation. The treatment system is expected to include a biological reactor, followed by a biologically-active multimedia filter and granular activated carbon (GAC) polishing treatment. Biological treatment methods are new to many water utilities, but biologically-active filters have been used in drinking water treatment for decades to help remove particles and biodegradable organic matter. The treatment train to be used in the San Gabriel Valley project will rely on biological treatment for primary removal of perchlorate, and is expected to include GAC as a backup process capable of limited perchlorate removal.

Ion Exchange

The second of the two perchlorate-removal technologies receiving the most attention is ion exchange, in which the perchlorate ion is replaced by chloride, a chemically similar but nontoxic ion. Ion exchange processes have been used in homes and businesses for water softening for decades. Bench-and pilot-scale studies have demonstrated that ion exchange systems can reliably reduce perchlorate concentrations in San Gabriel Valley groundwater from approximately 75 ppb to below detectable levels. The studies have also provided valuable information on resin selection and regeneration, brine production, and cost that will guide the design and operation of full scale systems. By Summer 1999, a 2500 gallon per minute ion exchange system is expected to be online producing potable water for use in the San Gabriel Valley.

The principal disadvantage of ion exchange systems is that they produce a concentrated brine that requires disposal and/or further treatment. Research is underway to try to identify methods of reducing the volume of perchlorate-contaminated brines to reduce the high cost of disposal.

Two other technologies have also been demonstrated capable of removing perchlorate, but probably at higher cost. Reverse osmosis and nanofiltration were tested by researchers at the Metropolitan Water District of Southern California and shown to be effective in removing perchlorate, but they are likely to be much more expensive to operate than ion exchange processes. Liquid phase GAC also removes perchlorate, but only for a limited period of time before regeneration or replacement of the carbon is required. Frequent carbon replacement would make relying solely on GAC for perchlorate removal very expensive. Perchlorate cannot be removed from water by conventional filtration, sedimentation, or air stripping technologies.

In the next two years, the results of perchlorate treatment research funded by a $2 million Federal appropriation to the American Water Works Association Research Foundation (AWWARF) will be available. AWWARF is funding studies into biological treatment methods, ion exchange, reverse osmosis, nanofiltration, and other processes. The results of the AWWARF research should allow more efficient design and operation of ion exchange and biological treatment processes, and may identify other technologies capable of more cost-effectively removing perchlorate from water.

The "best" technology for removal of perchlorate will probably vary from site to site. By the end of 1999, it is likely that full scale ion exchange and biological treatment systems will have been constructed and begun operation, providing cost and performance data that will be available to help others choose the best technology for their site. The results from recent and ongoing studies will be of use to water utilities in need of reliable, easy-to-operate treatment methods that can reliably reduce perchlorate concentrations to low or non-detectable levels, and in the remediation of non-potable contaminated groundwaters.

Analytical Issues

Ion chromatography (IC) is the state-of-the-art analytical method for the measurement of perchlorate in water. Federal, state, and private laboratories collaborated to study the existing IC method and its variations. The study design evaluated the within laboratory precision (repeatability), between laboratory precision (reproducibility), method accuracy (bias), detection limit, and sensitivity of the method. The results of this collaborative study will help focus future research and method development.

An increasing number of commercial and government laboratories are capable of low level perchlorate analysis, leading to further discoveries of perchlorate contamination. Development of a formal published method documenting the reproducibility and limitations of the technique is expected to facilitate the acceptance of perchlorate testing at low concentrations by laboratories across the country. The need for a reporting limit of 4 ppb taxes the sensitivity and reproducibility of the current IC method. Work is also being planned to develop different analytical techniques to confirm the results of the IC method.

Interagency Perchlorate Steering Committee (IPSC)

The Interagency Perchlorate Steering Committee (IPSC) was formed in January 1998 and now has representatives from 19 different government agencies. Its purpose is to ensure an integrated approach to addressing perchlorate issues and to inform and involve stakeholders about developments in the technical and regulatory arenas. Four EPA representatives serve on the Executive Committee of the IPSC and EPA representatives serve on all of the subcommittees of the IPSC (health effects/toxicity, ecological impacts/transport and transformation, occurrence, treatment technology, analytical, communications and outreach, and external peer review). The initial toxicological assessment effort for perchlorate was accomplished in an extraordinarily expedited time frame through the partnership of the IPSC membership.

As of June 1999, the following agencies are members of the IPSC: U.S. Environmental Protection Agency, Department of Defense, Agency for Toxic Substances and Disease Registry, National Institute for Environmental Health Sciences, National Aeronautics & Space Administration, Bureau of Indian Affairs, Arizona Department of Environmental Quality, Arizona Department of Health Services, California Department of Health Services, National Park Service, Nevada Division of Environmental Protection, Texas Natural Resource Conservation Commission, Utah Department of Environmental Quality, Utah Department of Health Laboratories, Cocopah Tribe, Colorado River Indian Tribes, Fort Mojave Tribe, Chemehuevi Tribe, Quechan Tribe.

U.S. Environmental Protection Agency World Wide Web Sites

EPA Perchlorate Web site:
http://www.epa.gov/ogwdw/ccl/perchlor/perchlo.html

NCEA External Review Document:
http://www.epa.gov/ncea/perch.htm

Other Region 9 World Wide Web Sites

California Department of Health Services:
http://www.dhs cahwnet.gov/ps/ddwem/chemicals/perchl/perchlindex.htm

Arizona Department of Environmental Quality:
http://www.adeq state az.us

Nevada Division of Environmental Protection:
http://www state nv.us/ndep/

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Drinking Water Issues
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***Press inquiries: Lois Grunwald,**
Office of Communications &
Government Relations
Tel: 415-744-1588

A number of documents related to perchlorate are indexed and available from the EPA's Region 9 Superfund Records Center, located at 95 Hawthorne Street in San Francisco, CA. The Superfund Records Center is open from 8:00 a.m. to 5:00p.m., Monday through Friday. For more information on document availability, contact the Superfund Records Center at 415-536-2000 or Catherine McCracken at 415-744-2182 or 800-231-3075 (toll-free from AZ, CA, HI, NV, and the U.S. Territories only).

U.S. Environmental Protection Agency, Region IX
75 Hawthorne Street (SFD-3)
San Francisco, CA 94105
Attn: Catherine McCracken

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HEALTH EFFECTS OF TEAR GAS

ACUTE EFFECTS

CS, or tear gas, is a clear white solid, which when burned creates a colorless gas with an acrid pepperlike smell, immediately irritating to the eyes and upper respiratory tract. The chemical name is *o*-chlorobenzlidene malonitrile. In heavy concentrations, CS creates nausea that leads to vomiting and sometimes convulsions. Exposure to CS also quickly leads to shortness of breath, thus causing a victim to inhale a lot of the vapor mass. Nausea and the illusion of suffocation typically cause a feeling of dizziness or a "swimming" sensation, so victims unused to tear gas commonly appear highly disoriented.

CHRONIC EFFECTS

DTSC thus far has not been able to locate information describing long term effects of tear gas due to exposure to low concentrations. We will continue to look to find out if such studies are available. However, the tear gas containing materials in the Landfill and at SWMU #9 will be excavated and hauled off site; thus, future users of the site will not be exposed to tear gas residues.

Attachment D

Memo by Paul Carpenter, R.G.

Department of Toxic Substances Control

Edwin F. Lowry, Director
400 P Street, 4th Floor, P.O. Box 806
Sacramento, California 95812-0806

Gray Davis
Governor

M E M O R A N D U M

TO: Christine P. Brown
Geology and Corrective Action Branch
Southern California Region, Cypress Office

Original contains signature

FROM: Paul Carpenter, R.G.
Hazardous Substances Engineering Geologist
Hazardous Waste Management Program
Geologic Services Unit

Original contains signature

CONCUR: Brian Lewis, CEG, CHG
Hazardous Substances Engineering Geologist Supervisor I
(C.E.G. No. 1414)
Permitting and Enforcement
Geologic Services Unit

DATE: July 13, 2000

SUBJECT: REVISED RESPONSES TO PUBLIC COMMENTS REGARDING GEOLOGY, HYDROGEOLOGY, AND SAMPLING AT THE AEROJET CHINO HILLS FACILITY, CHINO HILLS, CALIFORNIA

Per your request, I have revised the memorandum *Response To Public Comments Regarding Geology, Hydrogeology, And Sampling At The Aerojet Chino Hills Facility, Chino Hills, California*, dated October 20, 1999, to include new and updated information. The responses address both general and specific questions from the public comment package you provided to GSU. Responses to specific questions are referenced to their corresponding page number in the comment package. If you have any questions, please contact me at (916) 323-3636.

RESPONSES TO GENERAL COMMENTS

The Nature of Impacted Groundwater at the Facility

The investigations of the inactive Aerojet Chino Hills facility, which have been reviewed by DTSC, concluded that there are two documented locations where groundwater has been impacted by facility operations and one location where groundwater is likely to have been impacted. Groundwater in these areas (which are discussed separately below) has been impacted by dissolved chemicals which are the products of explosives and ordnance testing; the three chemicals that are of chief concern are HMX, RDX, and perchlorate. This impacted groundwater is at shallow levels (0-60 feet deep), occurs in loose deposits of sediments which lie on top of dense bedrock, and is localized to the three release areas. DTSC is requiring that the volume of this impacted groundwater be determined to evaluate the appropriate corrective measures.

There is no evidence that impacted groundwater has migrated offsite or to deeper levels in the subsurface, and the site geology indicates that this is highly unlikely. A number of geologic and environmental factors have contributed to this situation, and these are summarized in the June 6, 1996 *RCRA Facility Investigation Report,* which is available in the Chino Hills Public Library. The most critical geologic factors include: 1) bedrock composed of the Puente Formation rocks with low permeability (meaning that water flows and percolates through the rocks very slowly), and; 2) a deep (300 feet or greater) and very discontinuous regional groundwater aquifer which does not produce usable water, and which is geologically isolated (chiefly by contrasting rock types and faulting) from the drinking water aquifers in the nearby Chino Basin.

As indicated above, the dense bedrock material beneath the facility is generally "tight", meaning that it does not transmit water effectively. Where shallow groundwater has been documented to occur, it is generally found at the base of thin, discontinuous zones of loose sediment and soil (called alluvium) which overlie the dense bedrock. The shallow groundwater occurs where rain water and surface water have collected at the contact between the shallow sediments and bedrock. Some minor shallow groundwater also appears to have collected by the same method in small fractures, along bedding planes, and in sandy lenses within the upper few feet of the hard Puente Formation bedrock.

The deep groundwater beneath the Chino Hills (at depths of 300 feet or more) is similarly contained in tight rocks of the Puente Formation. This water is difficult to extract, is of poor quality that prevents its use as drinking water, and it is not hydraulically connected to the drinking water sources in the Chino Basin to the east. Comparisons of the chemistry of this deep water and the shallow groundwater indicate that these two zones are not connected. In the unlikely event that some dissolved explosive compounds reach this deep groundwater, this water cannot effectively migrate, nor can it be extracted for consumptive uses

The difficulty that groundwater encounters in moving away from the impacted areas is illustrated at the Redwater Pond site (which is discussed in detail below). The explosive compounds which have impacted shallow groundwater are highly mobile when dissolved, yet samples from the wells just downslope of the pond show that these compounds have not migrated away from the localized area beneath the former pond Similar investigation at the Upper A-12 site and the Former Landfill will be performed to characterize these areas.

Areas With Documented Groundwater Contamination

Investigations at the facility, as reported in the *RCRA Facility Investigation Report* (dated June 6, 1998) and the *RCRA Facility Investigation Addendum Report* (dated February 10, 1999) have documented only two areas where groundwater has been impacted by explosive compounds. These areas lie beneath the Former Redwater Pond (Solid Waste Management Unit (SWMU) #7) and the Upper A-12 Test Area (SWMU #15).

Former Redwater Pond. The Former Redwater Pond was an unlined pond where runoff water containing low concentrations of dissolved explosive compounds were discharged during facility operations. Groundwater samples were collected in October 1997 from one soil boring located within the former pond, and from two monitoring wells installed approximately 30 and 80 feet from the margins of the pond. Six explosive compounds were detected in shallow groundwater samples collected from depths of 35 feet and 58 feet below ground surface in the boring located in the pond. Two compounds (HMX and RDX) were reported at concentrations up to 4,200 parts per billion (ppb), and four compounds (1,3,5-TNB, 1,3-Dinitrobenzene, 4-Amino-2,6-Dinitrotoluene, and 2-Amino-4,6-Dinitrotoluene) at much lower concentrations (below 15

ppb). No explosives were detected in the samples collected from the monitoring wells located outside and downslope from the pond.

DTSC has reviewed the investigation of the Former Redwater Pond and has concluded that water impacted with explosive compounds has infiltrated directly below the former pond, but has not migrated laterally away from the pond DTSC has also concluded that this limited occurrence of impacted groundwater is not moving through the tight, low permeability rocks and sediments of this part of the Chino Hills, and does not pose a health or environmental hazard in its current location. The only potential pathway for impacted groundwater to flow offsite is for groundwater to discharge into Soquel Canyon Creek and flow off the facility at the southwestern boundary. Water samples have been and will continue to be collected from Soquel Canyon Creek for monitoring the same explosive compounds detected at the former Redwater Pond.

Groundwater impacted with low concentrations of explosive compounds may have infiltrated beneath the former pond to a depths greater than 60 feet (the maximum depth of the October 1997 investigation), but such compounds could not move offsite. All evidence demonstrates that no viable groundwater aquifer exists beneath the facility, and the discontinuous groundwater that is present is at great depth and is not hydraulically connected to any drinking water or surface water sources.

DTSC has required that Aerojet safely remove and treat the impacted shallow groundwater beneath the Former Redwater Pond, and perform further investigation to define the soil beneath the pond that contains explosive compounds. This cleanup and investigation will be performed when impacted soil is removed from the former pond area during the facility cleanup. A DTSC geologist will be present onsite to monitor the cleanup and investigation.

Upper A-12 Test Area. Perchlorate has impacted shallow groundwater at this site The compound was reported at a concentration of 877 parts per billion (ppb) in a shallow (25-30 feet below ground surface) water sample collected in November 1998 from a boring placed in the Upper A-12 Test Area, and at a concentration of 17 ppb in a spring discharging at the western part of the test pad. Rocket motors, propellant, and flares were tested at this area, and soil samples collected in 1998 revealed that

perchlorate had been released into the shallow soil at this test location The highest concentration of perchlorate in a soil sample was reported as 17.7 parts per million (ppm). DTSC has concluded that ponded rain water infiltrated through the perchlorate impacted soil, dissolved the highly soluble compound and collected in the shallow groundwater zone at a depth of 25-30 feet

With the approval of DTSC, Aerojet removed approximately 320 tons of perchlorate impacted soil from the central part of the testing area in November 1998, and the soil was transported to a permitted landfill facility. This was done to minimize additional impacts from perchlorate to both groundwater and surface water runoff from the site.

The depth and lateral extent of perchlorate impact to groundwater beneath the Upper A-12 test area are not yet known. DTSC has required that an investigation be performed to define the extent of groundwater impacted by perchlorate at this site and determine the most feasible method of cleanup. As is the case at the Former Redwater Pond, perchlorate is present in shallow groundwater which is likely localized to the area just below the site. DTSC will require that shallow contamination that is identified be cleaned up.

Based on the results of surface water samples collected in August 1998 from a location in Soquel Canyon Creek immediately downslope of the Upper A-12 site, perchlorate impacted water from this site may have been discharging via a spring into the creek. The investigation will also determine if this is occurring, and if confirmed, DTSC will mandate that Aerojet take measures to protect human health and the environment.

Area With Potential Groundwater Contamination

Former Landfill. DTSC has reviewed the data from the former landfill area and has determined that shallow groundwater may have been impacted by perchlorate. This conclusion is based on the results of surface water samples (specifically sample WG-01-14; see the attached Figure 1 for location) collected from Soquel Canyon Creek in the fall of 1998, and the documented use of the landfill to dispose of materials used in the handling of perchlorate. DTSC will require investigation of these areas, either in conjunction with or following the corrective measures work

at the facility If soil or groundwater beneath the former landfill is found to be impacted by perchlorate, DTSC will require that measures be taken to remove or clean up the contamination.

Potential for Facility Related Impacts to the Chino Hills Drinking Water Supplies

DTSC and the office of the Chino Basin Watermaster assessed the migration potential of groundwater from the Aerojet Chino Hills to the regional Chino Basin drinking water aquifer. The drinking water source is a large hydrologic feature called the Chino Basin, which lies to the east of the Chino Hills (see the attached Figure 2 for location). This basin covers 235 square miles of the upper Santa Ana River watershed, and is one of the largest basins supplying groundwater in Southern California. The Chino Basin consists of loose sediments up to 1,100 feet in thickness. These types of geologic materials store and transmit a large volume of water, unlike the hard bedrock which underlies the Aerojet facility. The majority of water recharging the basin comes from seasonal surface water from the Santa Ana River and its tributaries.

The Chino and Puente Hills lie along the western boundary of the Chino Basin, but are not part of the basin itself (see attached Figure 2). The boundary between the Chino Hills and Chino Basin is defined by geologic faulting and a difference in rock types (hard bedrock in the Chino Hills versus loose sediments in the Chino Basin). Along the western margin of the Chino Basin (near the City of Chino Hills), groundwater flows to the southeast, parallel to southbound Highway 71 Groundwater extracted from the Chino Basin wells near the City of Chino Hills has flowed to these wells from the northwest, which greatly reduces the possibility that any groundwater from the Chino Hills could be mixed into this area of the Chino Basin. In terms of groundwater flow, the Chino Hills drinking water supply wells are therefore "upgradient" of the facility.

The nature of the Chino Basin boundary, the southeastern flow direction of groundwater in the Chino Basin, and the very low volume of groundwater held in the rocks of the Chino Hills all combine to prevent the movement of significant groundwater from the Chino Hills into the Chino Basin near the City of Chino Hills. The *Chino Basin Optimum Basin Management Plan*, dated August 19, 1999, describes the relationship between the Chino Hills and the Chino Basin as follows (page 2-3):

> "Faults are one of the principle agents in the development of the landscape and restriction of groundwater flow in the Chino Basin. The basin is bounded by major fault systems along where the mountains and hills have been uplifted. The faults and groundwater barriers are significant in that they define the external boundaries of the Basin and influence the magnitude and direction of groundwater flow near the boundaries."

To verify that no contaminants impact drinking water supplies in the Chino Basin, the Watermaster conducts regular comprehensive water quality monitoring on samples from all drinking water wells. Phase I of an upgraded water quality monitoring program began in the Basin in July 1999, and a second phase is scheduled to start in July 2002. No contaminants originating from operations at the Aerojet Chino Hills Ordnance Facility have been detected in Chino Basin drinking water wells.

Location of City of Chino Hills Water Supply Wells

The *City of Chino Hills Water Facilities Plan* (July 16, 1996) depicts the locations of existing twelve water production wells and the future wellfield expansion area. All existing and proposed wells lie west of Highway 71 and pump water from the sediments of the Chino Basin. As described above, all of these wells are "upgradient" of the facility, and none pump groundwater which has flowed into the Chino Basin from the Chino Hills. To verify this conclusion, water samples from these wells are tested regularly by the Chino Basin Watermaster.

Miscellaneous Concerns Regarding Groundwater Contamination

A number of miscellaneous questions were raised regarding groundwater contamination during the public comment period. These are addressed individually below:

Alteration of Groundwater Flow by Earthquakes. Like much of Southern California, the Aerojet Chino Hills facility is located in a seismically active area with the potential for substantial ground shaking during an earthquake. Concern was expressed that such shaking could mobilize impacted groundwater and create an increased risk of exposure to humans or the environment. An example was cited from Sleepy Hollow in Long Beach, where an earthquake reportedly caused local hot springs to dry up or increase in discharge.

Seismic shaking has been documented to substantially alter groundwater discharge in situations where groundwater flows in open fractures, poorly consolidated sediments, or karst (cavern-like) settings. These situations are each characterized by extremely high permeabilities (such as open fractures), where earthquakes can collapse or alter the groundwater's large, open flow paths. Most hot springs are found in such settings, simply because hot water from depth can rapidly flow to the surface in an open pathway.

In contrast to these situations, impacted shallow groundwater at the Aerojet facility occurs at the bottom of thin deposits of sediments which overlie bedrock, or in weathered zones within the shallow parts of the bedrock. These deposits (and the bedrock containing the deeper groundwater beneath the facility) lack open flow paths and are not susceptible to dramatic modification by seismic shaking. Therefore, the limited subsurface water flow in these rocks should not be affected. The hard, cemented rocks of the Puente Hills formation are even more resistant to damage from seismic activity.

Seismic shaking may affect the discharge of surface seepages of shallow groundwater, which are observed at a number of locations around the facility (similar to anecdotal Loma Linda situation, cited on p. 217 of the comment package). However, the low volumes of shallow groundwater discharging in these seepages are very difficult to mobilize. In addition, all areas with impacted shallow groundwater will be cleaned prior to site closure until the subject compounds are removed or their concentrations are low enough that any potential seepage of will not be harmful to human health or the environment.

Release of Contaminated Groundwater by Landslides. A concern related to the potential release of contaminated groundwater by landslides was also raised in the comments. The topography and geology of the site give sparse evidence that older landslides have occurred, and indicate a low potential for future landslides. Shallow groundwater could potentially be mobilized and released to the surface by a landslide or slope failure. However, only small volumes of shallow groundwater are present at the facility, and the volume of water potentially released would be extremely small and would not migrate far from the slide. As stated above, areas with impacted groundwater will be remediated before corrective measures are terminated, and will therefore not present a threat of exposure in the event of landslide.

Is Contaminated Groundwater Moving Underground and Leaving the Facility? Impacted groundwater is held in near-surface sediment deposits and in shallow areas of bedrock. There is no evidence or indication that groundwater is flowing offsite via underground pathways at either shallow or deep levels. As addressed above, the geologic setting of the facility indicates such migration would be extremely difficult.

Surface Water

As reported in the *Addendum to the RFI Report*, surface water samples collected at the facility from Soquel Canyon Creek and its onsite tributaries in the Fall of 1998 were found to contain detectable concentrations of three compounds: HMX, RDX, and perchlorate. The results of these samples helped DTSC and the facility constrain the locations of the sources for these compounds to the Redwater Pond, the Upper A-12 test Area, the Landfill, and Area 3, all of which will be investigated and cleanup up during the site closure. These streams are dry for much of the year, and the sampling was performed during the rainy season when the creeks were flowing

Based on the chemical testing results, DTSC required Aerojet to perform both Human Health and Ecological (Wildlife) Risk Assessments for exposure to the three chemicals. These assessments were based on the highest concentrations of the chemicals detected, and assumed potential dermal exposure (contact with skin) and incidental ingestion (such as from swimming) with the surface water. The results of the risk assessment evaluations are shown on page 3-9 of the *Addendum to the RFI Report*. They indicate that the concentrations of chemicals previously reported in surface water are within health and ecological standards.

DTSC will require Aerojet to perform additional surface water sampling to evaluate and monitor the presence of these compounds in surface water, both within the facility and the offsite areas where the surface water flow exits the facility boundary. During cleanup of the facility, DTSC will require engineering controls to be used to protect surface water, and will require sampling to assure that surface water is not further impacted by operations.

RESPONSES TO SPECIFIC COMMENTS

Why use water from Redwater Pond for Dust Control? (P. 23 and p. 27) Water beneath Redwater Pond must be removed during excavation of this area. Because this water does not meet water quality standards, it will not be used for dust control during excavation.

Is it possible to analyze sediment at the bottom of the [Chino Hills State Park, Carbon Canyon Dam Reservoir]? (p. 31) DTSC will carefully evaluate the need to sample stream and reservoir sediments in offsite areas. Onsite testing of stream sediments have not revealed a significant problem with RDX, HMX, or perchlorate. To date, there is no evidence that significant amounts of any harmful compounds migrated to this reservoir

Where are the SW-01-01-0 5 and SW-01-04-0.5 areas? (P. 51) These are two soil samples collected at the Former Burn Area (SWMU #15). The locations are shown in Figure 4-1 in the *RCRA Facility Investigation Addendum Report* (February 10, 1999).

Can the "Walking Beam Well" and the Sikkama Well" be tested for 1,3,5, TNB? (P. 51) Water samples from the "Walking Beam", "Sikkama" wells were tested on October 10, 1997 using EPA Method 8330, which analyzes for explosive chemicals 1,3,5-trinitrobenzene. The tests did not detect any explosive contaminants or perchlorate.

Will removing perchlorate impacted soil be effective at preventing migration of this compound at the facility? (P. 61) Removing perchlorate impacted soil and waste at the facility is the most effective, safe, and permanent method to prevent this compound from dissolving, migrating into Soquel Canyon Creek, and potentially moving offsite.

Will wells at the facility be decommissioned during the closure, and if so will it be done properly? (P. 74) As required under state law, DTSC will consult with the Department of Conservation, Division of Mines and Geology, Department of Water Resources, and county agencies before any wells at the facility are decommissioned. This will be done to assure that all wells are properly sealed and will not be impacted by the site cleanup.

If contamination is hundreds of feet deep, how will it be recovered? (P. 143) There is no evidence that explosive compound contaminants have migrated to any significant depths below the facility. If contamination is determined to have migrated to deep levels, DTSC will evaluate if cleanup is required. The geology of the Chino Hills strongly indicates that contamination cannot migrate to such depths. In the unlikely event that contamination does migrate vertically, the small volume of water present at these depths and the "tight" nature of the rocks makes it very unlikely that water can flow and impact the wells or municipal water supply aquifers in the Chino Basin can be impacted.

Outside the Aerojet Property, what is the radius for testing of runoff pollution ? (P. 152) A water sample was collected approximately 1.75 mile downstream in Soquel Canyon creek (sample WG-01-03a; see the attached Figure 1 for location) No chemicals were detected in this sample.

Will surface water flowing northeast from the facility also be tested? (P. 188)

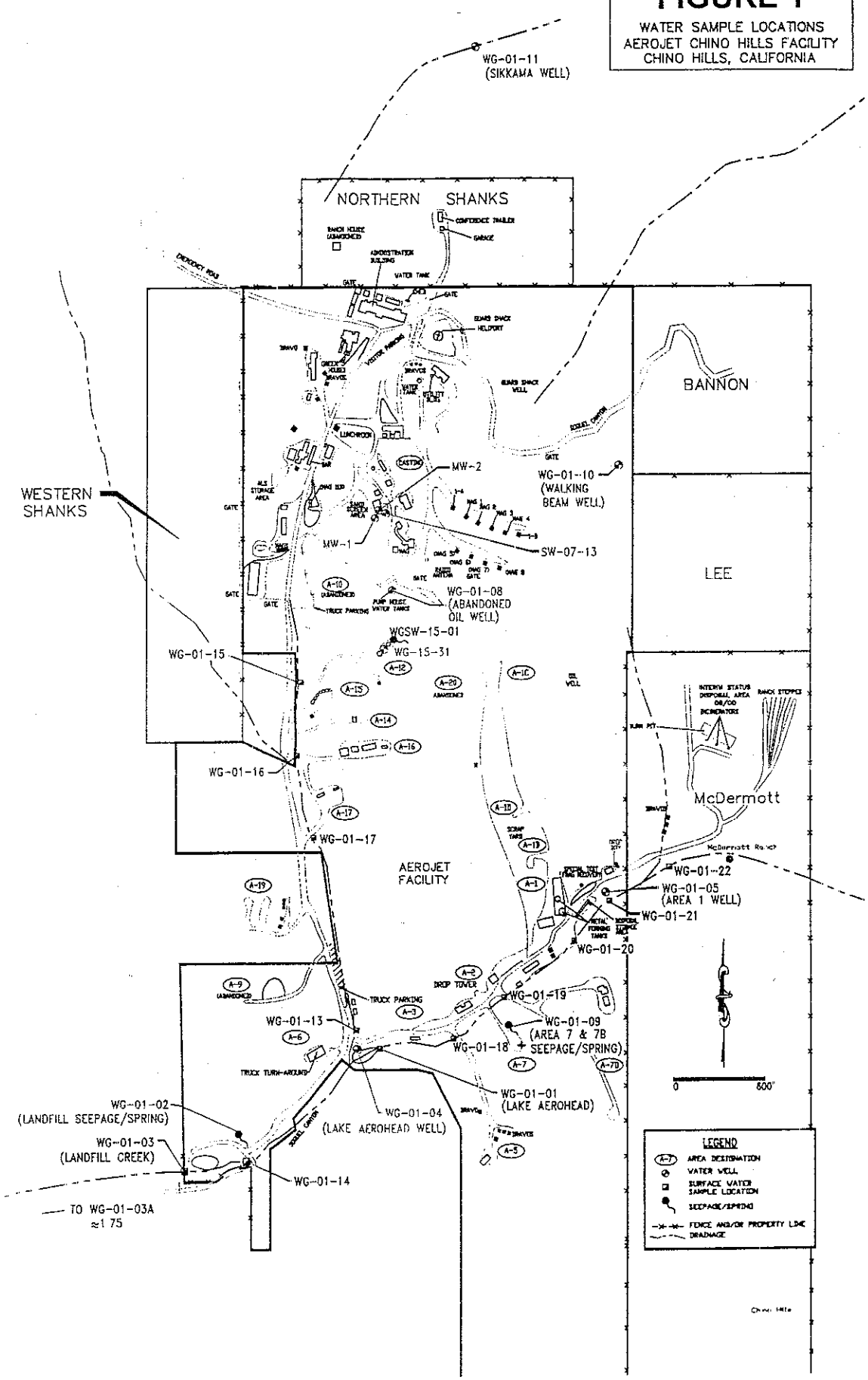
Two streambed soil samples were collected from the two drainage systems flowing northeast of the facility on October 8, 1997 (samples WEST GULLEY and EAST GULLEY in the February 10, 1999 *RCRA Facility Investigation Addendum Report;* see attached Figure 3 for location). No chemical agents, explosive chemicals, or CS were detected in these samples.

What are the Chino Hills and Soquel Canyon Anticlines, and how do they affect the cleanup? Anticlines are geologic structures that occur when flat-lying rock beds are compressed and bent into a fold, similar to the folding that occurs when a floor rug is pushed from both sides and bunches up. These are very common geologic features in Southern California, and there are at least seven mapped anticlines in the Chino and Puente Hills. The Chino Hills and Soquel Canyon Anticlines are two such structures. Anticlines are bedrock features which influence the accumulation of petroleum deposits deep underground. The areas of concern for soil and shallow groundwater at the Aerojet facility are within the

surficial sediments that cover the bedrock. The geologic factors controlling these deposits are the shallow erosional surfaces at the facility and the thickness of the sediments which fill them. These features are not affected by the large scale structures such as the Chino Hills and Soquel Canyon Anticlines.

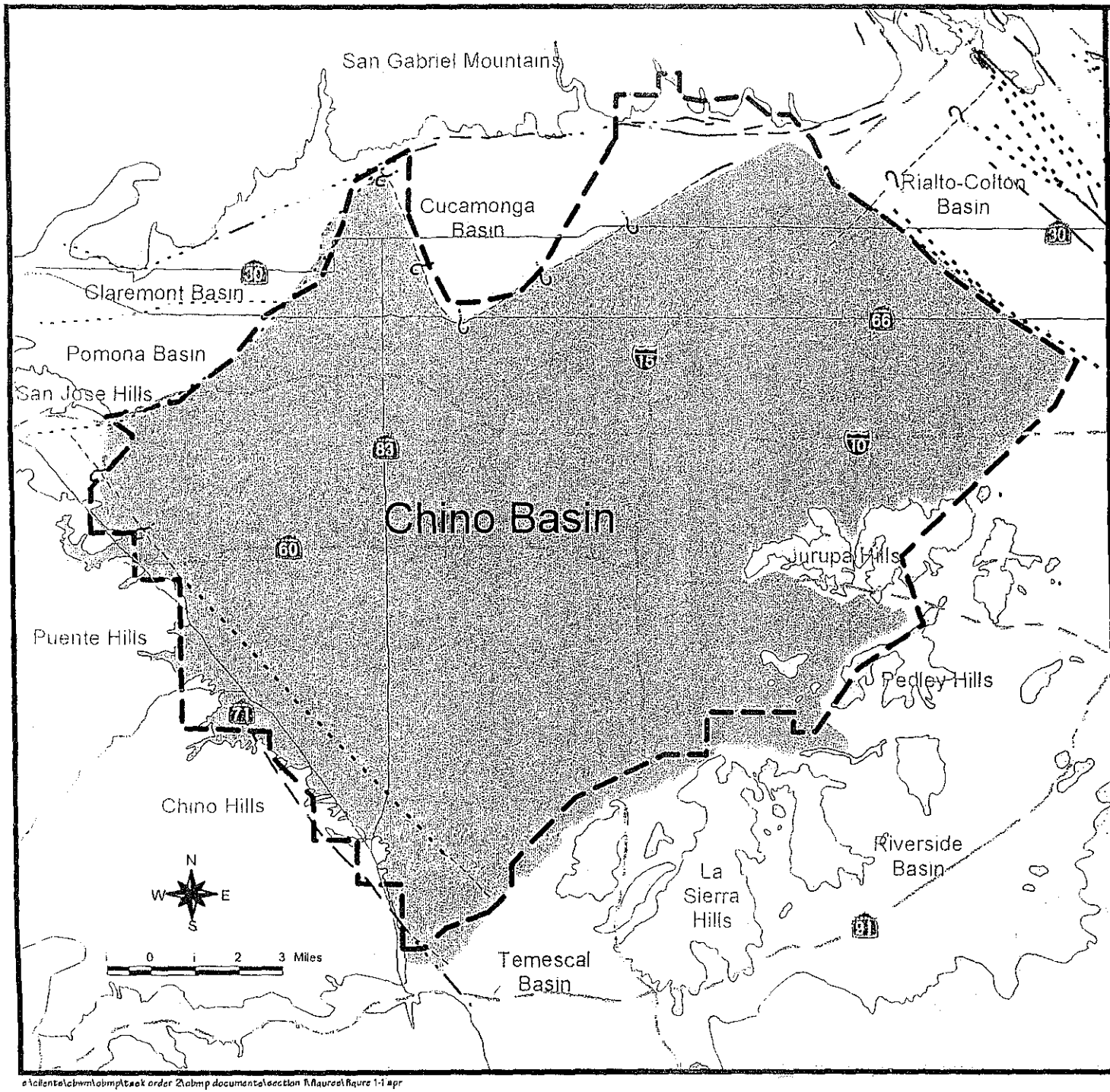
FIGURE 1

WATER SAMPLE LOCATIONS
AEROJET CHINO HILLS FACILITY
CHINO HILLS, CALIFORNIA



McLaren Hart

AERO/AERO_2/V981214e.dwg



Optimum Basin Management Program
Chino Basin Watermaster

Legend

- Chino Basin Adjudicated Boundary
- Hydrologic Chino Basin
- Fault
  - Dashed Where Approximate
  - Dotted Where Concealed
  - Queried Where Uncertain
  - Large Dots Where Groundwater Barrier (Suspected Fault)
- Bedrock

Vicinity Map

FIGURE 2

Chino Basin Hydrologic and Legal Boundaries

WE WILDERMUTH ENVIRONMENTAL, INC.

Date: August 19, 1999

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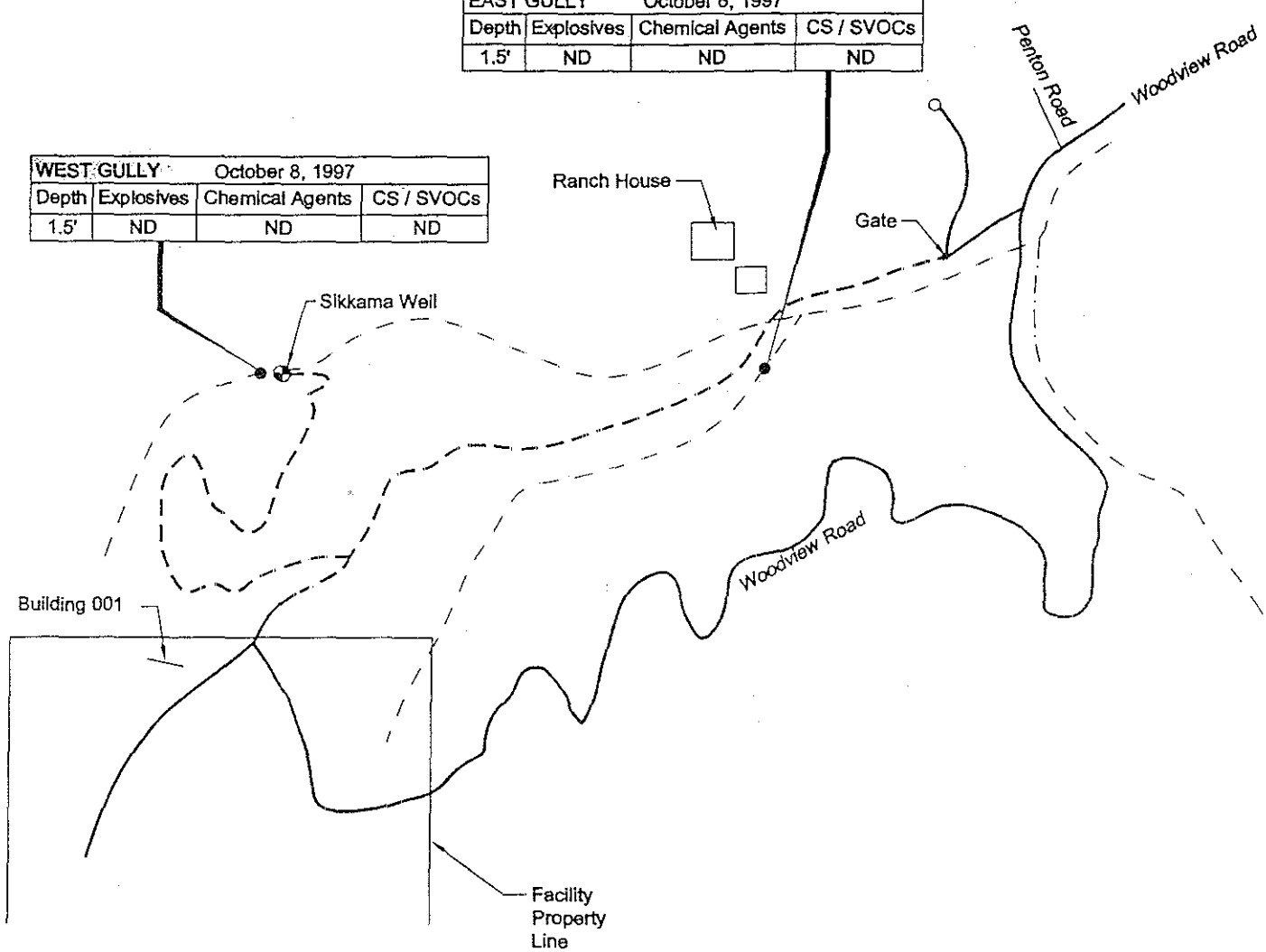
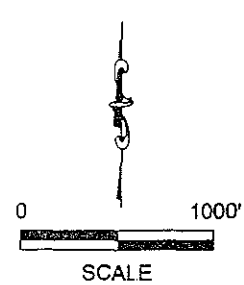
FIGURE 3

OFF-SITE SOIL SAMPLE LOCATIONS
AND ANALYTICAL RESULTS
CHINO HILLS FACILITY
CHINO HILLS, CALIFORNIA

EAST GULLY	October 8, 1997		
Depth	Explosives	Chemical Agents	CS / SVOCs
1.5'	ND	ND	ND

WEST GULLY	October 8, 1997		
Depth	Explosives	Chemical Agents	CS / SVOCs
1.5'	ND	ND	ND





Legend

- Asphalt Road
- Dirt Road
- Gully
- Monitor Well
- Soil Sample Location
- ND Not Detected

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AEROJET\C9902011.dwg (2/11/99)

Attachment E

Excel spread sheet
Air Emissions Calculations
For
Corrective Measures Activities

Emission Factors - Attachment 1

emissions formula: E = EF x H X N

E = Emissions in lb/day

EF = emissions factor = factor * load factor

H = 8 hr/day

N = number of vehicles

excavator

	factor	load	HP	EF	8-hr EF
Reactive organic gases:	0.001	0.58	168	0.09744	0.77952
carbon monoxide:	0.011			1.07184	8.57472
nitrogen oxides:	0.024			2.33856	18.70848
PM10:	0.0015			0.14616	1.16928
SOX:	0.002			0.19488	1.55904

grader

Reactive organic gases:	0.003	0.575	168	0.2898	2.3184
carbon monoxide:	0.008			0.7728	6.1824
nitrogen oxides:	0.021			2.0286	16.2288
PM10:	0.001			0.0966	0.7728
SOX:	0.002			0.1932	1.5456

dozer

Reactive organic gases:	0.002	0.59	285	0.3363	2.6904

carbon monoxide:	0.01			1.6815	13.452
nitrogen oxides:	0.021			3.53115	28.2492
PM10:	0.0005			0.084075	0.6726
SOX:	0.002			0.3363	2.6904

water/dump truck

Reactive organic gases:	0.002	0.41	185	0.1517	1.2136
carbon monoxide:	0.01			0.7585	6.068
nitrogen oxides:	0.021			1.59285	12.7428
PM10:	0.002			0.1517	1.2136
SOX:	0.002			0.1517	1.2136

front loader

Reactive organic gases:	0.002	0.465	140	0.1302	1.0416
carbon monoxide:	0.011			0.7161	5.7288
nitrogen oxides:	0.023			1.4973	11.9784
PM10:	0.0015			0.09765	0.7812
SOX:	0.002			0.1302	1.0416

backhoe

Reactive organic gases:	0.003	0.465	74	0.10323	0.82584
carbon monoxide:	0.015			0.51615	4.1292
nitrogen oxides:	0.022			0.75702	6.05616
PM10:	0.001			0.03441	0.27528
SOX:	0.002			0.06882	0.55056

power generator

Reactive organic gases:	0.002	0.74	40	0.0592	0.4736
carbon monoxide:	0.011			0.3256	2.6048
nitrogen oxides:	0.018			0.5328	4.2624
PM10:	0.001			0.0296	0.2368
SOX:	0.002			0.0592	0.4736

EMISSIONS FROM REMOVAL OF BELOW-GROUND CULVERTS FROM AOC #5 AND AOC #9

This activity will use the following off-road vehicles: excavator, dozer, grader, water truck
Duration of activity: 3 days

vehicle	ROG	CO	NOX	PM10	SOX
excavator	0.78	8.57	18.71	1.17	1.56
dozer	2.69	13.45	28.25	0.67	2.69
grader	2.32	6.18	16.23	0.77	1.55
truck	1.21	6.07	12.74	1.21	1.21
totals	7.00	34.28	75.93	3.83	7.01

EMISSIONS FROM SOIL EXCAVATION/MECHANICAL SCREENING FOR ORDNANCE

This activity will use the following off-road vehicles:

vehicle	duration of use (weeks)
excavator	3
dozer	1
loader (2 vehicles)	11
backhoe	1
water truck	11

dump truck (3 vehicle	1
generator	11

Approximately 610 tons dirt/day will be processed through the mechanical screening plant. Total emissions will be calculated on a time-weighted basis. Duration of vehicle use information is taken from Table 11-1 of the Corrective Measures Workplan.

Emissions from dirt handling

E = [0.0012 x (W/5)**1.3 / (H/2)**1.4] x T

where:	E = emissions of PM10	
	W = wind speed, assume light wind in summer of 5 miles per hour	5
	H = moisture content of soil, assume 15% (0.15) lightly moistened with water for dust supression purposes	0.15
	T = tons dirt handled per day, assume 610 tons (800 cubic yards)	610

E = 27.50587

vehicle		time fraction	ROG 8-hr emissions	ROG TW* emissions	CO 8-hr emissions	CO TW* emissions	NOX 8-hr emissions	NOX TW* emissions	PM10 8-hr emissions	PM10 TW* emissions	SOX 8-hr emissions	SOX TW* emissions
excavator	1	0.27	0.78	0.21	8.57	2.34	18.71	5.10	1.17	0.32	1.56	0.43
dozer	1	0.09	2.69	0.24	13.45	1.22	28.25	2.57	0.67	0.06	2.69	0.24
loaders	2	1.00	2.08	2.08	11.46	11.46	23.96	23.96	1.56	1.56	2.08	2.08
backhoe	1	0.09	0.83	0.08	4.13	0.38	6.06	0.55	0.28	0.03	0.55	0.05
water truc	1	1.00	1.21	1.00	6.07	6.06	12.74	12.74	1.21	1.21	1.21	1.21
dump truc	3	0.09	3.64	0.33	18.20	1.65	38.23	3.48	3.64	0.33	3.64	3.63
generator	1	1.00	0.47	0.47	1.23	1.23	4.26	4.26	0.24	0.24	0.47	0.47
dirt handling		1.00							27.50	27.50		
totals				4.42		24.34		52.66		31.25		8.12

EMISSIONS FROM EXCAVATION AND OFF SITE DISPOSAL OF CONTAMINATED SOIL

This activity considers emissions from off-road vehicles, dirt handling and dirt-hauling trucks
The activity is expected to last for approximately 12 days.
Approximately 625 tons/day of dirt will be handled.

This activity uses the following off-road vehicles: excavator, loader, dozer, water truck, dump truck

vehicle	ROG	CO	NOX	PM10	SOX
excavator	0.77952	8.57472	18.70848	1.16928	1.55904
loader	1.0416	5.7288	11.9784	0.7812	1.0416
dozer	2.6904	13.452	28.2492	0.6726	2.6904
2 trucks (2)	2.4272	12.136	25.4856	2.4272	2.4272
total	6.93872	39.89152	84.42168	5.05028	7.71824

emissions from dirt handling

E = [0.0012 x (W/5)**1.3 / (H/2)**1.4] x T

where:	E = emissions of PM10	
	W = wind speed, assume light wind in summer of 5 miles per hour	5
	H = moisture content of soil, assume 15% (0.15) lightly moistened with water for dust supression purposes	0.15
	T = tons dirt handled per day, assume 625 tons (800 cubic yards)	625

E = 28.18224

emissions from dirt-hauling trucks

assume trucks are diesel powered
assume 25 trucks/day
assume 20 mile trip to and from rail location at average speed of 25 mph

E = EF x N x M / 453.59

E = Emissions in lb/day

	ROG	CO	NOX	PM10
EF = emissions factor (gm/mile)	1.88	10.27	10.81	0.88
N = number of vehicles	25			
M = number of miles/trip	20			
453.59 gm/lb = conversion factor from grams to pounds			453.59	

truck emissions:	ROG:	2.072356
	CO:	11.3208
	NOX:	11.91605
	PM10:	0.970039
	SOX:	

total emissions for activity:	ROG:	9.01
	CO:	51.21
	NOX:	96.34
	PM10:	34.20
	SOX:	7.72

EMISSIONS FROM EXCAVATION AND SEGREGATION OF CS-CONTAINING MATERIAL

This activity will use the following off-road vehicles: backhoe, water truck. A portable screening plant (which requires a generator) will also be used. Assume 610 tons dirt (800 cubic yards) handled per day (limited by the capacity of the portable screening plant). Activity is expected to last approximately

vehicle	ROG	CO	NOX	PM10	SOX
backhoe	0.83	4.13	6.06	0.28	0.55
truck	1.21	6.07	12.74	1.21	1.21
generator	0.47	2.60	4.26	0.24	0.47
dirt				27.5	
totals	2.51	12.80	23.06	29.23	2.24

EMISSIONS FROM LANDFILL OR TEST AREA 1C GRADING

The following off-road vehicles will be used: dozer (2 vehicles), excavator, water truck.
Assume 1875 tons dirt handled per day.
This activity is expected to last approximately four days.

	vehicle	ROG	CO	NOX	PM10	SOX
2	dozer	5.38	26.90	56.50	1.35	5.38
1	excavator	0.78	8.57	18.71	1.17	1.56
1	truck	1.21	6.07	12.74	1.21	1.21
	dirt				84.55	
	total	7.37	41.55	87.95	88.27	8.15

emissions from dirt handling

E = [0.0012 x (W/5)**1.3 / (H/2)**1.4] x T

where: E = emissions of PM10
W = wind speed, assume light wind in summer of 5 miles per hour

H = moisture content of soil, assume 15% (0.15) lightly moistened with water for dust supression purposes		0.15
T = tons dirt handled per day, assume 1875 tons		1875
E =	84.54672	

EMISSIONS FROM PASSENGER AUTOMOBILES

Assume 10 cars/day, avg speed of 25 mph, all cars have catalytic converters, avg. round trip 40 miles, duration of project is approximately 6 months.

E = EF x N x M/453.59

		ROG	CO	NOX	PM10
E = emissions in lb/day					
EF = emission factor in gm/mile		0.31	5.16	0.56	0.01
M = number of miles	40				
N = number of cars	10				
453.59 gm/lb = conversion factor					
E =		0.27	4.55	0.49	0.01

Attachment F

List of Wastes Generated/Burned At the Aerojet Facility

2.0 CLOSURE PLAN

The interim status of the Ranch Steppes, the open burning pits, the popping oven, the trash incinerator and the drop box expired on November 8, 1992 These waste management units have not been operated since that date and are being closed at this time.

It is anticipated that this closure plan will be approved in June, 1993 The closure plan will be implemented upon approval. The estimated closure schedule is shown in Figure 8 0

A site-specific Health and Safety Plan (SSP) has been prepared and is included in Appendix E.

2.1 Estimate of Maximum Quantity or Inventory

The exact composition of most of the propellants, explosives and pyrotechnics (PEP) wastes treated at the facility is classified. However, compositions of these wastes are known by Aerojet Ordnance EOD personnel who are familiar with their properties.

Table 2.1 lists the types of wastes which were treated at the Ranch Steppes and at the open burning pits and Appendix C lists the waste disposal records for the period 1985-1991 These wastes are ignitable and reactive. At the federal level, their RCRA waste code is D003 and at the state level they are 134, 141, 181, 331 and 343:

TABLE 2.1: WASTES TREATED AT THE RANCH STEPPES & OB PITS

WASTE	COMMON NAME	MAX AMOUNT HANDLED @ ONE TIME	WASTE GENERATED PER MONTH
Propellant Explosives	Class B Explosives	325 Lb.	750 Lb.
HEI High Explosives	Class A Explosive	5 Lb.	100 Lb.
Explosive Loaded Components	Class C Explosive	10 Lb.	200 Lb.
Black Powder Contaminated Containers and Air Filters	Class A Explosives	1 Lb	20 Lb.
Scrap Primed Cartridge Cases	Class C Explosives	50 ea.	1,000 ea.

WASTE	COMMON NAME	MAX. AMOUNT HANDLED @ ONE TIME	WASTE GENERATED PER MONTH
30 mm/25 mm Rejects	Classes A & B Explosives	60 ea.	1,200 ea.
Explosive Contaminated Paper Cartons Rags, Gloves, Etc.	Contaminated Miscellaneous Materials	50 Lb.	1,000 Lb

The EOD personnel used their knowledge and training to determine which wastes were disposed via burning or detonation. In general, 25 mm and 30 mm shells and HEI explosives were detonated, while propellants, powders, contaminated filters, rags and gloves, etc., were open burned

Page ES-5, par. 1, line 4. It says from 1954 to 1965 they disposed of approximately 5,000 lbs. of waste a year at the site in Chino Hills. In 1965 they merged with the Riverside Plant. Paragraph 2, line 2, "However with the closure of the Riverside Facility in 1965, production activities at the facility produced increased quantities of explosives and propellant wastes."

a. *How much per year after merging with Riverside did they produce and dispose of there at the site if they were disposing 95%?*

In June 1965, the Aerojet Riverside facility was closed and operations expanded at the Chino Hills facility. Expanded operations generated increased quantities of explosive wastes; thus, the OB/OD area was constructed. Approximately 95% of the wastes disposed of at the Chino Hills Facility since its inception in 1954 was treated in the OB/OD area.

b. *How much total waste estimation that was disposed of at the Chino Hills site over the entire operation of the facility (of 41 years)?*

The exact volume of explosive/propellant wastes disposed of at the Facility is unknown. However, the following rough-order magnitude estimates were developed based on available records and interviews with employees:

Dates	Total years	Estimated yearly volume (pounds)	Estimated yearly volume (tons)	Total volume (ton)
1954 to 1965	11	50	0.01	0.13
1965 to 1967	2	1,000	0.5	1
1967 to 1972	5	5,000	2.5	12.5
1972 to 1982	10	12,600	6.3	63
1982 to 1985	3	12,000	6	18
1985 to 1989	4	24,000	12	48
1989 to 1991	2	600	0.3	0.6
1991 to 1995	4	7,200	3.6	14.4
total	41	--	--	157.63 tons

They disposed 95% of their total waste at the Chino Hills facility as stated by former employees, during their existence at the Chino Hills facility from 1954 to 1995, 41 years.

To clarify this statement in the RFI Report, reportedly, no wastes from any other Aerojet facility were ever disposed of at the Chino Hills Facility. Of the total amount of explosive/propellent wastes generated and disposed of at the site over 41 years of operation, approximately 95% (150 tons of the 158 tons generated) were disposed of at the OB/OD area.

Attachment G

Results of Off Site Sampling

6.0 ADDITIONAL CONFIRMATION SAMPLING RESULTS

Confirmation sample results for off-site locations, streambed sediments, Building 008, wipe samples and water samples are summarized in the following sections.

6.1 OFF-SITE LOCATIONS

Pursuant to the concerns raised by community members, off-site soil samples were collected from the two drainage systems leaving the site towards the north. These samples were informally named the east gully and west gully (the west gully sample was collected approximately 30 feet west of the Sikkama Well). Soil samples were collected from both locations at a depth of 1.5 feet. Deeper samples could not be collected in the gullies due to the presence of large cobbles/boulders and exposed bedrock. Soil samples were analyzed for the following:

- Explosives by EPA Method 8330
- Chemical agents by USAEC Method CSM-118
- CS/SVOCs by EPA Method 8270
- Title 22, Chapter 11, Article 3 requirement metals by EPA Method 6010/7000

Analytical results for the off site locations are summarized as follows:

- Explosives were not detected in any sample at concentrations exceeding the method detection limits.

- Chemical agents were not detected in any sample at concentrations exceeding the method detection limits.

- CS or SVOCs were not detected in any sample at concentrations exceeding the method detection limits

- All Title 22, Chapter 11, Article 3 requirement metals were detected at concentrations approximately equivalent to the mean background levels

Analytical results from off-site sources (soil and water, see Section 6.5) indicate that no chemicals of concern used at the facility have migrated off-site through the northern drainage systems.

Soil sample locations and analytical results for off-site soil sample locations are presented in Figure 6-1 and Table 6-1

6.5 WATER SAMPLING

Water samples were collected from the on-site Walking Beam Well (WG-01-10) and the off-site Sikkama Well (WG-01-11). Aerojet representatives previously did not have access to the Walking Beam well, and, the off-site Sikkama Well was considered initially not to provide relevant subsurface water information. However, to address local residents concerns, these wells were sampled for the following:

- Explosives by EPA Method 8330
- Chemical agents by USAEC Method CSM-118
- Perchlorate ion by EPA Method 300M
- Title 22, Chapter 11, Article 3 requirement metals by EPA Method 6010/7000
- General chemical constituents

In addition, the Lake Aerohead well (WG-01-04) was resampled for chemical agents by USAEC Method CSM-118 and perchlorate ion by EPA Method 300M. This well was selected for sampling since any potential chemical migration southward from the Caustic or Redwater pond areas or the Upper A-12 Test Area would be detected in this well. The Area 1 Well (SW-01-05) and the Abandoned Oil Well (SW-01-08) were resampled for perchlorate ion analysis by EPA Method 300M.

Water sample analysis results were reported as follows:

- Explosives were not detected in any of the samples at concentrations exceeding their method detection limit

- Chemical agents were not detected in any of the samples at concentrations exceeding their method detection limit.

- Perchlorate ion was not detected in any of the samples at concentrations exceeding the method detection limit.

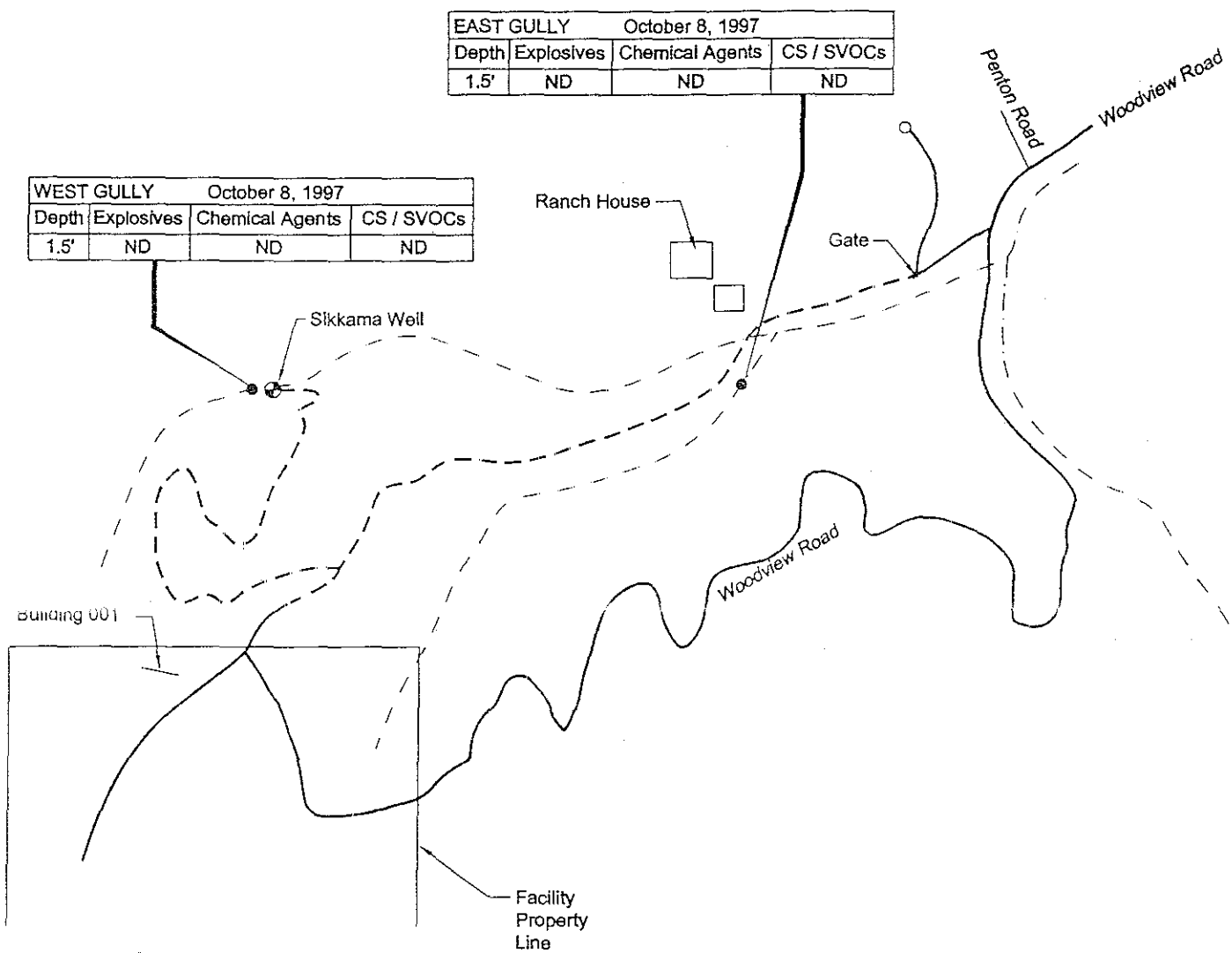
- Arsenic, barium, mercury, molybdenum, and zinc were the only Title 22, Chapter 11, Article 3 requirement metals detected. None of the metals was detected at concentrations exceeding respective primary or secondary MCL values (where applicable).

- Total dissolved solids (TDS) concentrations were 604,000 (WG-01-10) and 821,000 (WG-01-11) $\mu g/l$.

- pH levels were measured at 8.12 (WG-01-10) and 7.57 (WG-01-11)

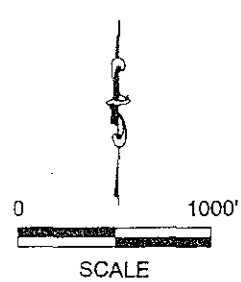
Water sample locations are shown in Figure 3-1 (Section 3.0). Laboratory analytical results are present in Table 6-5. A complete discussion of water sample results and conclusions is included as Section 3.0.

FIGURE 6-1
OFF-SITE SOIL SAMPLE LOCATIONS
AND ANALYTICAL RESULTS
CHINO HILLS FACILITY
CHINO HILLS, CALIFORNIA



EAST GULLY	October 8, 1997		
Depth	Explosives	Chemical Agents	CS / SVOCs
1.5'	ND	ND	ND

WEST GULLY	October 8, 1997		
Depth	Explosives	Chemical Agents	CS / SVOCs
1.5'	ND	ND	ND



Legend

- Asphalt Road
- Dirt Road
- Gully
- Monitor Well
- Soil Sample Location
- ND Not Detected

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Table 6-1
Analytical Results for Off-Site Locations (Soil Samples)
Aerojet Chino Hills Facility

ANALYTE	UNITS	SAMPLE DESCRIPTION	
		WEST GULLY 10/8/97	EAST GULLY 10/8/97
Metals (EPA Method 6010/7000)			
Antimony	mg/kg	ND	ND
Arsenic	mg/kg	3.41	2.43
Barium	mg/kg	72.3	41.3
Beryllium	mg/kg	0.248	0.227
Cadmium	mg/kg	0.743	1.92
Chromium	mg/kg	7.62	7.2
Cobalt	mg/kg	3.76	4.15
Copper	mg/kg	8.08	6.24
Lead	mg/kg	14.4	2.84
Mercury	mg/kg	0.0751	0.0347
Molybdenum	mg/kg	3.45	3.38
Nickel	mg/kg	12.2	10.1
Selenium	mg/kg	0.974	ND
Silver	mg/kg	ND	ND
Thallium	mg/kg	ND	ND
Vanadium	mg/kg	18.3	19.6
Zinc	mg/kg	29.9	24.8
Semi-volatile Organic Compounds (EPA Method 8270)			
CS	mg/kg	ND	ND
Chemical Agents (USAEC Method CSM-118)			
	mg/kg	ND	ND
Explosives (EPA Method 8330)			
	mg/kg	ND	ND

ND: Results below method detection limit for analytes indicated.

6-6

Attachment H

Information on Truck Activity Not related to Site Cleanup

GENCORP
AEROJET

P O Box 13222
Sacramento CA 95813-6000

30 August 1999

Via Fax/Mail

Mr. Robert Senga
Unit Chief
Department of Toxic Substances Control
5796 Corporate Avenue
Cypress, CA 90630

Subject: Chino Hills Facility

Dear Mr. Senga:

This is in response to your telephone call today requesting information about parties that enter and leave the Chino Hills Facilities. Following is a list of the normal movement of vehicles to and from the site

Site personnel
- Secretary
- Guards
- Maintenance Workers-two to three

Oil Lease operations
- Oil tank truck-once a month two round trips to haul extracted crud oil (there is an existing lease for the pumping and hauling of oil both on the site and on an adjacent parcel)

Cattle Rancher-cattle are grazed on the site

Ordnance Technicians-on-going work at the OB/OD site

McLaren Hart personnel

Aerojet personnel from other sites

County personnel-San Bernadino County operates the radio tower at the site and enter the site about once a month

Miscellaneous deliveries-bottled water, etc.

SR10108611

As a matter of general information, Aerojet has guards at the site on a 24 hours basis. These guards maintain a log of each vehicle that enters and leaves the site. Since 25 January 1999 Aerojet has been closing and locking the gate at the bottom of the hill each evening at 4:00 pm and opening the gate at 6:00 am the next day

I hope that this information will be of assistance to you.

Sincerely,

Original contains signature

Donald E. Vanderkar

cc: SL Phinney, Aerojet
JN Uranga, Aerojet
TP Griffin, Aerojet

SR10108611

GENCORP
AEROJET

P O Box 13222
Sacramento CA 95813-6000

916-351-8584

Terrance P Griffin
Director,
Real Estate

September 13, 1999

Mr Winston Ward
Assistant Community
Development Director
City of Chino Hills
2001 Grand Avenue
Chino Hills, CA 91709-4869

Re: Tanker Truck Activity at Aerojet

Dear Mr Ward:

Thanking for taking the time to meet with Aerojet on September 9, 1999. This letter is in response to your request during that meeting for clarification regarding the subject tank truck activity

Specifically regarding your query as to gasoline deliveries to the site, Aerojet has not received such deliveries in more than three years In fact, the gasoline storage tanks have been removed.

Aerojet keeps two gate logs reflecting entry and exit activity at the site. A Visitor Registration Log is kept for Aerojet workers and invitees. Access for uses unrelated to Aerojet activities such as cattle grazing, bee keepers, access to adjoining property and the oil leases are recorded on the Permissive Use Log.

A copy of the Permissive Use Log for the month of August 1999 is attached. You will note that there are 22 entries which indicate either "oil" or "oil lease". Two of the entries dated August 10th indicate "pick up oil". However, Aerojet is not involved in the activities on the oil lease land and therefore is not in a position to know whether trucks entering or leaving the gate are empty or full unless the driver chooses to disclose such information

Aerojet remains committed to keeping the City of Chino Hills informed of the status of activities at its site. As you know, we are currently in a quiet period awaiting approval from the California Department of Toxic Substances Control to proceed on the remediation work plan. Aerojet will continue to provide status briefings to the City during the remediation phase. Additionally,

I would like to take this opportunity to reaffirm our open invitation to the City Council, Management and Staff to tour the site before and/or during remediation activities. Feel free to call the undersigned at (916) 351-8584, Mr. Don Vanderkar, Remediation Director, at (916) 355-4282 or Edna Romero on site at (714) 528-7281.

Best regards,

Original contains signature

T. P. Griffin

Attachment

Cc: City of Chino Hills:
Mr. Douglas N. LaBelle, City Manager w/o attachment
Honorable Gary G. Larson, Mayor w/o attachment

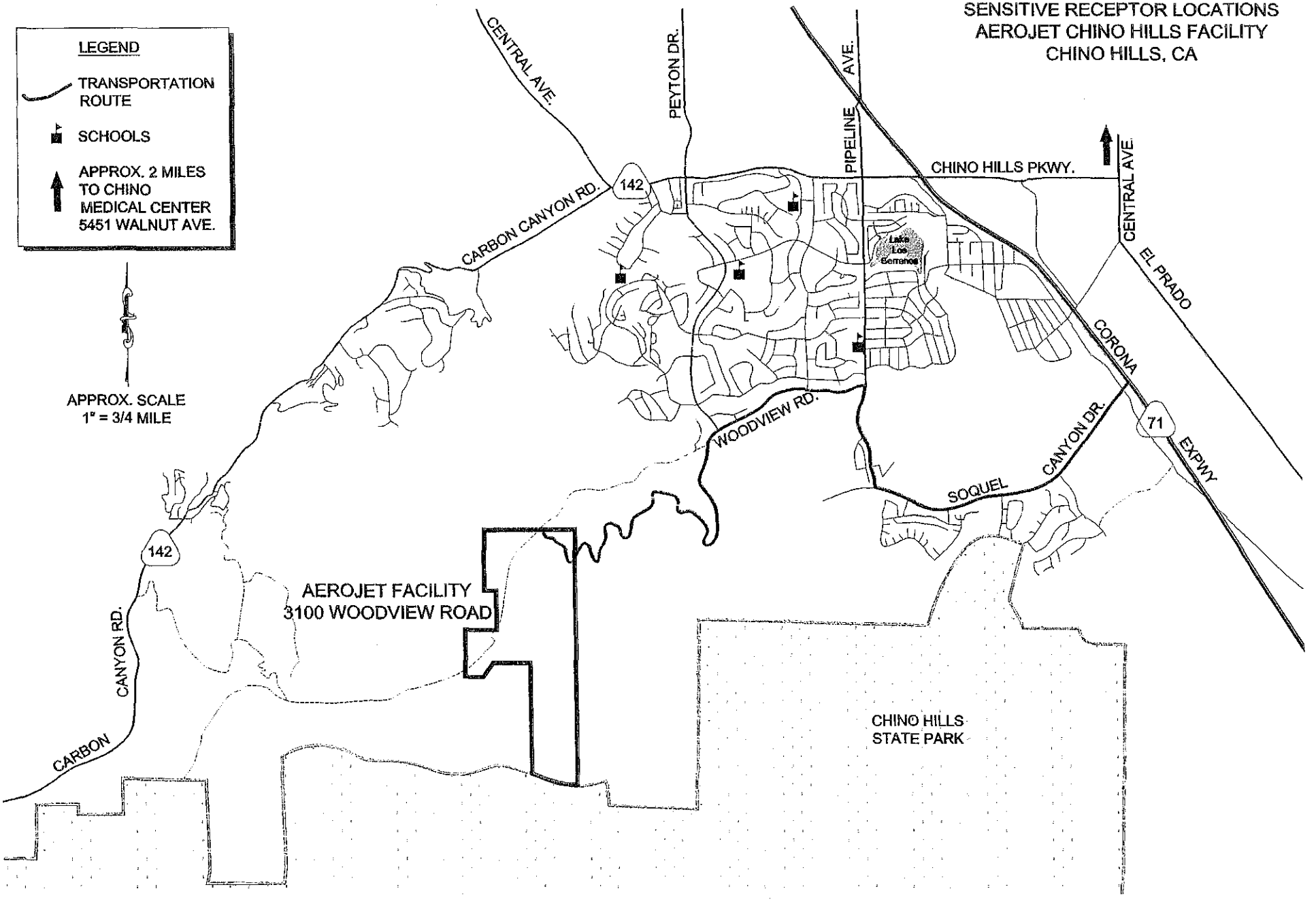
DTSC:
Ms. Marsha Mingay, Public Participation Specialist w/o attachment
Mr. Robert Senga, Unit Chief w/o attachment

TPG4299

Attachment I

Map of Truck Route For Truck Hauling of Contaminated Soil

FIGURE 1
REGIONAL MAP AND
SENSITIVE RECEPTOR LOCATIONS
AEROJET CHINO HILLS FACILITY
CHINO HILLS, CA



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Attachment J

Facility Plot Plan

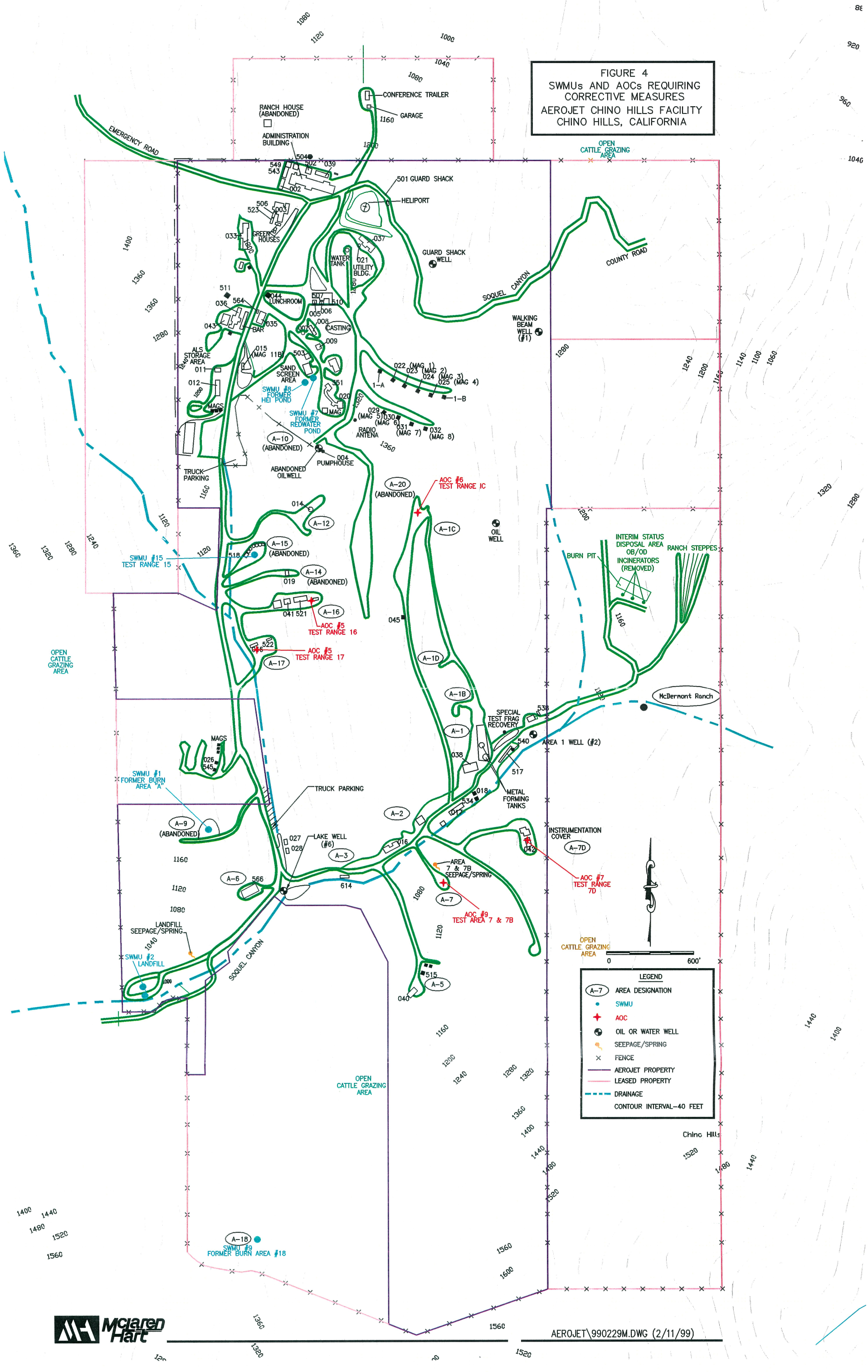
FIGURE 4
SWMUs AND AOCs REQUIRING CORRECTIVE MEASURES
AEROJET CHINO HILLS FACILITY
CHINO HILLS, CALIFORNIA
CONFERENCE TRAILER
GARAGE
RANCH HOUSE (ABANDONED)
ADMINISTRATION BUILDING
EMERGENCY ROAD
OPEN CATTLE GRAZING AREA
501 GUARD SHACK
HELIPORT
GREEN HOUSES
WATER TANK
UTILITY BLDG.
GUARD SHACK WELL
COUNTY ROAD
SOQUEL CANYON
LUNCHROOM
CASTING
BAR
ALS STORAGE AREA
MAGS
SAND SCREEN AREA
SWMU #8 FORMER HEI POND
SWMU #7 FORMER REDWATER POND
WALKING BEAM WELL (#1)
RADIO ANTENA
A-10 (ABANDONED)
ABANDONED OILWELL
PUMPHOUSE
TRUCK PARKING
A-20 (ABANDONED)
AOC #6 TEST RANGE 1C
A-1C
OIL WELL
A-12
A-15 (ABANDONED)
SWMU #15 TEST RANGE 15
A-14 (ABANDONED)
A-16
AOC #5 TEST RANGE 16
AOC #5 TEST RANGE 17
A-17
A-1D
A-1B
A-1
INTERIM STATUS DISPOSAL AREA OB/OD INCINERATORS (REMOVED)
RANCH STEPPES
BURN PIT
McDermont Ranch
SPECIAL TEST FRAG RECOVERY
AREA 1 WELL (#2)
METAL FORMING TANKS
SWMU #1 FORMER BURN AREA "A"
A-9 (ABANDONED)
LAKE WELL (#6)
A-2
A-3
A-6
INSTRUMENTATION COVER
A-7D
AREA 7 & 7B SEEPAGE/SPRING
AOC #7 TEST RANGE 7D
AOC #9 TEST AREA 7 & 7B
A-7
LANDFILL SEEPAGE/SPRING
SWMU #2 LANDFILL
A-5
A-18
SWMU #9 FORMER BURN AREA #18
Chino Hills
0
600'
LEGEND
A-7 AREA DESIGNATION
SWMU
AOC
OIL OR WATER WELL
SEEPAGE/SPRING
FENCE
AEROJET PROPERTY
LEASED PROPERTY
DRAINAGE
CONTOUR INTERVAL-40 FEET
McLaren Hart
AEROJET\990229M.DWG (2/11/99)