LAWRENCE
LIVERMORE
NATIONAL
LABORATORY

UCRL-TR-216940-VOL-1-REV-3

Human Health and Ecological Risk Assessment for the Operation of the Explosives Waste Treatment Facility at Site 300 of the Lawrence Livermore National Laboratory

Volume 1: Report of Results

Gretchen M. Gallegos
Jeffrey I. Daniels
Anthony M. Wegrecki

October 2007

This work performed under the auspices of the U.S. Department of Energy by
Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

Human Health and Ecological Risk Assessment for the Operation of the Explosives Waste Treatment Facility at Site 300 of the Lawrence Livermore National Laboratory

Table of Contents

Appendices

Figures

Tables

Background Information about Types of Explosives

(adapted from Mitchell, 1999)

High Explosive. An energetic material in which the decomposition process (detonation wave) proceeds through the entire material at supersonic speed. The rate at which the detonation wave passes through the energetic material depends on a large number of parameters, including the density of the energetic material, the heat released by the detonation, the geometric shape or dimensions of the energetic material, the degree of confinement, and the purity of the energetic material(s). High explosives can be divided into two subcategories: primary high explosives that detonate easily when exposed to an ignition source, and secondary high explosives that require the detonation of a primary high explosive before they detonate. Fuses and boosting charges are examples of primary high explosives. Trinitrotoluene (TNT), Research Department Explosive (RDX), tetryl, and nitroglycerin are examples of secondary explosives.

Low Explosive. An energetic material in which the decomposition process (deflagration) occurs at subsonic speed. The decomposition occurs only on the surface of the energetic material; and, unlike the high explosive, there is no shock wave. The rate determining factors for decomposition of a low explosive are the rate of heat transfer into the energetic material from the decomposition occurring on its surface and the rate of decomposition of the energetic material itself. The pressure that the decomposition products exert on the energetic material also affects the rate of heat transfer. Low explosives are usually divided into three largely unrelated categories: black powder (a mixture of sulfur, charcoal and potassium nitrate), pyrotechnics (materials used to produce light, smoke, heat or sound effects), and propellants (materials used for the propulsion of projectiles or rockets).

Propellant. A low-explosive energetic material. Some of the most commonly used propellant ingredients are nitrocellulose, nitroglycerin, and ammonium perchlorate. Propellants are placed into five subcategories based on their energetic composition: (1) single base, which contains only nitrocellulose; (2) double-base, which contains nitrocellulose and nitroglycerin; (3) triple-base, which contains nitrocellulose, nitroglycerin, and nitroguanidine; (4) ammonium perchlorate; and (5) composite, which contains an oxidizer, such as ammonium perchlorate, and a metal additive (e.g., powdered aluminum) held together by a polymeric substance, such as polybutadiene.

Human Health and Ecological Risk Assessment for the Operation of the Explosives Waste Treatment Facility at Site 300 of the Lawrence Livermore National Laboratory

Executive Summary

Human health and ecological risk assessments are required as part of the Resource Recovery and Conservation Act (RCRA) permit renewal process for waste treatment units. This risk assessment is prepared in support of the RCRA permit renewal for the Explosives Waste Treatment Facility (EWTF) at Site 300 of the Lawrence Livermore National Laboratory (LLNL).

The human health risk assessment is based on U.S. Environmental Protection Agency-(U.S. EPA) approved emissions factors and on California Environmental Protection Agency (CalEPA), California Air Resources Board (CARB) and U.S. EPA assessment and air dispersion models. This risk assessment identifies the receptors of concern and evaluates theoretical carcinogenic risk, and theoretical acute and chronic non-carcinogenic hazard, following those guidelines. The carcinogenic risk to a 30-year resident at the maximum off-site receptor location is 0.0000006 or 0.6 in 1 million. The carcinogenic risk to a 25-year worker at the maximum bystander on-site receptor location is also 0.0000006 or 0.6 in 1 million. Any risk of less than 1 in a million is below the level of regulatory concern. The acute non-carcinogenic hazard for the 30-year resident is 0.01, and the chronic non-carcinogenic hazard is 0.01. The acute non-carcinogenic hazard for the 25-year worker is 0.3, and the chronic non-carcinogenic hazard is 0.2. The point of comparison for acute and chronic non-carcinogenic hazard is 1.0; an estimate less than 1.0 is below the level of regulatory concern. The estimates of health effects are based on health conservative assumptions and represent an upper bound of the possible exposures to the receptors. Based on these results, emissions from the operations of the EWTF should not be of concern for human health.

For the ecological risk assessment (ERA), 10 receptor species (including plants), representing members of the trophic levels in the habitat of Site 300, were evaluated for the possibility of potential detrimental effects from EWTF emissions. The ecological hazard quotients (EHQs) at a location closest to the EWTF suggest a potential for adverse consequences. However, the conservatisms incorporated into the analysis may overestimate potential consequences and may explain the potential for impacts. Using less conservative values suggests that there is a possibility for limited to no additional impact to occur from the continuing operation of the EWTF.

Human Health and Ecological Risk Assessment for the Operation of the Explosives Waste Treatment Facility at Site 300 of the Lawrence Livermore National Laboratory

1. Introduction

This document contains the human health and ecological risk assessment for the Resource Recovery and Conservation Act (RCRA) permit renewal for the Explosives Waste Treatment Facility (EWTF). Volume 1 is the text of the risk assessment, and Volume 2 (provided on a compact disc) is the supporting modeling data. The EWTF is operated by the Lawrence Livermore National Laboratory (LLNL) at Site 300, which is located in the foothills between the cities of Livermore and Tracy, approximately 17 miles east of Livermore and 8 miles southwest of Tracy. Figure 1 is a map of the San Francisco Bay Area, showing the location of Site 300 and other points of reference.

One of the principal activities of Site 300 is to test what are known as "high explosives" for nuclear weapons. These are the highly energetic materials that provide the force to drive fissionable material to criticality. LLNL scientists develop and test the explosives and the integrated non-nuclear components in support of the United States nuclear stockpile stewardship program as well as in support of conventional weapons and the aircraft, mining, oil exploration, and construction industries.

Many Site 300 facilities are used in support of high explosives research. Some facilities are used in the chemical formulation of explosives; others are locations where explosive charges are mechanically pressed; others are locations where the materials are inspected radiographically for such defects as cracks and voids. Finally, some facilities are locations where the machined charges are assembled before they are sent to the on-site test firing facilities, and additional facilities are locations where materials are stored.

Wastes generated from high-explosives research are treated by open burning (OB) and open detonation (OD). OB and OD treatments are necessary because they are the safest methods for treating explosives wastes generated at these facilities, and they eliminate the requirement for further handling and transportation that would be required if the wastes were treated off site.

Figure 1. Location of Site 300.

2. OB/OD Operations at Site 300

OB/OD operations are conducted at the EWTF located at the Building 845 Complex at Site 300. The EWTF consists of three units: the detonation pad, the burn pan, and the burn cage.

The detonation pad, shown in Figure 2, is used for the treatment of those waste explosives whose configuration requires treatment by open detonation, i.e., those wastes in a form that cannot be safely treated by open burning. The materials treated are 90 to 100 percent explosive materials. The detonation pad consists of a level, 30-foot x 30-foot (9-m x 9-m) gravel pad with minimum gravel pack about 8 feet (2.4 m) thick. Detonation of explosives waste is accomplished with the use of detonators or other initiating devices, and the process is controlled remotely from the Building 845 control bunker under observation by surveillance cameras. No more than 350 pounds (159 kg) of explosives waste (net explosive weight) may be detonated at one time. The detonation process is virtually instantaneous.

Figure 2. EWTF detonation pad.

The burn pan is used for the treatment of small pieces and powders of explosives wastes. These materials are 80 to 100 percent explosive materials that will not detonate during the thermal treatment process. The burn pan is a 4-foot x 8-foot x 0.5-foot-deep, rectangular, welded steel, watertight pan mounted on steel legs. The pan is equipped with a remotely controlled, removable cover. Pieces of explosives waste are placed in the pan, and cellulose material or other combustible materials are used to initiate treatment by burning. No more than 100 pounds (45 kg) of explosives waste (net explosive weight) may be treated at one time. The duration of the combustion treatment is 10 minutes or less. Figure 3 is a photograph of the burn pan.

Figure 3. EWTF burn pan, covered. (UCRL-Photo-213179, July 16, 2005)

The burn cage is used for the treatment of explosives-containing process waste sludge, explosives-contaminated packaging, and explosives-contaminated laboratory waste. The explosive content of the material treated in the burn cage ranges from 1 to 80 percent. The burn cage is an 8-foot-diameter, ventilated, metal enclosure with a refractory lining and an elevated metal base. Propane fuel from a protected supply tank is supplied to the burn cage to assist the combustion process. No more than 260 pounds (118 kg) of total waste and 50 pounds (23 kg) net explosive waste may be treated in the burn cage at one time. Combustion treatments at the burn cage are completed in 35 minutes. Figure 4 is a photograph of the burn cage.

EWTF operations and controls are handled from a concrete and steel control bunker at Building 845 (see Figure 5).

Figure 4. **EWTF burn cage. (UCRL-Photo-213179, July 16, 2005)**

Figure 5. **EWTF control bunker (Building 845A). Detonation pad is in the background.**

Figure 6 is a site map for Site 300, showing the central location of the EWTF; this location maximizes the distance to off-site receptors. The inset in Figure 6 shows the relative locations of the detonation pad, the burn pan, and the burn cage.

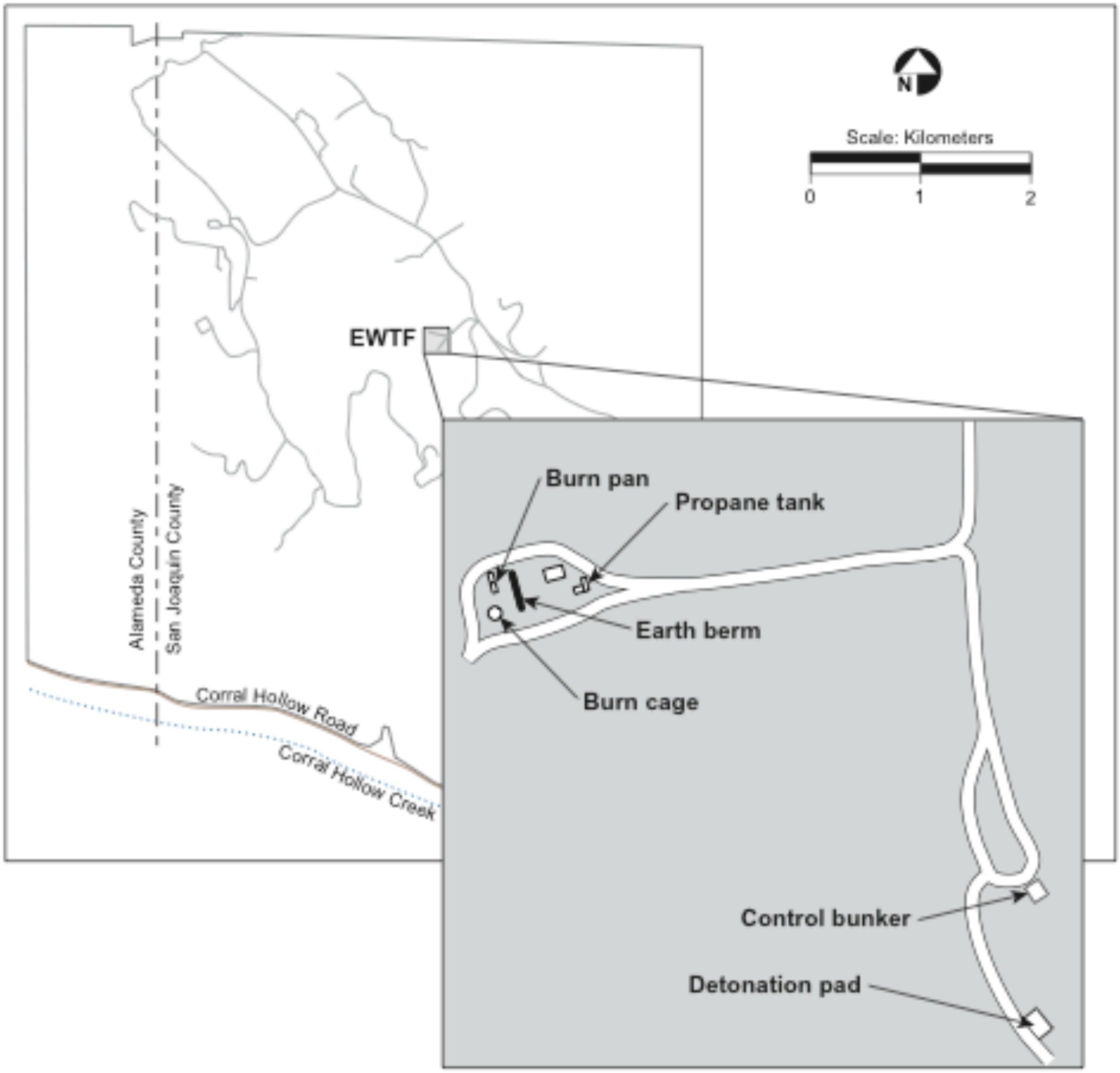


Figure 6. **Location of the EWTF at Site 300.**

3. Approach

The standard approach for a human health risk assessment is a four-step process stated by the National Academy of Sciences in *Risk Assessment in the Federal Government: Managing the Process* (NAS, 1983) and reiterated in *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments* (Office of Environmental Health Hazard Assessment [OEHHA], 2003). The four steps in the process are (1) hazard identification, (2) exposure assessment, (3) dose-response assessment, and (4) risk characterization.

For the operations at the EWTF, the first step, hazard identification, involves identifying emissions from the operations, i.e., the source term of specific pollutants of concern. Exposure assessment, the second step, involves emission quantification, modeling of environmental transport and fate, identification of exposure routes, identification of maximally exposed individuals, and estimation of short- and long-term exposures. The third step, dose-response assessment, characterizes the relationship between the exposure to a pollutant and any potential resulting health effect. For quantitative theoretical carcinogenic risk assessment, the dose-response relationship is estimated using cancer potency factors (CPFs) compiled by OEHHA and the U.S. Environmental Protection Agency (U.S. EPA) to calculate the theoretical risk of cancer associated with the estimated exposure. For non-carcinogenic acute and chronic effects, the dose-response relationship is quantified by comparison of modeled air concentrations with OEHHA- and U.S. EPA-defined acute and chronic reference exposure levels (RELs) for the inhalation pathway; and for the ingestion pathway, modeled dose is compared with a reference dose (RfD). The fourth and final step, risk characterization, combines the modeled exposures of the specific pollutants of concern with the dose-response relationship defined by a regulatory authority to estimate the potential health risks associated with the exposures. Each of these steps is discussed in this risk assessment.

3.1 Hazard Identification

The EWTF is a support facility at LLNL's Site 300 where wastes resulting from research activities involving explosives are treated. Most of the explosive wastes treated at Site 300 involve high explosives, such as the compounds Research Department Explosive (RDX), high melting explosive (HMX), and pentaerythritol tetranitrate (PETN), in a variety of formulations. Explosives other than high explosives are treated more rarely. The wastes treated at the EWTF are categorized into four forms described below:

Form 1 Waste. Waste explosives that, because of configuration or composition, are best treated by open detonation. Examples are explosive assemblies or devices that may detonate during open burning.

Form 2 Waste. Waste explosives that, because of configuration or composition, are best treated by open burning in the open burn pan. Examples are explosive parts and pieces generated during explosives formulation, processing, testing, or by removal from inventory.

Form 3 Waste. Waste explosives that, because of configuration or composition, are best treated by open burning in the thermal treatment unit (burn cage). Examples are wet machine fines generated during explosives processing, wet explosives-contaminated sludge from weirs and settling basins, and wet expendable filters from recycle systems.

Form 4 Waste. Waste material contaminated with energetic materials that are best treated by open burning in the thermal treatment unit (burn cage). Examples are paper, rags, plastic tubing, dry expendable filters from vacuum systems, and personal protective equipment used in explosives operations. The waste is judged to retain explosives hazards and is, therefore, considered to be a reactive waste.

Current permit limits allow 100 open detonations (Form 1 waste) and 100 open burn treatments (Forms 2, 3, or 4) annually. Table 1 presents the maximum mass amounts of treated material by treatment unit and waste form.

Table 1. Mass amounts of treated material by treatment unit and waste form.

Treatment unit/Waste form	Annual number of treatments	Maximum single treatment (lb)	Annual treatment (lb)
Detonation Pad/Form 1	100	350	35,000
Burn Pan/Form 2		100	10,000[a]
Burn Cage/Form 3	100	50	5,000[a]
Burn Cage/Form 4		260	26,000[a]

[a] Assuming 100 treatments at each unit; no accounting is made for the allocation of 100 permitted burn treatments among the three burn treatment options.

The estimation of potential emissions for explosives wastes is a subject of interest to both the EPA and the U.S. Department of Defense (DoD). The DoD has been seriously studying emissions from OB/OD operations since 1984. In the first comprehensive test, helicopters equipped with air sampling equipment were flown through plumes from OB and OD tests. The results were inconclusive. In 1988, the DoD began a series of studies that were contained in a large chamber called a “BangBox” at Sandia National Laboratories, Albuquerque, NM. After the first two studies, “ the DoD concluded that the emission factors derived from the BangBox tests were: (1) more reliable and reproducible than those from the field tests; (2) were *[sic]* statistically equivalent to these determined from the field tests; and (3) supported the original assumption that the detonations and burns were producing emission products consistent with detonation theory” (Mitchell and Suggs, 1998, p. 9). The DoD also determined that the materials emitted from field tests and BangBox studies were similar for all materials tested and were primarily N_2, CO_2, H_2O, particles, metals, and small quantities of CO, NO, NO_2, low molecular weight volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs) often found in ambient air.

In 1992, the EPA agreed to accept emission factors for OB/OD based on BangBox studies. The DoD built a BangBox at Dugway Proving Grounds in Dugway, UT, and conducted an additional series of studies that encompassed the open burning of 16 energetic materials and open detonation of 23 energetic materials. In 1998, EPA released a report summarizing the results and presenting emissions factors for OB/OD operations (Mitchell and Suggs, 1998). These emissions factors were incorporated into the Open Burn/Open Detonation Dispersion Model (OBODM) developed expressly for modeling OB/OD operations (Bjorklund et al., 1998). The emission factors in the OBODM were used to characterize air emissions due to the EWTF treatment activities.

Table 2 lists all 39 energetic materials that are contained in the OBODM. Although some of the 39 energetic materials are not treated at the EWTF, they are listed for completeness so that the method for source term identification would be totally transparent. Table 2 also lists the EWTF waste form in which the materials could be found, the methods by which the materials can be treated at the EWTF, and the frequency that the materials are treated at the EWTF. As seen in Table 2, three materials are routinely treated, 15 materials are treated with less than 5 percent frequency, and six materials are treated with less than 1 percent frequency. Two other materials could be treated after additional internal review, but they are not expected to be treated. Thirteen other materials are not treated at the EWTF.

This risk assessment used a reasonable[1] yet conservative approach to characterize air emissions due to EWTF treatment activities (i.e., emissions from Form 1 waste treatment at the detonation pad, Form 2 waste treatment at the burn pan, Form 3 waste treatment at the burn cage, and Form 4 waste treatment at the burn cage). First, a subset of the energetic materials contained in the OBODM, with similar compositions to those treated at the EWTF, was identified. Second, the identified materials were mapped to the EWTF waste form in which they could be present. Third, the energetic materials (and their emission factors) were grouped by type of treatment and waste form. For example, the energetic materials (and their emission factors) for Form 1 waste treatment at the detonation pad include TNT, RDX, Explosive D, Composition B, Tritanol, Amatol, HBX, etc. (see Table 2). Finally, the maximum chemical-specific emission factor was selected for each type of treatment and waste form.

---

[1] This is similar to the approach taken by the U.S. Navy and affirmed by the Agency for Toxic Substances Disease Registry (ATSDR) in evaluating emissions from Isla de Vieques, Puerto Rico, bombing range (http://www.atsdr.cdc.gov/HAC/PHA/vieques4/vbr_p5.html): "ATSDR further believes the Navy contractor's approach used to select emission factors from the available Bangbox studies was appropriate. For instance, to characterize emissions from air-to-ground exercises, the Navy contractor first identified the subset of Bangbox studies that tested explosives with similar compositions to those used at Vieques, and then selected the highest emission factor for every chemical from the various tests. As a result, the emission factors used are the highest measured releases of chemical by-products from the available Bangbox studies."

Table 2. Materials tested in the BangBox experiments, the treatment frequency at the EWTF, type of treatment at the EWTF, and associated EWTF waste form.

Tested material	Frequency of material[a] treatment at the EWTF	Type of treatment at the EWTF	EWTF waste form
TNT (2,4,6-Trinitrotoluene)	Routinely treated	Detonation Pad (Form 1), Burn Pan (Form 2)	1 and 2
RDX (cyclotrimethylenetrinitramine)	Routinely treated	Detonation Pad (Form 1), Burn Pan (Form 2)	1 and 2
Manufacturer's Waste (65% propell.)	Routinely treated	Burn Cage	3 and 4
Triple Base (M30-28% Nitrocellulose	<5%	Burn Pan	2
M1 (85% Nitrocellulose)	<5%	Burn Pan	2
Double Base (50% nitrocellulose)	<5%	Burn Pan	2
Propellant, ammonium perc., alum.	<5%	Burn Pan	2
Propellant, ammonium perc., nonal.	<5%	Burn Pan	2
Propellant, M-43	<5%	Burn Pan	2
Propellant, M-9	<5%	Burn Pan	2
Propellant, MK-23	<5%	Burn Pan	2
Propellant, M31A1E1	<5%	Burn Pan	2
Propellant, PBXN-110	<5%	Burn Pan	2
Smokeless Powder	<5%	Burn Pan	2
Propellant, Composite (MK-6)	<5%	Burn Pan	2
Propellant, M-3	<5%	Burn Pan	2
M6 (87.7% Nitrocellulose)	<5%	Burn Pan	2
Explosive D (ammonium picrate)	<5%	Detonation Pad (Form 1), Burn Pan (Form 2)	1 and 2
Composition B (56/38/6 RDX-TNT-WAX)	<1%	Detonation Pad	1
Tritonal (79% TNT, 21% Aluminum)	<1%	Detonation Pad	1
Tritonal with 2.5% Calcium Stearate	<1%	Detonation Pad	1
Amatol (50% TNT, 50% Ammn. Nitrate)	<1%	Detonation Pad	1
HBX (48/31/17/4 RDX-TNT-Al-WAX)	<1%	Detonation Pad	1
Propellant, Smokey Sam	<1%	Burn Pan	2
Detonating train	Only with additional internal review	Detonation Pad	1
40 mm HEI Cartridge	Only with additional internal review	Detonation Pad	1
Ground Illum. Signal, Red Star, M158	Not treated	Not treated	Not applicable
Signal, Illum, Arcrft, Rd Str, AN-M43A2	Not treated	Not treated	Not applicable
20 mm HEI Cartridge	Not treated	Not treated	Not applicable

Tested material	Frequency of material[a] treatment at the EWTF	Type of treatment at the EWTF	EWTF waste form
Impluse Cartridge, ARD 446-1	Not treated	Not treated	Not applicable
Impluse BBU-368 Cartridge	Not treated	Not treated	Not applicable
GGU-2/A Gas prss Prop. Act. Gen.	Not treated	Not treated	Not applicable
Impulse Cartridge, MK107 MOD01	Not treated	Not treated	Not applicable
Fuze, Inertia Tail, Bomb, FMU 54A/B	Not treated	Not treated	Not applicable
Flare, Cntermeas., Aircraft, M206	Not treated	Not treated	Not applicable
Fuze, Bomb, Tail, FMU 139A/B	Not treated	Not treated	Not applicable
Mine, Claymore, M18A1	Not treated	Not treated	Not applicable
T45E7 Adapter Booster	Not treated	Not treated	Not applicable
Diesel and Dunnage	Not treated	Not treated	Not applicable

[a] Material representative of materials treated at the EWTF.

The resulting emissions factors by type of treatment are presented in Table 3. As previously mentioned, the detonation pad only treats Form 1 wastes, the burn pan treats only Form 2 wastes and the burn cage treats only Form 3 and Form 4 wastes.

The emissions factors were used to calculate maximum hourly and annual average emissions from the EWTF. Maximum hourly emissions were calculated as follows: The maximum treatment amount for a single treatment was multiplied times the emission factor for each emitted chemical for each waste form. Annual average emissions were calculated in a similar manner: The annual treatment amount was multiplied by the emission factor for each emitted chemical for each waste form.

Table 3. Emissions factors for the burn pan, burn cage, and detonation pad at the EWTF.

Analyte ID	Analyte name	Burn pan emission factor (lb/lb)	Burn cage emission factor (lb/lb)	Detonation pad emission factor (lb/lb)
67562-39-4	1,2,3,4,6,7,8-Heptachlorodibenzofuran		3.40E-08	
55673-89-7	1,2,3,4,7,8,9-Heptachlorodibenzofuran		7.90E-09	
70648-26-9	1,2,3,4,7,8-Hexachlorodibenzofuran		2.10E-08	
57117-44-9	1,2,3,6,7,8-Hexachlorodibenzofuran		9.50E-09	
39001-02-0	Octachlorinated dibenzofuran		4.00E-08	
106-99-0	1,3-Butadiene	1.70E-06		9.00E-06
121-14-2	2,4-Dinitrotoluene	1.20E-09		
606-20-2	2,6-Dinitrotoluene	1.00E-10		
95-57-8	2-Chlorophenol	1.00E-05		
7429-90-5	Aluminum	1.10E-02	3.60E-02	2.50E-02
7440-36-0	Antimony	6.70E-07		6.70E-07
7440-39-3	Barium	8.20E-03	8.60E-05	8.20E-03

Analyte ID	Analyte name	Burn pan emission factor (lb/lb)	Burn cage emission factor (lb/lb)	Detonation pad emission factor (lb/lb)
71-43-2	Benzene	1.20E-04	4.50E-04	1.10E-04
7440-43-9	Cadmium	4.00E-05		4.00E-05
56-23-5	Carbon tetrachloride	1.10E-06	5.60E-06	4.50E-06
67-66-3	Chloroform	4.20E-07	2.30E-06	3.80E-07
7440-47-3	Chromium[a]	4.80E-05		8.80E-05
7782-50-5	Cl_2	9.20E-03	2.00E-04	
630-08-0	CO	7.20E-02	2.00E-02	5.30E-02
7440-50-8	Copper	3.70E-02	1.50E-05	8.90E-03
110-82-7	Cyclohexane	1.60E-06	2.00E-06	7.50E-06
122-39-4	Diphenylamine	2.60E-10		
75-00-3	Ethyl chloride			6.90E-07
100-41-4	Ethylbenzene	1.20E-06	2.40E-06	2.50E-06
206-44-0	Fluoranthene		2.00E-04	
7647-01-0	HCL	2.15E-01	8.30E-02	
98-82-8	i-Propylbenzene			7.30E-07
7439-92-1	Lead	1.20E-02	2.80E-04	1.10E-03
74-87-3	Methyl chloride	5.70E-06	2.00E-05	7.50E-07
71-55-6	Methyl chloroform			3.80E-07
108-87-2	Methylcyclohexane	5.10E-06	8.00E-06	7.00E-06
75-09-2	Methylenechloride	1.80E-04	1.20E-05	8.70E-04
91-20-3	Naphthalene	7.50E-08		
110-54-3	n-Hexane	1.90E-05	4.80E-06	1.90E-05
10102-44-0	Nitrogen dioxide (peroxide)	5.20E-03	6.60E-06	4.40E-03
78-11-5	Pentaerythritol tetranitrate (PETN)			5.60E-04
108-95-2	Phenol	3.43E-09		
115-07-1	Propene	7.20E-06	2.60E-05	7.30E-05
121-82-4	RDX	9.60E-06		7.40E-03
100-42-5	Styrene	1.50E-06		4.20E-05
7446-09-5	Sulfur dioxide	3.20E-03	8.60E-04	1.10E-03
127-18-4	Tetrachloroethylene		1.70E-06	1.80E-05
108-88-3	Toluene	8.60E-06	2.80E-05	2.60E-05
75-01-4	Vinyl chloride	1.50E-06		1.30E-06
7440-66-6	Zinc	4.00E-05	5.70E-04	1.10E-03
208-96-8	Acenaphthylene		1.60E-04	
86-57-7	n-Nitronaphthalene	1.40E-10		
620-14-4	m-Ethyltoluene	2.00E-06	2.60E-06	4.80E-07
622-96-8	p-Ethyltoluene	7.10E-06	5.00E-06	7.60E-06

Analyte ID	Analyte name	Burn pan emission factor (lb/lb)	Burn cage emission factor (lb/lb)	Detonation pad emission factor (lb/lb)
106-98-9	1-Butene	1.60E-06	8.30E-06	3.10E-05
592-41-6	1-Hexene			2.40E-05
109-67-1	1-Pentene	1.40E-06	5.10E-06	1.40E-05
74-86-2	Acetylene	8.30E-04	1.60E-03	1.30E-04
627-20-3	cis-2-Pentene	4.60E-07	5.60E-07	8.30E-07
287-92-3	Cyclopentane	4.70E-07	2.50E-07	1.70E-06
142-29-0	Cyclopentene	4.60E-07	9.40E-07	3.70E-06
74-84-0	Ethane	1.30E-06	9.50E-06	3.00E-05
74-85-1	Ethylene	7.20E-05	2.30E-04	3.90E-04
75-28-5	i-Butane	4.60E-07	1.40E-06	1.60E-06
115-11-7	i-Butene	1.00E-05	5.80E-06	2.40E-05
78-78-4	i-Pentane	2.60E-06	2.30E-05	9.10E-06
74-82-8	Methane	8.00E-03		2.40E-03
96-37-7	Methylcyclopentane	2.50E-06	1.10E-06	9.10E-06
106-97-8	n-Butane	4.80E-07	9.30E-06	3.10E-06
124-18-5	n-Decane	5.90E-06	1.40E-05	5.20E-06
142-82-5	n-Heptane	2.00E-06	4.70E-06	5.00E-06
111-84-2	n-Nonane	1.20E-06	1.30E-05	1.90E-06
111-65-9	n-Octane	2.90E-06	7.60E-06	3.60E-06
109-66-0	n-Pentane	3.30E-06	4.30E-06	1.30E-05
74-98-6	Propane	1.60E-06	4.50E-06	4.70E-06
624-64-6	trans-2-Butene	2.40E-06	2.10E-05	4.50E-06
646-04-8	trans-2-Pentene	4.60E-07	9.60E-07	5.00E-06

[a] Total Chromium

Also worthy of comment is the selection of emissions factors to represent Form 4 waste. The treatment of Form 4 waste in the burn cage was represented by the Bjorklund et al. (1998) emissions factors for ammonium perchlorate (AP) manufacturing waste surrogate. The AP manufacturing waste surrogate included plastic gloves, cotton rags, paper, wood, and similar material, and was burned using diesel fuel (Mitchell and Suggs, 1998). The burn cage at the EWTF does not use diesel fuel, but rather propane. It is expected that the combustion temperatures of propane minimize dioxin and furan formation; nevertheless, furan species were included for purposes of conservatism. Among the possible materials that could be used to represent Form 4 waste, the AP manufacturing waste surrogate is the most reasonable choice.

The resulting maximum hourly and annual average emissions for each waste form are shown in Tables 4 and 5. Although only a total of 100 burn treatments are permitted, all burn operations were calculated at 100 burns per year at this point in the assessment to enable comparison of effects later in the analysis.

Table 4. Maximum hourly (pound/hour) estimated emissions for the burn pan, burn cage (Forms 3 and 4), and detonation pad at the EWTF.

Analyte ID	Analyte name	Burn pan	Burn cage Form 3	Burn cage Form 4	Detonation pad
67562-39-4	1,2,3,4,6,7,8-HpCDF	0.00E+00	1.70E-06	8.84E-06	0.00E+00
55673-89-7	1,2,3,4,7,8,9-HpCDF	0.00E+00	3.95E-07	2.05E-06	0.00E+00
70648-26-9	1,2,3,4,7,8-HxCDF	0.00E+00	1.05E-06	5.46E-06	0.00E+00
57117-44-9	1,2,3,6,7,8-HxCDF	0.00E+00	4.75E-07	2.47E-06	0.00E+00
39001-02-0	OCDF	0.00E+00	2.00E-06	1.04E-05	0.00E+00
106-99-0	1,3-Butadiene	1.70E-04	0.00E+00	0.00E+00	3.15E-03
121-14-2	2,4-Dinitrotoluene	1.20E-07	0.00E+00	0.00E+00	0.00E+00
606-20-2	2,6-Dinitrotoluene	1.00E-08	0.00E+00	0.00E+00	0.00E+00
95-57-8	2-Chlorophenol	1.00E-03	0.00E+00	0.00E+00	0.00E+00
7429-90-5	Aluminum	1.10E+00	1.80E+00	9.36E+00	8.75E+00
7440-36-0	Antimony	6.70E-05	0.00E+00	0.00E+00	2.35E-04
7440-39-3	Barium	8.20E-01	4.30E-03	2.24E-02	2.87E+00
71-43-2	Benzene	1.20E-02	2.25E-02	1.17E-01	3.85E-02
7440-43-9	Cadmium	4.00E-03	0.00E+00	0.00E+00	1.40E-02
56-23-5	Carbon tetrachloride	1.10E-04	2.80E-04	1.46E-03	1.58E-03
67-66-3	Chloroform	4.20E-05	1.15E-04	5.98E-04	1.33E-04
7440-47-3	Chromium	4.80E-03	0.00E+00	0.00E+00	3.08E-02
7782-50-5	Cl_2	9.20E-01	1.00E-02	5.20E-02	0.00E+00
630-08-0	CO	7.20E+00	1.00E+00	5.20E+00	1.86E+01
7440-50-8	Copper	3.70E+00	7.50E-04	3.90E-03	3.12E+00
110-82-7	Cyclohexane	1.60E-04	1.00E-04	5.20E-04	2.63E-03
122-39-4	Diphenylamine	2.60E-08	0.00E+00	0.00E+00	0.00E+00
75-00-3	Ethyl chloride	0.00E+00	0.00E+00	0.00E+00	2.42E-04
100-41-4	Ethylbenzene	1.20E-04	1.20E-04	6.24E-04	8.75E-04
206-44-0	Fluoranthene	0.00E+00	1.00E-02	5.20E-02	0.00E+00
7647-01-0	HCL	2.15E+01	4.15E+00	2.16E+01	0.00E+00
98-82-8	i-Propylbenzene	0.00E+00	0.00E+00	0.00E+00	2.56E-04
7439-92-1	Lead	1.20E+00	1.40E-02	7.28E-02	3.85E-01
74-87-3	Methyl chloride	5.70E-04	1.00E-03	5.20E-03	2.63E-04
71-55-6	Methyl chloroform	0.00E+00	0.00E+00	0.00E+00	1.33E-04
108-87-2	Methylcyclohexane	5.10E-04	4.00E-04	2.08E-03	2.45E-03
75-09-2	Methylenechloride	1.80E-02	6.00E-04	3.12E-03	3.05E-01
91-20-3	Naphthalene	7.50E-06	0.00E+00	0.00E+00	0.00E+00
110-54-3	n-Hexane	1.90E-03	2.40E-04	1.25E-03	6.65E-03
10102-44-0	Nitrogen dioxide	5.20E-01	3.30E-04	1.72E-03	1.54E+00

Analyte ID	Analyte name	Burn pan	Burn cage Form 3	Burn cage Form 4	Detonation pad
	(peroxide)				
78-11-5	Pentaerythritol tetranitrate (PETN)	0.00E+00	0.00E+00	0.00E+00	1.96E-01
108-95-2	Phenol	3.43E-07	0.00E+00	0.00E+00	0.00E+00
115-07-1	Propene	7.20E-04	1.30E-03	6.76E-03	2.56E-02
121-82-4	RDX	9.60E-04	0.00E+00	0.00E+00	2.59E+00
100-42-5	Styrene	1.50E-04	0.00E+00	0.00E+00	1.47E-02
7446-09-5	Sulfur dioxide	3.20E-01	4.30E-02	2.24E-01	3.85E-01
127-18-4	Tetrachloroethylene	0.00E+00	8.50E-05	4.42E-04	6.30E-03
108-88-3	Toluene	8.60E-04	1.40E-03	7.28E-03	9.10E-03
75-01-4	Vinyl chloride	1.50E-04	0.00E+00	0.00E+00	4.55E-04
7440-66-6	Zinc	4.00E-03	2.85E-02	1.48E-01	3.85E-01
208-96-8	Acenaphthylene	0.00E+00	8.00E-03	4.16E-02	0.00E+00
86-57-7	n-Nitronaphthalene	1.40E-08	0.00E+00	0.00E+00	0.00E+00
620-14-4	m-Ethyltoluene	2.00E-04	1.30E-04	6.76E-04	1.68E-04
622-96-8	p-Ethyltoluene	7.10E-04	2.50E-04	1.30E-03	2.66E-03
106-98-9	1-Butene	1.60E-04	4.15E-04	2.16E-03	1.09E-02
592-41-6	1-Hexene	0.00E+00	0.00E+00	0.00E+00	8.40E-03
109-67-1	1-Pentene	1.40E-04	2.55E-04	1.33E-03	4.90E-03
74-86-2	Acetylene	8.30E-02	8.00E-02	4.16E-01	4.55E-02
627-20-3	cis-2-Pentene	4.60E-05	2.80E-05	1.46E-04	2.91E-04
287-92-3	Cyclopentane	4.70E-05	1.25E-05	6.50E-05	5.95E-04
142-29-0	Cyclopentene	4.60E-05	4.70E-05	2.44E-04	1.30E-03
74-84-0	Ethane	1.30E-04	4.75E-04	2.47E-03	1.05E-02
74-85-1	Ethylene	7.20E-03	1.15E-02	5.98E-02	1.37E-01
75-28-5	i-Butane	4.60E-05	7.00E-05	3.64E-04	5.60E-04
115-11-7	i-Butene	1.00E-03	2.90E-04	1.51E-03	8.40E-03
78-78-4	i-Pentane	2.60E-04	1.15E-03	5.98E-03	3.19E-03
74-82-8	Methane	8.00E-01	0.00E+00	0.00E+00	8.40E-01
96-37-7	Methylcyclopentane	2.50E-04	5.50E-05	2.86E-04	3.19E-03
106-97-8	n-Butane	4.80E-05	4.65E-04	2.42E-03	1.09E-03
124-18-5	n-Decane	5.90E-04	7.00E-04	3.64E-03	1.82E-03
142-82-5	n-Heptane	2.00E-04	2.35E-04	1.22E-03	1.75E-03
111-84-2	n-Nonane	1.20E-04	6.50E-04	3.38E-03	6.65E-04
111-65-9	n-Octane	2.90E-04	3.80E-04	1.98E-03	1.26E-03
109-66-0	n-Pentane	3.30E-04	2.15E-04	1.12E-03	4.55E-03
74-98-6	Propane	1.60E-04	2.25E-04	1.17E-03	1.65E-03
624-64-6	trans-2-Butene	2.40E-04	1.05E-03	5.46E-03	1.58E-03
646-04-8	trans-2-Pentene	4.60E-05	4.80E-05	2.50E-04	1.75E-03

Table 5. Maximum annual (pound/year) estimated emissions for the burn pan, burn cage (Forms 3 and 4), and detonation pad at the EWTF

Analyte ID	Analyte name	Burn pan	Burn cage Form 3	Burn cage Form 4	Detonation pad
67562-39-4	1234678-HpCDF	0.00E+00	1.70E-04	8.84E-04	0.00E+00
55673-89-7	1234789-HpCDF	0.00E+00	3.95E-05	2.05E-04	0.00E+00
70648-26-9	123478-HxCDF	0.00E+00	1.05E-04	5.46E-04	0.00E+00
57117-44-9	123678-HxCDF	0.00E+00	4.75E-05	2.47E-04	0.00E+00
39001-02-0	OCDF	0.00E+00	2.00E-04	1.04E-03	0.00E+00
106-99-0	1,3-Butadiene	1.70E-02	0.00E+00	0.00E+00	3.15E-01
121-14-2	2,4-Dinitrotoluene	1.20E-05	0.00E+00	0.00E+00	0.00E+00
606-20-2	2,6-Dinitrotoluene	1.00E-06	0.00E+00	0.00E+00	0.00E+00
95-57-8	2-Chlorophenol	1.00E-01	0.00E+00	0.00E+00	0.00E+00
7429-90-5	Aluminum	1.10E+02	1.80E+02	9.36E+02	8.75E+02
7440-36-0	Antimony	6.70E-03	0.00E+00	0.00E+00	2.35E-02
7440-39-3	Barium	8.20E+01	4.30E-01	2.24E+00	2.87E+02
71-43-2	Benzene	1.20E+00	2.25E+00	1.17E+01	3.85E+00
7440-43-9	Cadmium	4.00E-01	0.00E+00	0.00E+00	1.40E+00
56-23-5	Carbon tetrachloride	1.10E-02	2.80E-02	1.46E-01	1.58E-01
67-66-3	Chloroform	4.20E-03	1.15E-02	5.98E-02	1.33E-02
7440-47-3	Chromium	4.80E-01	0.00E+00	0.00E+00	3.08E+00
7782-50-5	Cl_2	9.20E+01	1.00E+00	5.20E+00	0.00E+00
630-08-0	CO	7.20E+02	1.00E+02	5.20E+02	1.86E+03
7440-50-8	Copper	3.70E+02	7.50E-02	3.90E-01	3.12E+02
110-82-7	Cyclohexane	1.60E-02	1.00E-02	5.20E-02	2.63E-01
122-39-4	Diphenylamine	2.60E-06	0.00E+00	0.00E+00	0.00E+00
75-00-3	Ethyl chloride	0.00E+00	0.00E+00	0.00E+00	2.42E-02
100-41-4	Ethylbenzene	1.20E-02	1.20E-02	6.24E-02	8.75E-02
206-44-0	Fluoranthene	0.00E+00	1.00E+00	5.20E+00	0.00E+00
7647-01-0	HCL	2.15E+03	4.15E+02	2.16E+03	0.00E+00
98-82-8	i-Propylbenzene	0.00E+00	0.00E+00	0.00E+00	2.56E-02
7439-92-1	Lead	1.20E+02	1.40E+00	7.28E+00	3.85E+01
74-87-3	Methyl chloride	5.70E-02	1.00E-01	5.20E-01	2.63E-02
71-55-6	Methyl chloroform	0.00E+00	0.00E+00	0.00E+00	1.33E-02
108-87-2	Methylcyclohexane	5.10E-02	4.00E-02	2.08E-01	2.45E-01
75-09-2	Methylenechloride	1.80E+00	6.00E-02	3.12E-01	3.05E+01
91-20-3	Naphthalene	7.50E-04	0.00E+00	0.00E+00	0.00E+00
110-54-3	n-Hexane	1.90E-01	2.40E-02	1.25E-01	6.65E-01
10102-44-0	Nitrogen dioxide (peroxide)	5.20E+01	3.30E-02	1.72E-01	1.54E+02

Analyte ID	Analyte name	Burn pan	Burn cage Form 3	Burn cage Form 4	Detonation pad
78-11-5	Pentaerythritol tetranitrate (PETN)	0.00E+00	0.00E+00	0.00E+00	1.96E+01
108-95-2	Phenol	3.43E-05	0.00E+00	0.00E+00	0.00E+00
115-07-1	Propene	7.20E-02	1.30E-01	6.76E-01	2.56E+00
121-82-4	RDX	9.60E-02	0.00E+00	0.00E+00	2.59E+02
100-42-5	Styrene	1.50E-02	0.00E+00	0.00E+00	1.47E+00
7446-09-5	Sulfur dioxide	3.20E+01	4.30E+00	2.24E+01	3.85E+01
127-18-4	Tetrachloroethylene	0.00E+00	8.50E-03	4.42E-02	6.30E-01
108-88-3	Toluene	8.60E-02	1.40E-01	7.28E-01	9.10E-01
75-01-4	Vinyl chloride	1.50E-02	0.00E+00	0.00E+00	4.55E-02
7440-66-6	Zinc	4.00E-01	2.85E+00	1.48E+01	3.85E+01
208-96-8	Acenaphthylene	0.00E+00	8.00E-01	4.16E+00	0.00E+00
86-57-7	n-Nitronaphthalene	1.40E-06	0.00E+00	0.00E+00	0.00E+00
620-14-4	m-Ethyltoluene	2.00E-02	1.30E-02	6.76E-02	1.68E-02
622-96-8	p-Ethyltoluene	7.10E-02	2.50E-02	1.30E-01	2.66E-01
106-98-9	1-Butene	1.60E-02	4.15E-02	2.16E-01	1.09E+00
592-41-6	1-Hexene	0.00E+00	0.00E+00	0.00E+00	8.40E-01
109-67-1	1-Pentene	1.40E-02	2.55E-02	1.33E-01	4.90E-01
74-86-2	Acetylene	8.30E+00	8.00E+00	4.16E+01	4.55E+00
627-20-3	cis-2-Pentene	4.60E-03	2.80E-03	1.46E-02	2.91E-02
287-92-3	Cyclopentane	4.70E-03	1.25E-03	6.50E-03	5.95E-02
142-29-0	Cyclopentene	4.60E-03	4.70E-03	2.44E-02	1.30E-01
74-84-0	Ethane	1.30E-02	4.75E-02	2.47E-01	1.05E+00
74-85-1	Ethylene	7.20E-01	1.15E+00	5.98E+00	1.37E+01
75-28-5	i-Butane	4.60E-03	7.00E-03	3.64E-02	5.60E-02
115-11-7	i-Butene	1.00E-01	2.90E-02	1.51E-01	8.40E-01
78-78-4	i-Pentane	2.60E-02	1.15E-01	5.98E-01	3.19E-01
74-82-8	Methane	8.00E+01	0.00E+00	0.00E+00	8.40E+01
96-37-7	Methylcyclopentane	2.50E-02	5.50E-03	2.86E-02	3.19E-01
106-97-8	n-Butane	4.80E-03	4.65E-02	2.42E-01	1.09E-01
124-18-5	n-Decane	5.90E-02	7.00E-02	3.64E-01	1.82E-01
142-82-5	n-Heptane	2.00E-02	2.35E-02	1.22E-01	1.75E-01
111-84-2	n-Nonane	1.20E-02	6.50E-02	3.38E-01	6.65E-02
111-65-9	n-Octane	2.90E-02	3.80E-02	1.98E-01	1.26E-01
109-66-0	n-Pentane	3.30E-02	2.15E-02	1.12E-01	4.55E-01
74-98-6	Propane	1.60E-02	2.25E-02	1.17E-01	1.65E-01
624-64-6	trans-2-Butene	2.40E-02	1.05E-01	5.46E-01	1.58E-01
646-04-8	trans-2-Pentene	4.60E-03	4.80E-03	2.50E-02	1.75E-01

Source term estimation is a difficult process for any waste treatment facility because the exact identity of the particular wastes that will be treated cannot be predicted with absolute certainty. The use of emissions factors, such as those presented in Bjorklund et al. (1998), enabled health conservative factors to be identified and used to set an upper bound on the possible future conditions. Further benefits of using the Bjorklund et al. (1998) data are that the data are approved by the U.S. EPA and available to the public, making calculations easily reproducible and transparent.

3.2 Exposure Assessment

3.2.1 Air Dispersion

The release of constituents of concern from OB/OD operations is to air. Generally, air dispersion modeling begins with (1) a stack height and (2) a plume rise associated with any momentum or temperature-induced flux that are added together and called the "effective release height." However, because open burns and open detonations do not occur in buildings with stacks, the air dispersion models that are commonly used in risk assessment, such as Industrial Source Complex Short-Term (ISCST) model, are not applicable, unless appropriate adjustments are made. Moreover, most air dispersion models assume continuous releases, not short-term releases such as those associated with OB/OD treatments. The Open Burn Open Detonation Dispersion Model (OBODM, Bjorklund et al., 1998) was developed specifically for OB/OD operations. The OBODM takes into account the short-term nature of OB/OD treatments (i. e., quasi-continuous and instantaneous releases) and incorporates unique equations specifically developed to model the effective release height for burns and detonations. This analysis used the OBODM to simulate the atmospheric release and dispersion of the constituents of concern from OB/OD operations at the EWTF.

The OBODM allows the user to input various treatment-specific data, including the mass of the material treated, duration of treatment, and whether the treatment is a burn or detonation. The OBODM allows the user to create a grid of receptors as well as up to 100 individual receptors not on the grid. It can be run in a mode that allows only one meteorological condition, or in a mode that allows many years of meteorological data to be taken into account. There are many output options available to the user; specific options used in this analysis are discussed below.

The OBODM was used to model the four different waste forms/treatments at the EWTF. Waste Form 1 was modeled as an instantaneous open detonation. Waste Forms 2, 3, and 4 were modeled as quasi-continuous open burns. The source material modeled was TNT. TNT was chosen because it had the lowest heat release of the commonly treated munitions, which, in turn, lowers the plume rise and the dispersion and increases the estimated concentrations to the downwind receptors.

The OBODM models one source material and chemical of concern per model run. However, because resulting air concentrations scale linearly with input emission rates, the OBODM output can be scaled to estimate the concentrations of all chemicals of concern for all waste forms. This type of scaling is consistent with the HotSpots Analysis and Reporting Program (HARP) model (described below), which was used to calculate theoretical cancer risks, chronic hazards and acute hazards. Barium was chosen as the scaling chemical. It was modeled at two different emission factor levels: 0.0082 for Forms 1 and 2 treatments, and at 0.000086 for Forms 3 and 4 treatments. The OBODM outputs were then input to the HARP model for scaling (see Appendix A for a description of the scaling approach). The OBODM and HARP input and output files are contained in Volume 2 (provided on the attached compact disc).

Four individual receptor locations were modeled (see Section 3.2.3) as well as locations necessary to complete the exposure pathways other than inhalation. Because the modeling region is located in complex terrain, the complex terrain option was employed, and the receptor elevations were input to the OBODM. The hours modeled were limited so that no operations would occur prior to 7:00 a.m. or after 6:00 p.m. PST. No limitations on wind speed were incorporated into the modeling because the OBODM warns that if such limitations were attempted the results may be invalidated. (The warning in the OBODM meteorological data limits menu states: "If any value in this menu is changed, program results may be invalid and cannot be supported by the authors of the OBODM program" [Bjorklund et al., 1998].)

Five years (2000-2004) of on-site hourly meteorological data were used in the modeling analysis. The Site 300 meteorological monitoring tower sensors record 15-minute average wind speed (from which average hourly wind speed is calculated), wind direction, sigma theta (standard deviation of the horizontal wind direction), temperature, delta temperature (delta-T is the difference in temperature between 2 and 10 meters), solar radiation and other parameters. The sensors meet or exceed the performance requirements found in the U.S. EPA document, *Meteorological Monitoring Guidance for Regulatory Modeling Applications* (U.S. EPA, 2000). The tower's equipment undergoes annual audits and calibrations. Data completeness for each of the 5 years far exceeds 90 percent. Prior to December 2003, the atmospheric stability class was calculated using the sigma theta and mean wind speed method. After December 2003, the atmospheric stability class was calculated using the solar radiation/delta-T method.

Hourly, site-specific mixing height data are not available for Site 300. Therefore, a reasonable, yet conservative mixing height value of 600 meters was assumed for the entire 5-year dataset. A 600-meter mixing height is reasonable yet conservative choice because 600 meters is lower than the mixing height that would be applied in common practice,[2] thus resulting in a lower vertical mixing layer, less vertical dispersion and higher air concentrations. For the open burns, maximum plume height is less than 100 meters and, for the open detonations, less than 264 meters; therefore, the use of a 600-meter mixing height ensured that the plume would neither be above the mixing layer where the plume would remain trapped nor mix downward to contribute to ground-level concentrations.

The meteorological data was entered into the OBODM (and ISCST) model-ready format. The meteorological data file (Sit3y5.vec) is on the compact disk provided with this risk assessment.

3.2.2 Receptors

Site 300 is located in a scarcely populated area, and only about 5 percent of the area is developed (see Figure 7). However, two residences are located very near the southern boundary of the site. One is located to the southeast of the Site 300 boundary; the other, the residence of the park rangers for the Carnegie Vehicle Recreation Park, is located near the middle of Site 300's southern boundary. Both locations were evaluated to determine the location of maximum impact. Similarly, two other locations on site at Site 300 were evaluated. These locations were the Building 812 Complex and Building 895 where bystander workers—i.e., workers who are not conducting EWTF operations—are present (see Figure 8).

[2] For mixing heights in rural areas, the common practice is to apply the mean afternoon mixing height given by Holzworth (1972) to stability classes B, C and D, and 1.5 times the mean afternoon mixing height to stability class A (U. S. EPA, 1995). Holzworth (1972) indicates that the annual average afternoon mixing height, for the Site 300 area, is approximately 1200 meters. Following common practice would result in mixing height values of 1600 meters for stability class A and 1200 meters for stability classes B, C and D. Furthermore, the Industrial Source Complex Long-Term model assumes unlimited mixing for stability classes E and F for both rural and urban conditions, and a large value such as 10,000 meters may be input for those classes (U. S. EPA, 1995).

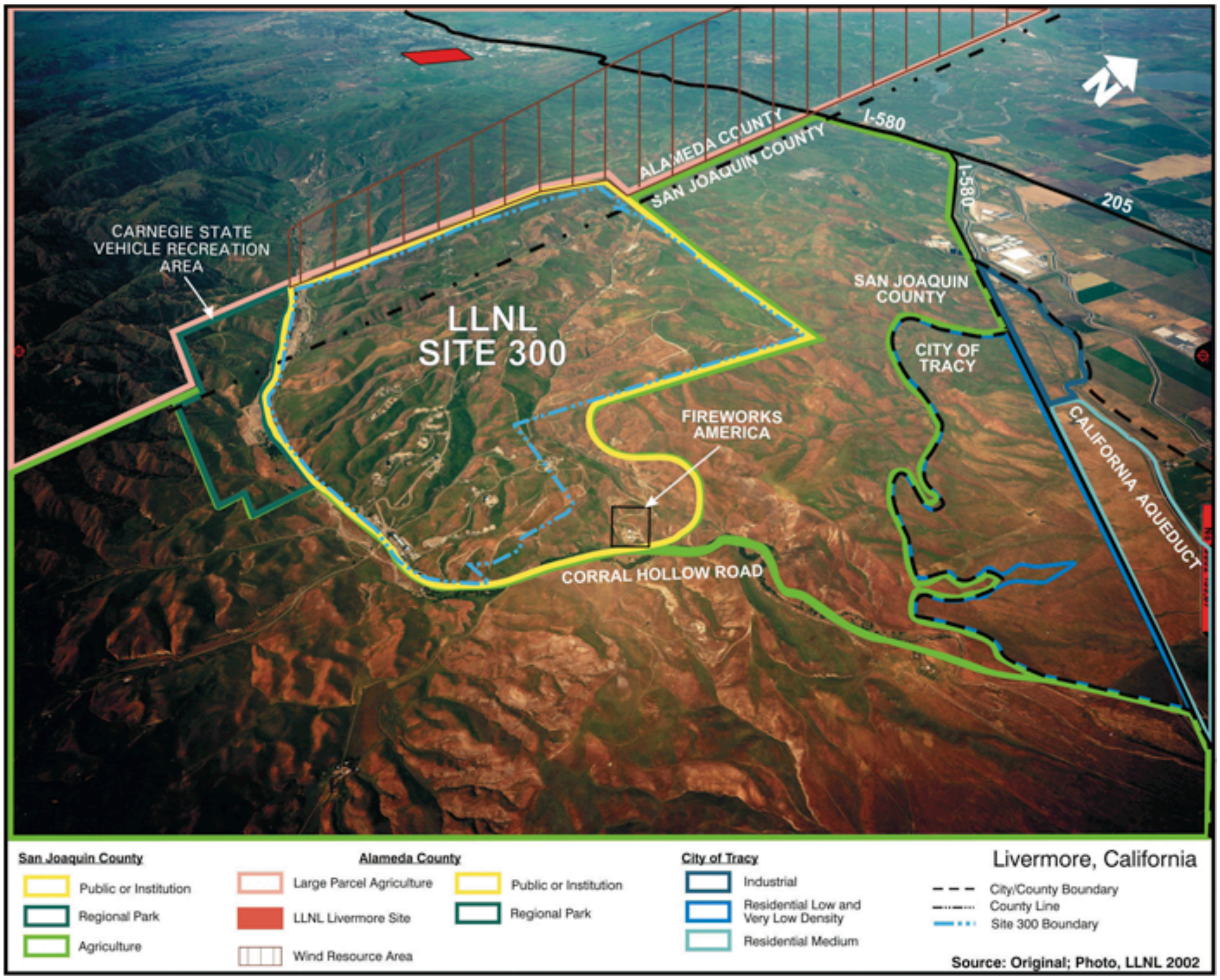


Figure 7. Site 300 environs.

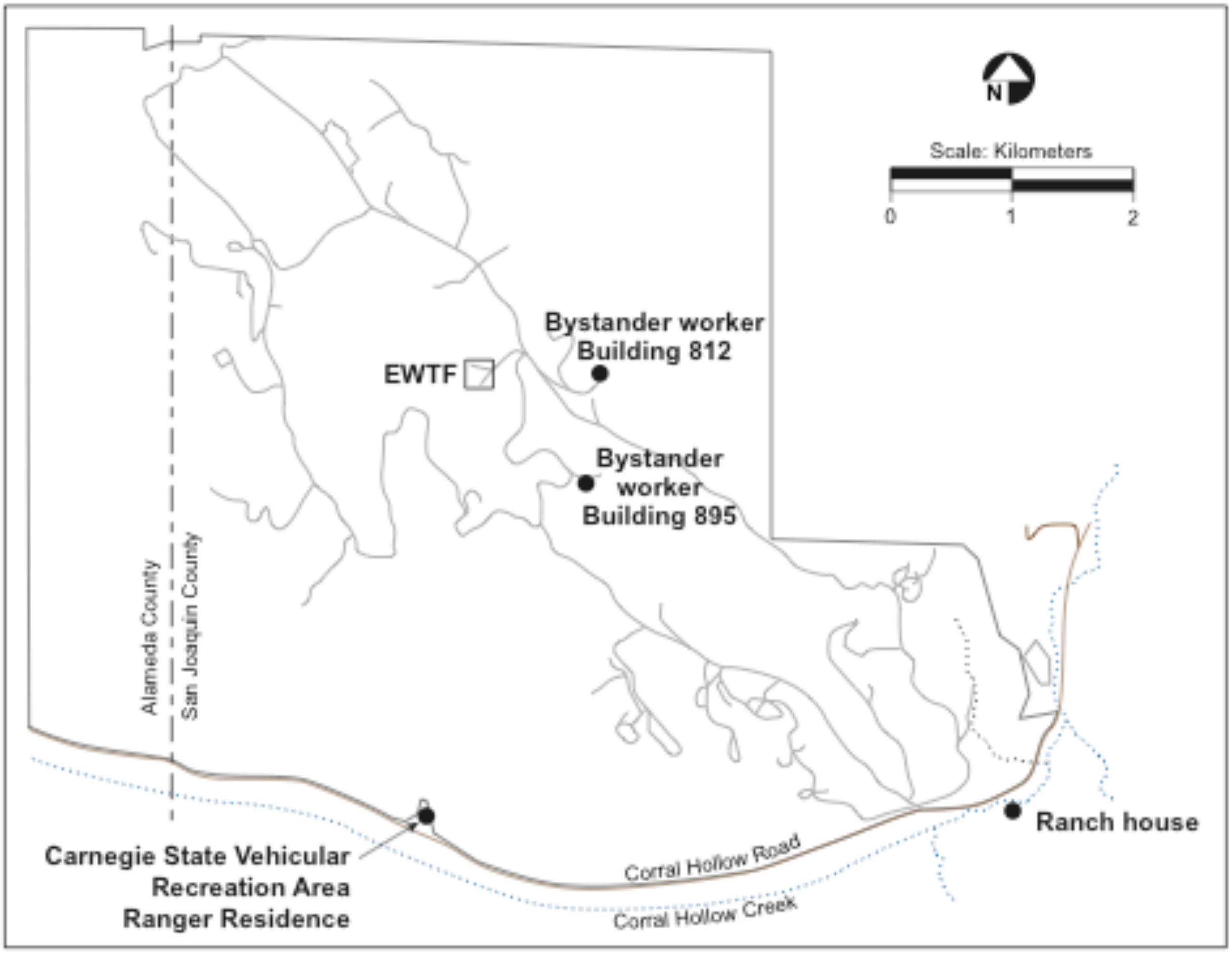


Figure 8. Locations of potentially maximally exposed receptors.

Two types of off-site receptors were evaluated for theoretical carcinogenic risk: a child for the first 9 years of life and a child/adult for a 30-year residence period. A 30-year residency is the 95th-percentile estimate of population mobility stated in the *Exposure Factors Handbook* (U.S. EPA, 1997). The on-site bystander worker was evaluated for a 25-year work duration for theoretical carcinogenic risk—a tenure that is well above the U.S. EPA-recommended occupational tenure value of 6.6 years (U.S. EPA, 1997). For non-carcinogenic hazard, because of the limitations of the risk assessment tool (California Air Resources Board [CARB], 2003), only the adult 70-year exposure was considered.

3.2.3 Exposure Pathways

Inhalation was the primary exposure pathway of concern for all receptors. The residential receptors also have the possibility of dermal exposure, ingestion of homegrown produce and meats, and incidental soil ingestion. Because furans have been included as constituents of concern, this assessment followed OEHHA guidance and evaluated the mother's milk exposure pathway (OEHHA, 2003, p. 5-3).

OEHHA guidance on worker exposure is that those individuals have potential exposure due to incidental soil ingestion and dermal exposure. However, dermal exposure is an exposure pathway for which exposure factors have been developed for outside workers, such as construction workers, gardeners, and utility workers (U.S. EPA, 2004b, p. 3–15). Bystander worker areas identified for the EWTF are for inside workers. In view of the lack of exposure factor data available for indoor workers and the low probability that indoor workers have dermal exposure to soil, this risk assessment did not calculate the dermal exposure pathway for bystander worker. The HARP model (CARB, 2003) was used to calculate theoretical carcinogenic risk and acute and chronic non-carcinogenic hazard. The HARP model, a multi-pathway model, includes calculations for inhalation, ingestion, dermal and mother's milk pathways. The model contains default CARB/OEHHA-recommended exposure parameters, which, in some cases, can be adjusted to better fit the factual situation. The exposure parameters used in this risk assessment along with their regulatory sources are listed in Table 6. In addition, the HARP model offers a choice of analysis methods for theoretical carcinogenic risk, including average and high-end point estimates and stochastic estimates. For this risk assessment, the high-end point estimate was used, and the high-end exposure parameters are listed in Table 6.

Table 6. Exposure parameters used in the EWTF risk assessment[a].

Exposure parameter	Child (9-year exposure)	Adult resident (30-year exposure)	Adult worker (25-year exposure)
Body weight (kg)	18	63	70
Exposure frequency (d/y)	350	350	245
Inhalation rate [L/(kg•d); 95th percentile]	581 (10.46 m^3/day)	393 (24.76 m^3/day)	149 (10.4 m^3/day)
Soil Loading [mg/(cm^2•d); 95th percentile]	1.0	1.0	1.0
Exposed skin surface area (cm^2; 95th percentile)	3044	5500	Not applicable
Soil Ingestion Rate [mg/(kg•d)]	8. 7	1.7 [b]	0.7[c]

[a] Unless otherwise noted, all parameters are implemented in the HARP (CARB, 2003) as described in OEHHA (2003) and represent high endpoints.

[b] Corresponds to 100 mg/day.

[c] U.S. EPA, 1997; corresponds to 50 mg/day.

The HARP (CARB, 2003) contains detailed calculations for the ingestion pathway, including the portions of the various types of foods ingested and the uptake of contaminants by agricultural animals. The home-produced fractions of the diet were adjusted to reflect local conditions. Table 7 shows the fractions that were changed for this risk assessment and their default values. (Although some of the default factors were set at 1, a common screening model representation of a hypothetical exposure, it is unlikely that any individual in California obtains all of his beef, pork, chicken, dairy, and eggs from one location.) The fractions used in the assessment were all obtained from the U.S. EPA's *Exposure Factors Handbook*, Table 13-71 (U.S. EPA, 1997), using the values stated for non-metropolitan areas.

Table 7. Food consumption fraction estimated to be affected by the EWTF.

Food type	Value used in risk assessment[a]	HARP default value[b]
Exposed produce	0.207	0.15
Leafy produce	0.082 (cabbage)	0.15
Protected produce	0.134	0.15
Root produce	0.088	0.15
Beef	0.107	1.0
Chicken	0.026	1.0
Pork	0.04	1.0
Dairy	0 (Not applicable)	1.0
Eggs	0.029	1.0

[a] U.S. EPA, 1997, Table 13-71, non-metropolitan.
[b] CARB, 2003.

The concentrations of contaminants of concern in the non-inhalation pathways were calculated in the HARP, based on a single deposition velocity for all contaminants of concern, and did not take into account particle size or mass. The default deposition velocity in the HARP is 0.05 m/s for uncontrolled sources—an extremely conservative value. An authoritative review article by Sehmel (1980) on particle dry deposition indicates that only the largest particles would have such a deposition velocity. Moreover, particles with a deposition velocity of 0.05 m/s would, in reality, deposit very close to the source and would not deposit at the distances to residences of interest in this risk assessment. To be conservative, but realistic, a deposition velocity measured for dioxin was chosen to represent all contaminants of concern; this deposition velocity is 0.0072 m/s (Wevers et al., 2004).

3.3 Dose-Response Assessment

The dose-response effects of chemicals in the environment are the subject of state and federal regulatory guidance. The cancer potency factors (CPFs), the acute and chronic inhalation reference exposure levels (RELs), and the chronic oral reference doses (RfDs) used in this assessment were compiled, first, from the OEHHA guidance as incorporated into the HARP model in the file called the health.mdb file, with a secondary source of such data obtained from a table in the U.S. EPA Region 9 Preliminary Remediation Goal (PRG; U.S. EPA, 2004a). The U.S. EPA (2004a) table lists the CPFs and RELs used in deriving the preliminary remediation goals. Table 8 presents the CPFs, RELs, and RfDs used in this risk assessment.

Table 8. Cancer potency factors, relative exposure levels, and reference doses for chemicals of concern for the EWTF.

Material CAS Number	Material name	Inhalation cancer slope factor [a] [1/(mg/kg-d)]	Oral cancer slope factor [a] [1/(mg/kg-d)]	Inhalation chronic REL [a] (μg/m3)	Oral chronic RfD [a] (mg/kg-d)	Acute REL (μg/m^3)
106-99-0	1,3-Butadiene	6.00E-01		2.00E+01		
67562-39-4	1234678-HpCDF	1.30E+03	1.30E+03	4.00E-03	1.00E-06	
55673-89-7	1234789-HpCDF	1.30E+03	1.30E+03	4.00E-03	1.00E-06	
70648-26-9	123478-HxCDF	1.30E+04	1.30E+04	4.00E-04	1.00E-07	
57117-44-9	123678-HxCDF	1.30E+04	1.30E+04	4.00E-04	1.00E-07	
121-14-2	2,4-Dinitrotoluene	3.10E-01	*6.10E-01*	*7.30E+00*	*2.00E-03*	
606-20-2	2,6-Dinitrotoluene	*6.80E-01*	*6.80E-01*	*3.70E+00*	*1.00E-03*	
95-57-8	2-Chlorophenol			1.80E+01	*5.00E-03*	
7429-90-5	Aluminum			*5.10E+00*	*1.00E+00*	
7440-36-0	Antimony			2.00E-01		
7440-39-3	Barium			*5.20E-01*	*7.00E-02*	
71-43-2	Benzene	1.00E-01		6.00E+01		1.30E+03
7440-43-9	Cadmium	1.50E+01		2.00E-02	5.00E-04	
56-23-5	Carbon Tetrachloride	1.50E-01		4.00E+01		1.90E+03
67-66-3	Chloroform	1.90E-02		3.00E+02		1.50E+02
7440-47-3	Chromium				*1.50E+00*	
7782-50-5	Cl_2			2.00E-01		2.10E+02
630-08-0	CO					2.30E+04
7440-50-8	Copper			2.40E+00	*4.00E-02*	1.00E+02
110-82-7	Cyclohexane			*6.20E+03*	*1.70E+00*	
122-39-4	Diphenylamine			*9.10E+01*	*2.50E-02*	
75-00-3	Ethyl chloride	*2.90E-03*		3.00E+04		
100-41-4	Ethylbenzene			2.00E+03		
206-44-0	Fluoranthene			*1.50E+02*	*4.00E-02*	
7647-01-0	HCL			9.00E+00		2.10E+03
98-82-8	i-Propylbenzene (cumene)			*4.00E+02*	*1.00E-01*	
7439-92-1	Lead	4.20E-02	8.50E-03			
74-87-3	Methyl chloride (Chloromethane)			*4.50E+01*		
71-55-6	Methyl chloroform (1,1,1-TCA)			1.00E+03		6.80E+04
108-87-2	Methylcyclohexane			*3.10E+03*		
75-09-2	Methylenechloride	3.50E-03		4.00E+02		1.40E+04
91-20-3	Naphthalene	1.20E-01		9.00E+00		

Material CAS Number	Material name	Inhalation cancer slope factor [a] [1/(mg/kg-d)]	Oral cancer slope factor [a] [1/(mg/kg-d)]	Inhalation chronic REL [a] (μg/m3)	Oral chronic RfD [a] (mg/kg-d)	Acute REL (μg/m^3)
110-54-3	n-Hexane			7.00E+03		
10102-44-0	Nitrogen dioxide (peroxide)			4.70E+02		4.70E+02
39001-02-0	OCDF	1.30E+01	1.30E+01	4.00E-01	1.00E-04	
108-95-2	Phenol			2.00E+02	*3.00E-01*	5.80E+03
115-07-1	Propene			3.00E+03		
121-82-4	RDX	*1.10E-01*	*1.10E-01*	*6.10E-02*	*3.00E-03*	
100-42-5	Styrene			9.00E+02		2.10E+04
7446-09-5	Sulfur dioxide			6.60E+02		6.60E+02
127-18-4	Tetrachloroethylene	2.10E-02		3.50E+01		2.00E+04
108-88-3	Toluene			3.00E+02		3.70E+04
75-01-4	Vinyl chloride	2.70E-01		2.60E+01		1.80E+05
7440-66-6	Zinc			3.50E+01	*5.00E-02*	

[a] Toxicity factors in italics are from U.S. EPA (2004a) all others are from CARB (2003).

Neither the HARP model nor the U.S. EPA PRG table had toxicity data available for 27 constituents of concern. Because of the uncertainty in the source term, it seemed reasonable to choose surrogates from the other constituents based on the fundamental structure of the molecule for which toxicity data were unavailable. On that basis, RDX was chosen as a surrogate for PETN; naphthalene was chosen as a surrogate for acenaphthalene and 1-nitronaphthalene; ethylbenzene was chosen as a surrogate for m- and p–ethyltoluene; and hexane was chosen as a surrogate for short-chain and cyclic aliphatic hydrocarbons. A petroleum-industry toxicological review undertaken by the Total Petroleum Hydrocarbon Criteria Working Group (TPHCWG, 1997, p. 8) to develop reference doses and reference concentrations evaluates materials by number of carbons in the compound and whether or not the material is aromatic or aliphatic. Consequently, hexane is a reasonable surrogate for these compounds.

3.4 Risk Characterization

3.4.1 OBODM/HARP Interface

As previously mentioned, the OBODM is limited to the evaluation of one constituent of concern at a time; and it has no capability for assessing risk or hazard. On the other hand, the HARP is capable of handling many chemicals simultaneously; and it incorporates the OEHHA methodology for assessing theoretical carcinogenic risk and non-carcinogenic hazard for the inhalation, food and incidental soil ingestion, and dermal and mother's milk exposure pathways. (In this risk assessment, HARPExpress, a commercial user interface to the HARP model was actually used.)

The HARP model is, in fact, three separate computer programs linked together. The first program is a database program in which the user enters site-specific data, such as building locations, emissions locations, emissions characteristics (usually stack height, diameter and release rate) and annual and maximum emissions. The second program is the ISCST model, a U.S. EPA continuous emission model for dispersion of air pollutants based on the Gaussian plume dispersion equations. The third program is the OEHHA-approved risk assessment equations combined with a database of OEHHA-approved toxicity factors, by which theoretical carcinogenic risk and acute and chronic non-carcinogenic hazard are calculated.

Because, for reasons previously discussed, the ISCST model is not the most reasonable model to use for OB/OD operations, the OBODM model is the preferred model for these operations. However, because the HARP model is functionally three separate models linked together, it was possible to run both the HARP model and the OBODM model with the same emissions scenarios and replace the ISCST output with the OBODM output. The details of the HARP/OBODM interface are presented in Appendix A.

3.4.2 Identification of Maximally Exposed Receptors

Theoretical carcinogenic risk and acute and chronic non-carcinogenic hazard were calculated within the HARP (with the OBODM dispersion results), using OEHHA-approved equations. The calculations were conducted for the two possible off-site residential receptors and for the two closest on-site locations of bystander workers. When the HARP provides the results for more than one receptor, the HARP output cannot be interrogated by source contribution. Because the contribution of each waste form was not known before the HARP model was run, all waste forms were modeled as if 100 events occurred annually in order to screen the waste forms and identify the maximally exposed receptors. Therefore, the screening level health effects for identifying the maximally exposed receptors were for a total of 100 detonations and 300 burns (100 from each form of waste). These screening results yielded greater health effects than would occur under the permit condition limits of no more than 100 detonations and 100 burns. (Historically, annual treatments are much less, both in frequency and mass, than the permitted limits.) The results of the HARP model screening runs are shown in Table 9. Output from the runs is in Volume 2 of this risk assessment (provided on a compact disc.)

Table 9. Screening results for identification of maximally exposed receptors.

Receptor	Carcinogenic risk	Chronic hazard index	Acute hazard index
Carnegie Ranger Station (SW)	0.0000007	0.02	0.02
Ranch Residence (SE)	0.0000004	0.01	0.01
Bystander Worker Building 812 (E)	0.0000006	0.3	0.2
Bystander Worker Building 895 (SE)	0.0000007	0.3	0.3

3.4.3 Effects on Maximally Exposed Receptors

After the maximally exposed receptors were identified, the HARP model was run again for the two individual receptors—the resident at the Carnegie State Vehicular Park ranger residence and the bystander worker at Building 895—to determine the contribution of each of the EWTF sources to the risk, and the risk outcome for the permitted level of treatments of 100 open detonations and 100 open burns. The 100 burns were represented by the greatest value among the three waste forms that are treated by burning. Because the acute hazard index is a measure of the greatest possible 1-hour exposure, the result of interest is the highest 1-hour hazard index for a single waste form, not the total of all waste forms. These results are presented in Table 10. The HARP output is contained in Volume 2 (provided on a compact disc).

In contrast to the 30-year exposure duration for the assessment of theoretical carcinogenic risk, chronic hazard values were calculated for a 70-year exposure because the HARP model uses chronic RELs based on ambient air concentrations, rather than RfDs based on exposures, receptor body weight, and exposure duration. When an REL is developed, an exposure duration is assumed. In the case of the RELs used in the HARP model, the exposure duration is 70 years. This also means that a chronic hazard specific to childhood exposure cannot be calculated. In addition, the acute hazard calculation, while fundamentally the same for both the bystander worker and residential receptors, uses a greater inhalation rate for the worker than for the resident (1.3 m^3/h for the worker and 1.0 m^3/h for the resident). The result for the chronic hazard index reported by the HARP model is the maximum value among the target organs or systems evaluated. In all cases in this EWTF health evaluation, the maximally affected organ/system was the respiratory system.

Table 10. Theoretical health effects for maximally exposed receptors.

Receptor	Treatment unit (waste form)	Risk adult (30-year exposure)	Risk child (9-year exposure)	Chronic hazard index	Acute hazard index
Carnegie ranger residence (SW)	Open Detonation (Form 1)	0.0000004	0.0000003	0.002	0.02
	Burn Pan (Form 2)	0.00000004	0.00000002	0.01	0.01
	Burn Cage (Form 3)	0.00000004	0.00000002	0.0008	0.0004
	Burn Cage (Form 4)	0.0000002	0.0000001	0.004	0.002
	Total (100 OD + 300 OB)	0.0000007	0.0000004	0.02	Max: 0.02
	Current permit limits (100 OD + 100 OB)	0.0000006	0.0000004	0.01	Max: 0.01
Bystander worker (Building 895)	Open Detonation (Form 1)	0.0000004	Not applicable	0.02	0.1
	Burn Pan (Form 2)	0.0000001	Not applicable	0.2	0.2
	Burn Cage (Form 3)	0.00000003	Not applicable	0.01	0.006
	Burn Cage (Form 4)	0.0000001	Not applicable	0.05	0.03
	Total (100 OD + 300 OB)	0.0000007		0.3	Max: 0.3
	Current permit limits (100 OD + 100 OB)	0.0000006		0.2	Max: 0.3

The carcinogenic risk to a 30-year resident at the maximum off-site receptor location is 0.0000006 or 0.6 in 1 million. The carcinogenic risk to a 25-year worker at the maximum bystander on-site receptor location is also 0.0000006 or 0.6 in 1 million. Any risk of less than 1 in a million is below the level of regulatory concern. The acute non-carcinogenic hazard for the 30-year resident is 0.01, and the chronic non-carcinogenic hazard is 0.01. The acute non-carcinogenic hazard for the 25-year worker is 0.3, and the chronic non-carcinogenic hazard is 0.2. The point of comparison for acute and chronic non-carcinogenic hazard is 1.0; an estimate less than 1.0 is below the level of regulatory concern. The estimates of health effects are based on health conservative assumptions and represent an upper bound of the possible exposures to the receptors.

3.5 Lead

Possible emissions from OB/OD operations at the EWTF of Site 300 include elemental lead (Pb). The chronic non-cancer effects of lead exposure are related to blood-lead levels (as opposed to ambient air concentrations). The health risk from exposure to lead in this risk assessment was determined using the lead risk assessment spreadsheet obtained from the California Department of Toxic Substances Control (DTSC, 2000).

The DTSC Lead Risk Assessment Spreadsheet—LeadSpread 7 (DTSC, 2000)—is a model for estimating blood-lead concentrations resulting from exposure to lead via dietary intake, soil and dust ingestion, inhalation, and dermal contact. The modeled concentrations of lead in air and soil 1 cm deep at the Carnegie State Vehicular Park ranger residence and at the bystander worker location (Building 895) were used in the LeadSpread 7 calculations.

LeadSpread 7 contains equations that relate incremental blood-lead increase to a concentration in an environmental medium, using currently accepted contact rates and empirically determined ratios. Exposure-pathway contributions to blood-lead levels were summed to arrive at an estimate of the median blood-lead concentration for multiple exposure pathways. The 99th-percentile concentration was then estimated from the median value by assuming a lognormal distribution for blood-lead concentration with a geometric standard deviation (GSD) of 1.6. The blood-lead concentration of concern for children and adults is 10 μg Pb/dL, and risk management is considered applicable if there is a 0.01 risk of exceeding this value (DTSC, 1996).

Table 11 contains the values for the input factors required for performing the necessary calculations using LeadSpread 7. The air and soil/dust were obtained from the OBODM/HARP atmospheric dispersion and deposition modeling (Bjorklund et al., 1998; CARB, 2003), and the percentage of homegrown produce consumed for the residence is the average of the data presented in Table 7. The default value for respirable dust already incorporated into LeadSpread 7 was not changed.

Table 11. Values for input factors required for the lead risk assessment spreadsheet model, LeadSpread 7.

Environmental medium	Carnegie ranger residence	Bystander worker (Bldg. 895)
Air	0.00182 μg Pb/m^3	0.0286 μg Pb/m^3
Soil/dust	1.09 μg Pb/g	17.0 μg Pb/g
Home-grown produce	13% of diet	0% of diet
Respirable dust	1.5 μg Pb/m^3	1.5 μg Pb/m^3

Table 12 contains the 99th-percentile blood-lead levels predicted from lead emissions for adult and child exposures at the ranger residence location and for adult-worker exposures at Building 895. None of the receptors, even the pica-child, is expected to achieve a blood-lead level that equals the 10 μg Pb/dL level at the 99th-percentile upper confidence limit. Consequently, no receptor is considered to attain a concentration of lead in blood that would be considered to be of concern.

Table 12. Predicted blood-lead levels for adult and child exposures at the ranger residence location and for adult-worker exposures at the Building 895 location using the lead risk assessment spreadsheet model, LeadSpread 7.

Percentile estimate of blood lead concentration	Adult exposure at Carnegie ranger residence (μg/dL)	Child exposure at Carnegie ranger residence (μg/dL)	Pica-child exposure at Carnegie ranger residence (μg/dL)	Bystander worker exposure at Building 895 (μg/dL)
99th	0.6	1.5	1.5	0.8

4. Ecological Risk Assessment

The Ecological Risk Assessment (ERA) for the EWTF was conducted following currently accepted practice. This practice involves seven steps.

1. Each contaminant of potential ecological concern (CPEC) emission from the OB/OD operations at the Site 300 EWTF was identified, and its soil concentration over a 6-inch (15-cm) depth (mg/kg_{soil}) was predicted for a receptor location of interest based on atmospheric dispersion and deposition modeling.

2. Representative receptors of ecological interest (RREIs) were selected in the habitat of interest for each trophic level of the applicable wildlife food web. A reasonable approximation of total daily dietary intake was obtained from the literature for each vertebrate RREI and quantified per unit body weight (i.e., avian, reptile, and mammal [mg/[kg_{bw} d]); whereas, a lowest observed adverse effect concentration (LOAEC; mg/kg_{soil}), obtained for the earthworm from data in the literature, was applied to invertebrates. Plants were evaluated as a separate vegetation category of RREI, and a LOAEC (mg/kg_{soil}) generalizeable to all plants was obtained from the literature for this purpose.

3. For each vertebrate RREI evaluated (i.e., avian, reptile, and mammal), a location-specific minimum ecological soil screening level ($ESSL_{LS\text{-}min}$; mg/kg_{soil}) concentration is derived for each CPEC emission based on an applicable low toxicity reference value (TRV_{Low}). Each applicable TRV_{Low} corresponds to a no observed adverse effect level (NOAEL) for the respective vertebrate. This was not done for invertebrates and plants because a lowest observed adverse effect concentration (LOAEC) is interpreted to represent the $ESSL_{LS\text{-}min}$ for the invertebrate and vegetation category of RREI. Accordingly, each respective $ESSL_{LS\text{-}min}$ corresponds to a location-specific concentration in soil that is considered protective of a particular wildlife (wlf) receptor (e.g., mammal, bird, reptile, invertebrate, or plant) at each trophic level of the food web that might have contact with such soil, directly or indirectly. Note, it is assumed in ecological risk assessment practice that for plants and invertebrates that if the LOAEC threshold is not exceeded significantly by a soil concentration, it is unlikely there will be any impact to these elements of the food web (Suter et al., 2000).

4. The most conservative (lowest) location-specific minimum animal "$ESSL_{LS\text{-}min}$" is selected from a comparison among all of the non-vegetation wildlife (wlf) $ESSL_{LS\text{-}min}$ values—reptile (wlf = rep), avian (wlf = brd), invertebrate (wlf = inv) and mammal (wlf = mam) RREI . The $ESSL_{LS\text{-}min}$ for the vegetation category is addressed separately, where that LOAEC is generalized to be applicable to all plants and so is considered to represent the $ESSL_{LS\text{-}min}$ for plants. Further plants are evaluated first with respect to measured concentrations of CPECs, which are considered background soil concentrations. These measured soil concentrations were available only for seven metals considered applicable across Site 300. Next, the CPECs for

which measured soil concentrations exist are evaluated for plants with respect to model–predicted concentrations.

5. The most conservative animal $ESSL_{LS\text{-}min}$ is then compared to the respective CPEC-specific soil concentrations predicted from atmospheric dispersion and deposition modeling at specific receptor locations near and around the EWTF over a depth of 6 inches (15 cm) . This comparison was made by dividing each modeled CPEC-specific soil concentration value at a specific location by the applicable most conservative animal $ESSL_{LS\text{-}min}$ value, where the result equates to a location-specific maximum ecological hazard quotient ($EHQ_{LS\text{-}max}$) for animal RREIs with respect to the CPEC at the selected location. Thus, a CPEC-specific $EHQ_{LS\text{-}max}$, or the sum of CPEC-specific $EHQ_{LS\text{-}max}$ values for a category of CPEC with similar toxic action, that exceeds one for the animal RREIs suggests further examination for the possibility for adverse ecological impact. CPEC-specific $EHQ_{LS\text{-}max}$ values also were computed at all receptor locations near the EWTF for two RREIs of particular concern at Site 300—the San Joaquin Kit Fox and the Burrowing Owl—and these sensitive-organism specific $EHQ_{LS\text{-}max}$ values were based on $ESSL_{LS\text{-}min}$ values derived specifically for these particular organisms (which may or may not equate to the most conservative [lowest] animal $ESSL_{LS\text{-}min}$). A similar evaluation was performed for plants with respect to measured soil concentrations and model-predicted concentrations for those measured CPECs. Here, the contribution of a model-predicted result to a measured based result was also compared.

6. For those CPECs for which an $EHQ_{LS\text{-}max}$ value for animal wildlife exceeds one, an additional evaluation is performed that derives an $ESSL_{LS}$ value for these substances for vertebrate animals (i.e., mg/kg_{soil}) that in this case will equate to a lowest observed adverse effect level (LOAEL). The resulting EHQ_{LS} derived using these higher $ESSL_{LS}$ values will be lower than the $EHQ_{LS\text{-}max}$ values. This is because the $ESSL_{LS}$ used to derive them are not the most protective and so are not the lowest possible. In this case, the most conservative (lowest), location specific maximum vertebrate $ESSL_{LS\text{-}max}$ is now used to compute the new $EHQ_{LS\text{-}min}$, which will be less than the $EHQ_{LS\text{-}max}$. Again, this $ESSL_{LS\text{-}max}$ will be the lowest from among all those calculated for avian, reptile, and mammal RREIs, and it is derived using the TRV_{High} or a comparable value (i.e., a 10-fold increase in the TRV_{Low}, where a TRV_{High} is not available in the literature). Because the lowest observed adverse effect concentration (LOAEC) was already considered for the invertebrate, that animal category is not addressed in this additional screening analysis. Also no further screening is performed for plants because for vegetation the LOAEC was already employed for screening. $EHQ_{LS\text{-}min}$ values for those CPECs with $EHQ_{LS\text{-}max}$ values greater than one are also determined at all six receptor locations for the two species of particular concern at Site 300—the San Joaquin Kit Fox and the Burrowing Owl.

7. In the last phase of screening, those 7 CPEC metals for which measurement of soil concentrations exist at Site 300 (and are considered to be background levels) are examined with regard to potential impact on animal wildlife RREIs. The screening of these 7 metal CPECs is performed first with respect to $EHQ_{LS\text{-}max}$ values for all

animal wildlife. Then, additional screening is performed with respect to any CPECs not filtered from further consideration by this process. For this additional screening thresholds for soil screening level concentrations for these particular CPECs are derived from lowest observed adverse effect levels (LOAELs). Thus, the location-specific soil screening level that is used to evaluate each of these metals will be applicable to a vertebrate RREI, and will have a value greater than the $ESSL_{LS-min}$ used previously for a vertebrate RREI. (As mentioned in Step 6, no additional screening is performed for invertebrates or plants because LOAEC values have already been used as $ESSL_{LS-min}$ values for these members of the food web.) Consequently, each ecological soil screening level used for purposes of this additional screening is going to be a maximum ($ESSL_{LS-max}$), and because this $ESSL_{LS-max}$ is used in the denominator of the ecological hazard quotient (EHQ), the result will be a minimum (i.e., EHQ_{LS-min}). In concluding this last phase of screening, all 7 metal CPECs for which measurement data exists for Site 300 are then evaluated with respect to the two organisms of particular concern at Site 300 (the San Joaquin Kit Fox and the Burrowing Owl) and this is done by first using EHQ_{LS-max} values and then EHQ_{LS-min} values specific to these two organisms and all 7 CPEC metals measured at Site 300.

The details of all the calculations for the ecological risk assessment are provided in Appendix B. A summary of the various ecological site investigations that have been conducted at Site 300 is presented in Appendix E of the *Final Site-side Environmental Impact Statement for Continued Operation of Lawrence Livermore National Laboratory and Supplemental Stockpile Stewardship and Management Programmatic Environmental Impact Statement* (DOE/NNSA 2005). The 21 CPECs emitted from the EWTF that are to be evaluated are categorized in Table 13.

The 10 RREIs addressed are 5 categories of mammals, 1 reptile, 2 categories of birds, the soil invertebrate, and vegetation, all of which appear in Table 14 (see also Figure B-1 in Appendix B). The individual exposure pathways considered relevant for each animal RREI were incidental ingestion of contaminated soil particles and ingestion of forage or prey for which uptake of a CPEC from soil or forage or prey was estimated using a bioaccumulation factor (BAF), which is the ratio of uptake of a CPEC in a specific dietary matter to its concentration in soil. For purposes of conservatism, all the living, foraging, and prey capturing by the RREIs were considered to occur in the habitat associated with OB/OD operations and the absorption fraction of each CPEC for each RREI was considered to be 100 percent.

Table 15 (where invertebrate data do not appear because the $ESSL_{LS}$ for the invertebrate was taken directly from the literature) shows the eight vertebrate organisms of interest and their body weight and dietary behavior. This information (along with

Table 13. The 21 contaminants of potential ecological concern (CPECs) at the EWTF.

Five PCDFs[a]	Three energetics and other thermally labile compounds[b]	Eight metals	Five SVOCs
1-4, 6-8 HpCDF	2,4-Dinitrotoluene	Aluminum	2-Chlorophenol
1-4, 7-9 HpCDF	2,6-Dinitrotoluene	Antimony	Diphenylamine
1-4, 7, 8 HxCDF	RDX	Barium	Fluoranthene[d]
1-3, 6-8 HxCDF		Cadmium[c]	Naphthalene[d]
1-9 OCDF		Chromium	Phenol
		Copper	
		Lead[c]	
		Zinc	

[a] All PCDFs are considered to have similar toxic action.

[b] All energetics are considered to have similar toxic action.

[c] Only cadmium (Cd) and lead (Pb) are considered to have similar toxic action.

[d] Only the polycyclic aromatic hydrobarbons (PAHs)—fluoranthene and naphthalene—are considered to have similar toxic action (based on similar chemical structures).

Table 14. Ten representative receptors of ecological interest (RREIs) at the EWTF.

Mammals	Reptile	Birds	Soil Invetebrate	Vegetation
Omnivorous small mammal (Deer Mouse [*Peromyscus maniculatus*])	Insectivorous reptile (Side-Blotched Lizard Lizard [*Uta stansburiana*])	Omnivorous bird (Savannah Sparrow [*Passerculus sandwichensis*])	Earthworm	Plants
Granivorous small mammal (Ground Squirrel [*Spermophilus beecheyi*])		Carnviorous bird (Burrowing Owl [*Athene cunicularia*])		
Herbivorous small mammal (Pocket Gopher [*Thomomys bottae*])				
Herbivorous large mammal (Black-Tailed [Mule] Deer [*Odocoileus hemionus columbianus*])				
Carnivorous mammal (San Joaquin Kit Fox [*Vulpes macrotis mutica*])				

Table 15. Representative vertebrate receptors of ecological interest (RREI) and respective physiological characteristics, including body weight (BW) and dietary dry-matter intake (DMI)[a].

Organism	BW (kg)	Daily DMI intake (kg_{dmi}/d)	Daily DMI intake per unit BW (kg_{dmi}/d per kg_{bw})	Fraction of total dietary dry-matter intake (DMI)				
				Vege-tation	Inverte-brate	Reptile	Mammal	Soil
Mammals								
Omnivorous small mammal (Deer Mouse)	0.0179	0.00381	0.2128	0.7	0.3	0	0	0.1
Granivorous small mammal (Ground Squirrel)	0.56	0.0383	0.0683	1	0	0	0	0.077
Herbivorous small mammal (Pocket Gopher)	0.104	0.013	0.1250	1	0	0	0	0.1
Herbivorous large mammal (Black-Tailed [Mule] Deer)	39.1	1.565	0.04	1	0	0	0	0.02
Carnivorous mammal (San Joaquin Kit Fox)	1.48	0.0702	0.0474	0	0	0.5	0.5	0.028
Reptile								
Insectivorous reptile (Side-Blotched Lizard)	0.0032	0.000037	0.011563	0	1	0	0	0.1
Birds								
Omnivorous bird (Savannah Sparrow)	0.0187	0.00574	0.3070	0.39	0.61	0	0	0.04
Carnviorous bird (Burrowing Owl)	0.157	0.024	0.154	0	0.333	0.333	0.333	0.05

[a] The soil invertebrate (earthworm) does not appear in Table 15 because an $ESSL_{LS}$ for it was taken directly from literature values (see Tables B-6a and B-6b in Appendix B).

bioaccumulation factors [BAFs], toxicity reference values [TRVs], and location-specific concentrations) was used to derive a chemical-specific $ESSL_{LS}$ for each organism (see Appendix B). Regulatory agencies have not developed TRV or other necessary information to derive $ESSL_{LS}$ values for amphibians that may be present near the EWTF, such as the California Red-legged Frog (*Rana aurora draytonii*) and the California Tiger Salamander (*Ambystoma californiense*). However, as discussed in Appendix B, serious impacts to amphibians in the area of the EWTF would be unlikely. Further, the $ESSL_{LS}$ for the reptile was computed as mammal and avian based because of a lack of reptile data corresponding to an LOAEC or with respect to TRVs. Accordingly, in both cases respective reptile $ESSL_{LS}$ values are uncertain, although a reptile is considered more similar to birds physiologically and metabolically than to mammals.

The technical basis for this ecological risk assessment was an analysis that included the overwhelmingly dominant exposure pathway (ingestion) for each CPEC with respect to a particular vertebrate receptor. Any $EHQ_{LS\text{-}max}$ exceeding 1.0 suggests a potential for producing an adverse effect in each individual or population of receptor species; however, the assumptions made are conservative at this time. $EHQ_{LS\text{-}min}$ and $EHQ_{LS\text{-}max}$ values based on background soil concentrations for CPECs measured for Site 300 are also evaluated. Appendix B contains a detailed description of the ERA analysis and the input data required for it to be performed. A separate document describes the spreadsheet calculations for populating the Appendix B data tables that pertain to the ERA analysis (Daniels, 2007).

A summary of the results of the ERA analysis discussed in Appendix B appear in Tables 16a, 16b, 17, 18, and 19 of this section (corresponding specifically to data in Tables B-9; B-15; B-11; B-18 and B-19; and B-20 to B-23). These tables contain the pertinent information upon which to base recommendations for further evaluation designed to reduce uncertainty.

In Table 16a the most conservative $EHQ_{LS\text{-}max}$ values appear for animals that are derived based on model predicted soil concentrations. These values are from the ratio of soil concentration, which is a model predicted value in this case, to the most conservative minimum ecological soil screening level, $ESSL_{LS\text{-}min}$ for a location. For vertebrates, the $ESSL_{LS\text{-}min}$ value for each CPEC was based on a low toxicity reference value (TRV_{Low}) equating to a no observed adverse effect level (NOAEL). For invertebrates the value for an $ESSL_{LS\text{-}min}$ equates to an LOAEC directly.

The $EHQ_{LS\text{-}max}$ results appearing for individual CPECs at the EWTF location in Table 16a suggest that further evaluation is needed for three PCDFs (1-4, 6-8 HpCDF; 1-4, 7, 8 HxCDF; and 1-3, 6-8 HxCDF), and five heavy metals (Al, Cd, Cu, Pb, and Zn). Additionally, the cumulative $EHQ_{LS\text{-}max}$ values are greater than one for PCDFs at three locations and for cadmium and lead at all six locations (Table 16a). Nevertheless, aluminum can be dismissed from further discussion because it is unlikely that the soil pH will be low enough to render aluminum a problem in soil (i.e., the site is geologically basic chemically and only acidic soil pH will yield Al in a form that is mobile and soluble for uptake by organisms; see Appendix B for further details). Therefore, additional analysis was performed for only the remaining seven substances with respect to animals.

Table 16a. Location-specific maximum ecological hazard quotients (EHQ_{LS-max}s) for chemicals of potential concern for all animal wildlife at different receptor locations. Each location-specific EHQ_{LS} is maximum because it is derived from the most conservative (lowest) $ESSL_{LS-min}$ for all organisms evaluated.

	Receptor Location					
Chemical	**EHQ_{LS-max} (EWTF/ $ESSL_{LS-min}$)**	**EHQ_{LS-max} (Bldg 812/ $ESSL_{LS-min}$)**	**EHQ_{LS-max} (Bldg 895/ $ESSL_{LS-min}$)**	**EHQ_{LS-max} (EstPst/ $ESSL_{LS-min}$)**	**EHQ_{LS-max} (Crnge/ $ESSL_{LS-min}$)**	**EHQ_{LS-max} (Ranch/ $ESSL_{LS-min}$)**
Polychlorinated dibenzofurans (PCDFs)						
1-4, 6-8 HpCDF (1,2,3,4,6,7,8-HpCDF)	*1.16E+00*	1.42E-01	1.31E-01	7.19E-03	7.94E-03	3.78E-03
1-4, 7-9 HpCDF (1,2,3,4,7,8,9-HpCDF)	2.30E-01	3.03E-02	2.83E-02	1.67E-03	1.84E-03	8.79E-04
1-4, 7, 8 HxCDF (1,2,3,4,7,8-HxCDF)	*6.80E+00*	8.33E-01	7.72E-01	4.44E-02	4.90E-02	2.34E-02
1-3, 6-8 HxCDF (1,2,3,6,7,8-HxCDF)	*2.82E+00*	3.65E-01	3.40E-01	2.01E-02	2.22E-02	1.06E-02
1-9 OCDF (OCDF)	1.40E-02	1.70E-03	1.57E-03	8.46E-05	9.34E-05	4.45E-05
PCDF Cumulative EHQ_{LS-max}	1.1E+01	1.4E+00	1.3E+00	7.3E-02	8.1E-02	3.9E-02
Energetics & other thermally labile compounds						
2,4-Dinitrotoluene	1.22E-08	1.57E-09	1.47E-09	9.20E-11	8.85E-11	4.28E-11
2,6-Dinitrotoluene	5.10E-10	6.55E-11	6.14E-11	3.83E-12	3.69E-12	1.78E-12
RDX	1.12E-01	1.55E-02	2.20E-02	1.90E-03	1.98E-03	1.14E-03
Energetics Cumulative EHQ_{LS-max}	1-1E-01	1.6E-02	2.2E-02	1.9E-03	2.0E-03	1.1E-03
Metals						
Aluminum	*3.83E+00*	5.61E-01	5.69E-01	3.73E-02	4.01E-02	2.03E-02
Antimony	1.23E-03	1.64E-04	1.93E-04	1.48E-05	1.51E-05	8.27E-06
Barium	1.09E-01	1.46E-02	1.71E-02	1.31E-03	1.33E-03	7.30E-04
Cadmium[a]	*4.27E+00*	*1.40E+00*	*1.54E+00*	3.73E-01	3.77E-01	2.71E-01
Chromium	6.99E-02	9.44E-03	1.18E-02	9.40E-04	9.67E-04	5.41E-04
Copper	*1.60E+00*	8.11E-01	8.19E-01	3.70E-01	3.67E-01	3.06E-01
Lead[a]	*7.85E+01*	*1.57E+01*	*1.53E+01*	*1.92E+00*	*1.89E+00*	*1.27E+00*
Zinc	*1.16E+00*	6.05E-01	6.27E-01	2.67E-01	2.85E-01	2.47E-01
Cd + Pb Cumulative EHQ_{LS-max}[a]	8.3E+01	1.7E+01	1.7E+01	2.3E+00	2.3E+00	1.5E+00
Semi-volatile organic compounds (SVOCs)						

	Receptor Location					
Chemical	**EHQ_{LS-max} (EWTF/ $ESSL_{LS-min}$)**	**EHQ_{LS-max} (Bldg 812/ $ESSL_{LS-min}$)**	**EHQ_{LS-max} (Bldg 895/ $ESSL_{LS-min}$)**	**EHQ_{LS-max} (EstPst/ $ESSL_{LS-min}$)**	**EHQ_{LS-max} (Crnge/ $ESSL_{LS-min}$)**	**EHQ_{LS-max} (Ranch/ $ESSL_{LS-min}$)**
2-Chlorophenol	3.03E-04	3.90E-05	3.65E-05	2.28E-06	2.19E-06	1.06E-06
Diphenylamine	1.06E-08	1.36E-09	1.27E-09	7.95E-11	7.65E-11	3.70E-11
Fluoranthene[b]	5.86E-04	8.80E-05	8.22E-05	4.85E-06	5.36E-06	2.55E-06
Naphthalene[b]	8.35E-05	1.25E-05	1.17E-05	6.91E-07	7.63E-07	3.63E-07
Phenol	6.28E-07	8.06E-08	7.56E-08	4.72E-09	4.54E-09	2.20E-09
PAH Cumulative EHQ_{LS-max}[b]	6.7E-04	1.0E-04	9.4E-05	5.5E-06	6.1E-06	2.9E-06

Note: EHQ values greater than 1 appear in italics (e.g. see EHQ values for Pb).

[a] Sum of cadmium (CD) and lead (PB) only, based on similar toxic action.

[b] Sum of polyaromatic hydrocarbons, fluoranthene and naphthalene only, based on similarity in structure and presumed similarity in toxic action.

Table 16b shows similar information for vertebrate animals to that appearing in Table 16a, with the following exceptions. First, the CPECs evaluated for EHQ_{LS-max} values in Table 16b are *only* for those CPECs for which a location-specific EHQ_{LS-max} exceeded one in Table 16a at any location (e.g., see EWTF). Second, the CPEC-specific EHQ_{LS-min} values appearing in Table 16b are now associated with the most conservative (lowest) location-specific $ESSL_{LS-max}$ value for vertebrate animals that was derived using a TRV_{High}, which corresponds to a lowest observed adverse effect level (LOAEL) in contrast to the TRV_{Low} used in Table 16a. Invertebrates are not addressed here because the $ESSL_{LS-min}$ for invertebrates was already represented by an LOAEC. An EHQ_{LS-min} value (which is computed as the ratio of model predicted soil concentrations to $ESSL_{LS-max}$ values that are derived from TRV_{High} values) less than one indicates that less conservative assumptions remove the material as a CPEC. When this value does exceed one, then further investigation may be warranted. However, the information in Table 16b suggests a reasonable degree of uncertainty exists for all CPECs (at no location does any EHQ_{LS-min} exceed one either individually or as a categorical cumulative EHQ_{LS-min}), even for the EWTF location.

Table 17 summarizes EHQ_{LS-max} values for vegetation for the seven metals—antimony (Sb), barium (Ba), cadmium (Cd), hexavalent chromium (considered 17% of total chromium; Cr), copper (Cu), lead (Pb), and zinc (Zn)—for which soil measurement data exist for Site 300. However, in this table the EHQ_{LS-max} values were determined for both model predicted and Site 300 measured soil concentrations relative to terrestrial plant $ESSL_{LS-min}$ values taken from the literature as LOAECs. Further, the measured soil concentrations are considered to be the background levels for these substances at Site 300, and so the contribution to the total cumulative EHQ_{LS-max}, which is dominated by total chromium and zinc at the EWTF location, relative to measured data is determined with respect to the cumulative EHQ_{LS-max} obtained for the model predicted data for each location. For example, $EHQ_{LS\text{-}max}$ data in Table 17 applicable to measured soil concentrations at Site 300 would suggest background levels of total chromium and zinc could be contributing to ecological impacts. However, no model predicted soil concentrations at any location appear to contribute to ecological impacts with respect to vegetation, and constitute only a small contribution to the total cumulative $EHQ_{LS\text{-}max}$ related to background levels.

Table 16b. Location-specific minimum ecological hazard quotients ($EHQs_{LS\text{-}min}$) for chemicals of potential concern (CPECs) for vertebrate animals at different receptor locations, where the $EHQ_{LS\text{-}max}$ exceeded one (see Table 16a). Each $EHQ_{LS\text{-}min}$ in this table is derived from the most conservative (lowest) $ESSL_{LS\text{-}max}$ for all vertebrate organisms evaluated, where a TRV_{High} serves as the basis for each $ESSL_{LS\text{-}max}$ derivation.

Chemicals of potential ecological concern	EWTF	Bldg. 812	Bldg. 895	East Pasture	Carnegie	Ranch
	$EHQ_{LS\text{-}min}$	$EHQ_{LS\text{-}min}$	$EHQ_{LS\text{-}min}$	$EHQ_{LS\text{-}min}$	$EHQ_{LS\text{-}min}$	$EHQ_{LS\text{-}min}$
PCDDs/PCDFs						
1-4, 6-8 HpCDF (1,2,3,4,6,7,8-HpCDF)	1.2E-01	1.4E-02	1.3E-02	7.2E-04	7.9E-04	3.78E-04
1-4, 7, 8 HxCDF (1,2,3,4,7,8-HxCDF)	6.8E-01	8.3E-02	7.7E-02	4.4E-03	4.9E-03	2.34E-03
1-3, 6-8 HxCDF (1,2,3,6,7,8-HxCDF)	2.8E-01	3.6E-02	3.4E-02	2.0E-03	2.2E-03	1.06E-03
PCDF Cumulative $EHQ_{LS\text{-}min}$	1.1E+00	1.3E-03	1.2E-01	7.2E-03	7.9E-03	3.E-03
Heavy Metals						
Cadmium[a]	9.7E-02	3.2E-02	3.5E-02	8.5E-03	8.6E-03	6.16E-03
Copper	7.0E-02	3.6E-02	3.6E-02	1.6E-02	1.6E-02	1.34E-02
Lead[a]	1.3E-01	2.5E-02	2.5E-02	3.1E-03	3.0E-03	2.03E-03
Zinc	1.2E-01	6.1E-02	6.3E-02	2.7E-02	2.9E-02	2.47E-02
Cd + Pb Cumulative $EHQ_{LS\text{-}min}$[a]	2.2E-01	5.7E-02	5.9E-02	1.2E-02	1.2E-02	8.2E-03

[a] Sum of cadmium (Cd) and lead (Pb) only, based on similar toxic action.

Table 17. Location-specific maximum ecological hazard quotients (EHQ_{LS-max}) for plants based on measured (considered background) and model predicted soil concentrations for Site 300 at six receptor locations at or near the EWTF, where $ESSL_{LS-min}$ values equate to benchmark lowest observed adverse effect concentrations (LOAECs).

Chemicals of potential ecological concern	Terrestrial Plant $ESSL_{LS-min}$ (mg/kgdw)	Measured soil concen-tration for Site 300 (mg/kg_{soil})[a]	Ratio of measured soil concentration to $ESSL_{LS-min}$ ($EHQ_{LS-max[measured]}$)	EWTF modeled 15-cm soil concen-tration (mg/kg)	Ratio of EWTF modeled soil concentration to $ESSL_{LS-min}$ ($EHQ_{LS-max[modeled]}$)	Bldg. 812 modeled 15-cm soil concen-tration (mg/kg)	Ratio of Bldg. 812 modeled soil concentra-tion to $ESSL_{LS-min}$ ($EHQ_{LS-max[modeled]}$)	Bldg. 895 modeled 15-cm soil concen-tration (mg/kg)	Ratio of Bldg. 895 modeled soil concentration to $ESSL_{LS-min}$ ($EHQ_{LS-max[modeled]}$)
Heavy Metals									
Antimony	5[b]	1.0	2.0E-01	8.36E-04	1.7E-04	1.12E-04	2.2E-05	1.31E-04	2.6E-05
Barium	500[b]	331.0	6.6E-01	1.04E+01	2.1E-02	1.39E+00	2.8E-03	1.63E+00	3.3E-03
Cadmium	32[c]	2.6	8.1E-02	4.99E-02	1.6E-03	6.66E-03	2.1E-04	7.84E-03	2.5E-04
Chromium	1.2[b,]	45.6	*3.8E+01*	8.39E-02	7.0E-02	1.13E-02	9.41E-03	1.41E-02	1.2E-02
Copper	100[b]	34.0	3.4E-01	2.93E+01	2.9E-01	3.82E+00	3.8E-02	3.94E+00	3.9E-02
Lead	120[c]	70.3	5.9E-01	8.93E+00	7.4E-02	1.17E+00	9.7E-03	1.14E+00	9.5E-03
Zinc	50[b]	78.0	*1.6E+00*	1.70E+00	3.4E-02	2.48E-01	5.0E-03	2.76E-01	5.5E-03
Cumulative EHQ_{LS-max}			4.1E+01		4.9E-01		6.5E-02		7.0E-02
Contribution of $EHQ_{modeled}$ to $EHQ_{measured}$					1.02E-02		1.6E-03		1.7E-03

(continued)

Table 17. (continued)

Chemicals of potential ecological concern	East Pasture modeled 15-cm soil concentration (mg/kg)	Ratio of East Pasture modeled soil concentration to ESSL ($EHQ_{modeled}$)	Carnegie modeled 15-cm soil concentration (mg/kg)	Ratio of Carnegie modeled soil concentration to ESSL ($EHQ_{modeled}$)	Ranch modeled 15-cm soil conc. (mg/kg)	Ratio of Ranch modeled soil concentration to ESSL ($EHQ_{modeled}$)
Heavy Metals						
Antimony	1.01E-05	2.0E-06	1.03E-05	2.1E-06	5.63E-06	1.1E-06
Barium	1.25E-01	2.5E-04	1.27E-01	2.5E-04	6.96E-02	1.4E-04
Cadmium	6.01E-04	1.9E-05	6.13E-04	1.9E-05	3.36E-04	1.1E-05
Chromium	1.13E-03	9.4E-04	1.16E-03	9.7E-04	6.49E-04	5.4E-04
Copper	2.71E-01	2.7E-03	2.68E-01	2.7E-03	1.39E-01	1.4E-03
Lead	7.37E-02	6.1E-04	7.25E-02	6.0E-04	3.61E-02	3.0E-04
Zinc	1.98E-02	4.0E-04	2.12E-02	4.2E-04	1.13E-02	2.3E-04
Total Cumulative EHQ		4.9E-03		5.0E-03		2.6E-03
Contribution of $EHQ_{modeled}$ to $EHQ_{measured}$		1.2E-04		1.2E-04		6.3E-05

Note: Contribution of modeled to measured $EHQ_{LS\text{-}max} = 1 - \left[\frac{\left(EHQ_{LS\text{-}max(measured)} - EHQ_{LS\text{-}max(modeled)}\right)}{EHQ_{LS\text{-}max(measured)}}\right]$.

a Measured metal concentration in Site 300 soil from Peterson et al.(2006). Measured concentration for other chemicals of potential concern are not available (Peterson et al. 2006).

b Efroymson et al. (1997, Table 1 and Appendix A), where chromium reported ESSL is for potassium chromate (chromium VI; 0.2 mg/kg), but the measured chromium is for total chromium. Because, chromium VI is considered to be 17% of total chromium measurements (US EPA, 2004), the reported chromium ESSL is multiplied by a factor of 6 to obtain the total chromium ESSL for comparison (i.e., 6 × 0.2 = 1.2 mg/kg).

c USEPA (2005c, 2005d).

A similar analysis to that performed for plants in Table 17 was also performed with respect to measured background soil concentrations and animals, and those results appear in Tables 18 and 19. Table 18 contains two sets of EHQ_{LS} values, one representing the ratios of the measurement data available for the seven metals measured at Site 300 already mentioned to the $ESSL_{LS\text{-}max}$ values derived for animals from applicable TRV_{Low} values and the other representing the ratio of the measurement data to the $ESSL_{LS\text{-}min}$ derived for vertebrate animals from applicable TRV_{High} values. The former results indicate that potential ecological impacts may be occurring from background levels, but the latter results suggest no individual substance of potential ecological concern with respect to background levels. Also in the former case the cumulative $EHQ_{LS\text{-}max}$ does exceed one for cadmium and lead (and both exceed one individually). In the case where the cumulative $EHQ_{LS\text{-}min}$ is calculated, the sum for cadmium and lead is only slightly more than one (i.e., 1.56) and neither cadmium nor lead have $EHQ_{LS\text{-}min}$ values greater than one individually.

Table 18. Comparison of animal EHQ values for measured (considered background) soil concentrations for Site 300 based on $ESSL_{LS}$ values determined either from TRV_{Low} or TRV_{High} toxicity factors.

Chemicals of potential ecological concern	Back-ground soil concentra-tion at Site 300 (mg/kg)	TRV_{Low} based $ESSL_{LS\text{-}min}$ (mg/kg_{soil})	Organism	Site 300 measured $EHQ_{LS\text{-}max}$	TRV_{High} based $ESSL_{LS\text{-}max}$ (mg/kg_{soil})	Organism	Site 300 measured $EHQ_{LS\text{-}min}$
Heavy Metals							
Antimony	1.00E+00	6.81E-01	OSM[a]	*1.47E+00*	6.81E+00	OSM[a]	1.47E-01
Barium	3.31E+02	9.53E+01	OA[b]	*3.47E+00*	9.53E+02	OA[b]	3.47E-01
Cadmium[c]	2.60E+00	5.99E-02	OA[b]	*4.34E+01*	2.93E+00	HLM[d]	8.89E-01
Chromium	4.56E+01	1.20E+00	INV[e]	3.80E+01	1.61E+05	OSM[a]	2.83E-04
Copper	3.40E+01	2.02E+01	OA[b]	*1.69E+00*	4.58E+02	OA[b]	7.42E-02
Lead[c]	7.03E+01	1.68E-01	OA[b]	*4.19E+02*	1.05E+02	OA[b]	6.70E-01
Zinc	7.80E+01	1.80E+01	OA[b]	*4.33E+00*	1.80E+02	OA[b]	4.33E-01
Cd + Pb Cumulative EHQ_{LS}[c]				4.62E+02			1.56E+00

[a] OSM = Omnivorous small mammal
[b] OA = Omnviorous avian
[c] For animals the cumulative EHQ_{LS} is the sum of cadmium (CD) and lead (Pb) only, based on similar toxic action.
[d] HLM = Herbivorous large mammal
[e] INV = Invertebrate

Table 19. Comparison of Kit Fox and Burrowing Owl EHQs for measured (considered background) soil concentrations for Site 300 based on ESSL values determined for each animal (i.e., $ESSL_{LS-min}$ or $ESSL_{LS-max}$) either from applicable TRV_{Low} or TRV_{High} toxicity factors.

		Kit Fox for Site 300 measured concentration		Burrowing Owl for Site 300 measured concentration	
Chemicals of potential ecological concern	**Background soil concentration at Site 300 (mg/kg)**	**TRV-Low based EHQ_{LS-max}**	**TRV-High based EHQ_{LS-min}**	**TRV-Low based EHQ_{LS-max}**	**TRV-High based EHQ_{LS-min}**
Heavy Metals					
Antimony	1.00E+00	8.26E-01	8.26E-02		
Barium	3.31E+02	1.69E-01	1.69E-02	1.81E+00	1.81E-01
Cadmium	2.60E+00	*1.49E+00*	3.40E-02	1.40E+01	1.07E-01
Chromium	4.56E+01	8.40E-04	8.40E-05		
Copper	3.40E+01	4.33E-01	1.83E-03	1.46E+00	6.44E-02
Lead	7.03E+01	*1.93E+00*	8.00E-03	4.15E+02	6.63E-01
Zinc	7.80E+01	5.02E-01	1.17E-02	1.70E+00	1.70E-01
CD + Pb Cumulative $EHQ_{Site\ 300}$		*3.42E+00*	4.20E-02	*4.28E+02*	7.71E-01

Nevertheless, additional analysis shown in Appendix B (Table B-18) reveals that even though for animals nearest the EWTF all seven metals may be problematic with respect to background levels (i.e., measurement data), and even though model predicted concentrations at the EWTF for Cd, Cu, Pb, and Zn have EHQ_{LS-max} values exceeding one, with lead having an EHQ_{LS-max} value greater than one as far away as the Ranch location, the contributions to the cadmium and lead cumulative EHQ_{LS-max} values associated with background levels from those calculated using model predicted concentrations is a relatively small fraction (ranging from about 18% at the ETWF to only about 0.3% at the Ranch). Further, additional data appearing in Appendix B (Table B-19) illustrate that when $ESSL_{LS-max}$ values for vertebrate animals are used that are derived from TRV_{High} toxicity factors, there appears to be no potential impact with respect to Site 300 background measurements; and, the remaining EHQ_{LS-min} values corresponding to the model predicted values are all now less than one, and no cumulative EHQ_{LS} for cadmium and lead exceed one. Additionally, Appendix B (Table B-19) contains data that clearly illustrate that the contribution to the cadmium and lead cumulative EHQ_{LS-min} values that were derived for measured background soil concentrations from those derived for the model predicted concentrations remains quite small.

Finally, Table 19 further investigates the impact of measured values on the two sensitive animal species—the San Joaquin Kit Fox, and the Burrowing Owl. Thus, Table 19 is analogous to Table 18, except that it focuses specifically on EHQ_{LS} data derived for the Kit Fox and the Burrowing Owl using $ESSL_{LS-min}$ and $ESSL_{LS-max}$ values determined from TRV_{Low} and TRV_{High} toxicity factors.

Accordingly, with respect to the Kit Fox, the EHQ_{LS-max} values (those developed with $ESSL_{LS-min}$ values calculated from TRV_{Low} toxicity factors) for background (measurement) concentrations at Site 300 exceed one for Cd and Pb; whereas, none of the EHQ_{LS-min} values for the Kit Fox that were determined for background concentrations using $ESSL_{LS-max}$ values derived from TRV_{High} values exceeds one, and neither does the corresponding cumulative EHQ_{LS-min} for cadmium and lead. Table 19 also illustrates that with respect to the Burrowing Owl, the EHQ_{LS-max} values (those developed with $ESSL_{LS-min}$ values calculated from TRV_{Low} toxicity factors) for background measurement concentrations at Site 300 exceed one for all of the metals for which TRV_{High} data exist in the literature; whereas, none of the EHQ_{LS-min} values for the Burrowing Owl that were determined for background concentrations using $ESSL_{LS-max}$ values derived from available TRV_{High} values exceed one, nor does the cumulative EHQ_{LS-max} for cadmium and lead.

An additional analysis was performed where EHQ_{LS} values were also determined for the Burrowing Owl using avian toxic reference values (TRVs) for cadmium and lead taken from U. S. EPA documents (2005a,b). This value for the avian TRV for cadmium is a geometric mean; and the TRV value for lead is the highest bounded no-observed adverse effect level (NOAEL) that is below the lowest bounded Lowest Observed Adverse Effect Level (LOAEL). Using these values (1.47 mg/[kg d] for cadmium and 1.63 mg/[kg d] for lead) as the TRVs for cadmium and lead for the Burrowing Owl yielded $ESSL_{LS}$ values that were then used along with Site 300 measured soil concentrations to produce EHQ_{LS} values for these chemicals. In both cases, the values at the EWTF were significantly lower than those appearing in Table 19 for the TRV_{Low} based EHQ_{LS-max} (0.8 for cadmium and about 4 for lead). Accordingly, the more conservative choices for TRVs may indicate a potential for impact (see Table 19), but the more recent and potentially more applicable values for TRVs for cadmium and lead considered suitable for avian species strongly suggest no ecological impact is likely from Cd, even from background levels, and a smaller, if any, impact would be predicted from background levels for Pb.

In summary, for this ERA, ten receptor species, including vegetation (see Table 14), were identified as representative members of trophic levels in the habitat of Site 300, and were evaluated for the possibility of potential detrimental effects from EWTF emissions. Overall, the data tabulated in Tables 16a, 16b, and 17 through 19 suggest that further investigation may be warranted. This is because the calculated screening results in this analysis can generally be considered conservative, and so potential impacts suggested by this analysis may be overestimates.

5. Uncertainties and Conservatisms

Quantification of health risk from the operation of the EWTF involved

- Estimating the magnitude of emissions.

- Predicting the concentrations of the constituents of concern in various environmental media.
- Evaluating the magnitude of exposure as well as the exposure frequency and duration for exposure pathways of concern for specific receptors.

This risk assessment implemented 95th-percentile estimates, when possible, and health-conservative estimates, when the distribution of the parameter was unknown, for the parameters that could be controlled within the models used.

Quantification of the source term for the EWTF is uncertain because it is difficult to predict the exact nature of the explosives that will be treated. This risk assessment addressed this uncertainty by using the most conservative emissions factors that can be reasonably justified. The continued research conducted by the DoD in this area will improve emission factors for future permitting efforts and reduce the uncertainty from the emission factors, but the inherent uncertainty in exactly predicting releases from waste treatment operations at a research institution will remain.

Quantification of the air concentrations is uncertain. This uncertainty has been addressed by using the most health conservative munition, TNT, in the OBODM model. TNT is the most health conservative because it has the lowest heat of combustion, leading to the least plume rise, and, therefore, the greatest downwind concentrations. The uncertainty in the prediction of air concentrations was reduced by using 5 years of site-specific meteorological data in the air dispersion modeling.

Quantification of the soil concentrations is uncertain. This risk assessment addressed this uncertainty by using a deposition velocity for the constituents of greatest health concern, polychlorinated dibenzodioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs).

There are uncertainties as to the magnitude of exposure. These uncertainties were addressed through the use of 95th-percentile inhalation rates for residential receptors and bystander workers, for the incidental soil ingestion rate for residential receptors, for the skin surface area and dermal adhesion factor for the dermal exposure route for residential receptors. The dermal exposure route is uncertain for the indoor receptors because there are no recommended exposure factors for this route/receptor combination; however, it is unlikely that any indoor worker would have a significant dermal exposure to resuspended soil.

The 30-year residency exposure assumption is the 95th-percentile estimate of population mobility stated in the U.S. EPA's *Exposure Factors Handbook* (U.S. EPA, 1997). The average residence in one place is estimated to be significantly less, at 11.4 years for homeowners and 2.4 years for renters (Israeli and Nelson, 1992). The on-site bystander worker was evaluated for a 25-year work duration, well above the U.S. EPA-recommended occupational tenure value of 6.6 years (U.S. EPA, 1997). It should also be noted that the HARP model does not have distinct point estimates and data distributions for the 30-year and 70-year exposure scenarios. The documentation states:

> However, in the interest of simplicity, the 30-year exposure duration scenario uses the same exposure point-estimates and data distributions as the 70-year exposure duration scenario. This assumption to use the 70-year exposure point-estimate for both 30 and 70-year exposures probably results in a small underestimation of dose for the 30-year exposure scenario, since the exposure parameters for earlier years are higher than years spent as an adult (OEHHA, 2003).

Quantification of toxic effects involves applying appropriate toxicity data to the constituents of potential concern. However, not all constituents of concern for the EWTF have toxicity data. This uncertainty was addressed by identifying surrogate materials and using the toxicity data for the surrogate material to estimate risk and hazard.

Cancer potency factors were estimated from long-term animal studies where the dose is typically held constant and the exposure is conducted continuously over a major portion of the life span of the animals (i.e., lifetime exposure). Human cancer risk assessments, on the other hand, typically involve estimating exposures over less than a lifetime (e. g., 9 years, 25 years, or 30 years) and multiplying the lifetime average daily dose (less than lifetime exposure total dose averaged over a 70-year lifetime) times the cancer potency factor. Although the U. S. EPA and OEHHA support the use of cancer potency factors for estimating cancer risk for these exposure durations, uncertainties are associated with applying the cancer potency factors to less than lifetime exposures or to exposures that are not continuous but intermittent (i.e., like OB/OD operations). Some chemicals are more potent carcinogens when exposures occur early in life but have little or no effect later in life; other chemicals are more potent carcinogens when exposures occur late in life but have little or no effect earlier in life. Thus, depending on when the actual less than lifetime (or intermittent) exposure occurs during one's lifetime, using lifetime average daily dose and cancer potency factors can lead to under- or overestimating theoretical cancer risks. Halmes et al. (2000) indicate that although typical linear adjustments for less-than-lifetime exposure in cancer risk assessment can theoretically result in under- or overestimation of risks, underestimation of risks from short-term exposures is more likely.

Studies of the compounding of conservatism in probabilistic risk assessments show that setting as few as two factors at high-end levels (e.g., near the 90th percentile), and setting the remaining variables at less conservative, or expected values, result in a product of all input variables that approximate a maximum exposure value (e.g., 99th-percentile value) (Cullen, 1994). This risk assessment used 95th-percentile estimates for inhalation rates, residential ingestion rates, and skin surface exposure. As a result, it provides a very conservative estimate of health effects that are, nonetheless, below any level of concern.

Quantification of the ecological risk posed by release of a particular contaminant to a specific habitat is complicated by additional uncertainties related to limited data concerning the physiological and behavioral characteristics of those wildlife species that were considered to be present. To overcome such difficulties, ecological risk assessments, as currently practiced, focus on modeling location-specific ecological soil screening levels ($ESSL_{LS}$ values) and translating them to location-specific ecological hazard quotients (EHQ_{LS} values) for an individual organism of one or more species (and most often only for adults due to data limitations) in the potentially affected habitat. This approach allows any impact to an individual of a particular species to be translated to an impact to the population, and, by inference, to a potential impact on the entire local ecosystem.

This ERA followed a similar approach, examining the potential for impact from a contaminant of potential ecological concern for an individual receptor from more than one species, and each species was considered to be at a different trophic level in the local ecosystem near the EWTF. Additional conservatism was added to these calculations by:

- Maximizing the amount of material deposited (by considering a habitat location at Site 300 quite close to the OB/OD operations—the source of emissions).
- Optimizing the receptor behavior to maximize exposures (i.e., living, foraging, and capturing prey exclusively in that immediate habitat).
- Using concentrations of CPECs that represented a depth of 6 inches (15 cm). Although 2 feet (60 cm) is a common depth for evaluating the effects on fossorial animals, soil at that depth would not be expected to have the same level of air-deposited contamination as would be present at the surface.
- Fixing the absorption fraction of each contaminant of each receptor at 100 percent.

Furthermore, this ERA employed very conservative values for wildlife TRV_{Lo} values generally, especially for the avian RREI with respect to cadmium and lead (i.e., 0.08 mg/kg d for cadmium and 0.014 mg/kg d for lead) (see avian BTAG values presented in DTSC [2000]). In fact, the U.S. EPA TRVs for cadmium and lead, (1.47 mg/kg d and 1.63 mg/kg d, respectively) as derived in Ecological Soils Screening Level documents (U.S. EPA, 2005a,b), still represent NOAEL levels but are not as conservative as those presented by DTSC (2000). These U.S. EPA documents identify the avian wildlife TRV for cadmium as a geometric mean value, and the highest bounded NOAEL that is below the lowest bounded LOAEL as the avian TRV for lead. Accordingly, the EHQ_{LS} values at the EWTF for cadmium and lead that are derived using these TRV values from U.S. EPA (2005a,b), respectively, would indicate far less, if any, ecological risk from these substances, even from background levels. Based on such results, there is sufficient uncertainty to warrant further analyses, including soil sampling, to determine to what degree, if any, a CPEC emitted from the EWTF may pose a potential ecological risk.

6. Summary of Risks and Hazards

Source term estimation is a difficult process for any waste treatment facility because the exact identity of the particular wastes that will be treated cannot be predicted with absolute certainty. The use of publicly available emissions factors, such as those presented here, enables health conservative factors to be identified and used to set an upper bound on the possible future conditions, and makes calculations easily reproducible and transparent.

The calculations evaluating human health risk in this assessment are based on health conservative assumptions for nearly every parameter. The use of conservative assumptions yields a very conservative upper bound estimate of potential health effects. The calculations demonstrate that the operations at the EWTF do not constitute a human health risk: the carcinogenic risk is less than 1 in 1 million, and the acute and chronic hazard indices are less than 1. In addition, the modeled 99^{th} percentile blood-lead levels used to assess non-carcinogenic hazard are all well below the 99^{th} percentile upper confidence limit for a blood-lead level of 10 μg Pb/dL, which represents the threshold that would be considered of concern.

The EHQ_{LS} values calculated based on DTSC guidance for TRV values exceed 1 in some cases. However, it is likely that the conservatisms used in the modeling overestimate the consequences significantly. In fact, using more realistic avian TRVs for both cadmium and lead produces $ESSL_{LS}$ values that when compared with the available Site 300 measurements of background soil concentrations yield EHQ_{LS} values for cadmium and lead that would produce no impact or little if any. Thus, this analysis cannot determine unequivocally whether or not the EWTF will actually contribute to any future ecological impacts at Site 300, although calculations using background measurement data for selected metals would suggest any impact to be minimum relative to background levels. Based on all results, emissions from the operations of the EWTF should not be of concern for human health and may also be of *de minimis* concern with regard to ecological impacts for the majority of emissions. However, because of the uncertainty concerning the results of the ecological risk analysis, additional soil sampling for the concentrations of CPECs is warranted.

References

Bjorklund, J. R., J. F. Bowers, G. C. Dodd, and J. M. White (1998), *Open Burn/Open Detonation Dispersion Model (OBODM) User's Guide,* West Desert Test Center, Dugway Proving Ground, Dugway, UT (DPG Document No. DPG-TR-96-008a, URL: http://www.epa.gov/scram001/tt22.htm.

California Environmental Protection Agency, Air Resources Board (CARB) (2003), *HotSpots Analysis and Reporting Program User Guide*, developed by Dillingham Software Engineering, Inc., Air Resources Board, Stationary Source Division, Sacramento, California.

Cullen, A.C. (1994), "Measures of Compounding Conservatism in Probabilistic Risk Assessment," *Risk Analysis*, 14(4):389–393.

Daniels, J.I. (2007), *Description of Spreadsheet Calculations for Populating Data Tables of the Ecological Risk Assessment (Appendix B of the Human Health and Ecological Risk Assessment Document) for the Explosive Waste Treatment Facility (EWTF) at Site 300*, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-TR-235449.

Department of Toxic Substances Control (DTSC) (1996), "Chapter 7: Assignment of Health Risks from Inorganic Lead in Soil," in *Supplemental Guidance for Human Health Multimedia Risk Assessments of Hazardous Waste Sites and Permitted Facilities,* State of California Environmental Protection Agency, Office of Scientific Affairs, Department of Toxic Substances Control, Sacramento, CA, OSA Guidance (July 1992/corrected and reprinted August 1996).

Department of Toxic Substances Control (DTSC) (2000), *LeadSpread 7: DTSC Lead Risk Assessment Spreadsheet,* State of California Environmental Protection Agency (CalEPA), Department of Toxic Substances Control (DTSC), Sacramento, CA, URL: http://165.235.111.242/AssessingRisk/leadspread.cfm

Department of Toxic Substances Control (DTSC) (2002a), *Revised U.S. Environmental Protection Agency (USEPA) Region 9 Biological Technical Assistance Group (BTAG) Mammalian Toxicity Reference Value (TRV) for Lead: Justification and Rationale,* State of California Environmental Protection Agency (CalEPA), Department of Toxic Substances Control (DTSC), Sacramento, CA, Human and Ecological Risk Division (HERD) Ecological Risk Assessment (ERA) Note Number 5 (EcoNote5), November 21, 2002, URL: http://165.235.111.242/AssessingRisk/eco.cfm#EcoNOTE5.

Department of Toxic Substances Control (DTSC) (2002b), *Currently Recommended U.S. Environmental Protection Agency Region 9 Biological Technical Assistance Group (BTAG) Mammalian and Avian Toxicity Reference Values (TRVs),* State of California Environmental Protection Agency (CalEPA), Department of Toxic Substances Control (DTSC), Sacramento, CA, November 21, 2002; two data tables and accompanying references, URL: http://165.235.111.242/AssessingRisk/eco.cfm#EcoNOTE5.

Efroymson, R.A., M.E. Will, G.W. Suter, II, A.C. Wooten (1997), Toxicological Benchmarks for Screening Contaminants fo Potential Concern for Effects on Terrestrial Plants: 1997 Revision, Lockheed Martin Energy Systems, Inc, managing Oak Ridge National Laboratory, Oak Ridge, TN, ES/ER/TM-85/R3.

Halmes N., S. Roberts, J. Tolson and C. Portier (Halmes et al., 2000), "Reevaluating Cancer Risk Estimates for Short-term Exposure Scenarios," *Toxicological Sciences* 58, 32-42.

Holzworth, G. C. (1972), *Mixing Heights, Wind Speeds, and Potential for Urban Air Pollution Throughout the Contiguous United States*, U.S. Environmental Protection Agency (U.S. EPA), Office of Air Programs, Research Triangle Park, North Carolina, (AP-101).

Israeli, M., and C. B. Nelson (1992), "Distribution and Expected Time of Residence for U.S. Households," *Risk Analysis* 12, 65–72.

Mitchell, W.J., and J.C. Suggs (1998), *Emission Factors for the Disposal of Energetic Materials by Open Burning and Open Detonation (OB/OD)*, U.S. Environmental Protection Agency, MD-46, Research Triangle Park, NC 27711, (EPA/600/R-98-103).

Mitchell, W.J. (1999), *State of the Science and Research Needs in the Characterization and Minimization of the Emissions from Ordnance Use and Disposal Activities*, Strategic Environmental Research and Development Workshop, June 2-4, 1999, co-sponsored by American Academy of Environmental Engineers, URL: http://www.aaee.net/newlook/air_quality_issues.htm

National Academy of Sciences (NAS) (1983), *Risk Assessment in the Federal Government: Managing the Process.* National Academy Press, Washington, DC.

Office of Environmental Health Hazard Assessment (OEHHA) (2003), *Air Toxics Hot Spots Program Risk Assessment Guidelines the Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments,* Office of Environmental Health Hazard Assessment, California Environmental Protection Agency (CalEPA), Oakland, California.

Peterson, S.R., D. Armstrong, N.A. Bertoldo, S. Brigdon, R.A. Brown, C.G. Campbell, S. Cerruti, C.L. Conrado, A.R. Grayson, H.E. Jones, J. Karachewski, D.H. MacQeen, S. Mathews, L. Paterson, M.A. Revelli, D. Rueppel, L. Sanchez, B. Schad, M.J. Taffet, K. Wilson, J. Woollett (2006), *Environmental Report 2005*, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-50027-05 (in preparation).

Sehmel, G., (1980), "Particle and Gas Dry Deposition: A Review," *Atmospheric Environment* 14, 983–1011.

Suter, G.W., II, R.A. Efroymson, B.E. Sample, and D.S. Jones (2000), *Ecological Risk Asssessment for Contaminated Sites,* Lewis Publishers, CRC Press, Washington, DC.

Total Petroleum Hydrocarbon Criteria Working Group (TPHCWG) (1997), *Development of Fraction Specific Reference Doses (RfDs) and Reference Concentrations (RfCs) for Total Petroleum Hydrocarbons (TPH)*, Prepared by Exxon Biomedical Sciences, Inc.: D.A. Edwards, M.D. Andriot, M.A. Amoruso, A.C. Tummey, C.J. Bevan, A. Tveit, L.A. Hayes; EA Engineering, Science, and Technology, Inc.: S.H. Youngren;

Remediation Technologies, Inc.: D.V. Nakles, Amherst Scientific Publishers, Amherst, Massachusetts.

United States Department of Energy/National Nuclear Security Administration (DOE/NNSA) (2005), *Final Site-side Environmental Impact Statement for Continued Operation of Lawrence Livermore National Laboratory and Supplemental Stockpile Stewardship and Management Programmatic Environmental Impact Statement* (DOE/EIS-0348, DOE/EIS-0236-S3, March 2005), URL: http://www.eh.doe.gov/nepa/eis/eis0348/eis0348toc.htm

United States Environmental Protection Agency (U.S. EPA) (1995), *User's Guide for the Industrial Source Complex (ISC3) Dispersion Models Volume 1 – User's Instructions*, Office of Air Quality Planning and Standards Emissions, Monitoring and Analysis Division, Research Triangle Park, NC (EPA-454/B-95-003a).

United States Environmental Protection Agency (U.S. EPA) (1997), *Exposure Factors Handbook,* United States Environmental Protection Agency (U.S. EPA), Office of Research and Development, National Center for Environmental Assessment, Washington, DC (EPA/600/P-95/002Fa, August 1997).

United States Environmental Protection Agency (U.S. EPA) (2000), *Meteorological Monitoring Guidance for Regulatory Modeling Applications*, Office of Air Quality Planning and Standards, Research Triangle Park, NC (EPA-454/R-99-005).

United States Environmental Protection Agency (U.S. EPA) (2002), *Draft Final Open Burning/Open Detonation Permitting Guidelines* (Tetra Tech, Inc., prepared for U.S. Environmental Protection Agency, Region III, Philadelphia, PA, February 2002).

United States Environmental Protection Agency (U.S. EPA) (2004a), *Region 9 Preliminary Remediation Goal Table* (U.S. Environmental Protection Agency, Region 9, San Francisco, CA, October 2004), URL: http://www.epagov/region09/waste/sfund/prg

United States Environmental Protection Agency (U.S. EPA) (2004b), *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment,)* Office of Superfund Remediation and Technology Innovation U.S. Environmental Protection Agency Washington, DC, (EPA/540/R/99/005 OSWER 9285.7-02EP PB99-963312).

United States Environmental Protection Agency (U.S. EPA) (2005a), *Ecological Soil Screening Levels for Antimony, Interim Final*, Office of Solid Waste and Emergency Response, United States Environmental Protection Agency, Washington, DC, OSWER Directive 9285.7–61, URL: http://www.epa.gov/ecotox/ecossl/ (see Table 2.1 [p. 2] and Table 6.2 [p. 8]).

United States Environmental Protection Agency (U.S. EPA) (2005b), *Ecological Soil Screening Levels for Barium, Interim Final*, Office of Solid Waste and Emergency Response, United States Environmental Protection Agency, Washington, DC, OSWER Directive 9285.7–63, URL: http://www.epa.gov/ecotox/ecossl/ (see Table 2.1 [p. 2] and Table 6.2 [p. 9]).

United States Environmental Protection Agency (U.S. EPA) (2005c), Ecological Soil Screening Levels for Cadmium, Interim Final, Office of Solid Waste and Emergency Response,United States Environmental Protection Agency, Washington, DC, OSWER Directive 9285.7–65, URL: http://www.epa.gov/ecotox/ecossl/ (see Table 2.1 [p. 3]).

United States Environmental Protection Agency (U.S. EPA) (2005d), Ecological Soil Screening Levels for Lead, Interim Final, Office of Solid Waste and Emergency Response, United States Environmental Protection Agency, Washington, DC, OSWER Directive 9285.7–70, URL: http://www.epa.gov/ecotox/ecossl/ (see Table 2.1 [p. 3]).

Wevers, M., R. DeFré, and M. Desmedt (2004), "Effect of backyard burning on dioxin deposition and air concentrations," *Chemosphere* 54, 1351–1356.

List of Acronyms and Abbreviations

AP	Ammonium perchlorate
ATSDR	Agency for Toxic Substances Disease Registry
B	Building
BAF	Bioaccumulation factors
BJC	Bechtel Jacobs Company, LLC
brd	bird
BTAG	Biological Technical Assistance Group
BW	Body weight
CalEPA	California Environmental Protection Agency
CARB	California Air Resources Board
CAS	Chemical Abstract Service
Cd	Cadmium
Cl_2	Chlorine
CO	Carbon monoxide
CO_2	Carbon dioxide
CPEC	Contaminant of potential ecological concern
CPF	Cancer potency factor
Cu	Copper
DF	Dietary fraction
DMI	Dry-matter intake
DOD	U.S. Department of Defense
DTSC	Department of Toxic Substances Control
EHQ	Ecological hazard quotient
EPA	U.S. Environmental Protection Agency
ERA	Ecological risk assessment
ESSL	Ecological soil screening level
ETS	Experimental Test Species
EWTF	Explosives Waste Treatment Facility
GSD	Geometric standard deviation
H_2O	water
HARP	HotSpots Analysis and Reporting Program
HCL	Hydrogen chloride
HERD	Human and Ecological Risk Division
HMX	High melting explosive
ID	Identification

inv	invertebrate
IRIS	Integrated Risk Information System
ISCST	Industrial Source Code/Complex Short-Term
LLNL	Lawrence Livermore National Laboratory
LOAEC	Lowest observed adverse effect concentration
LOAEL	Lowest observed adverse effect level
mam	mammalian
N_2	Nitrogen
NAS	National Academy of Sciences
NM	New Mexico
NO	Nitrogen oxide
NO_2	Nitrogen dioxide
NOAEL	No observed adverse effect level
NOEC	No-observed effect concentrations
OB	Open Burn
OBODM	Open Burn/Open Detonation Dispersion Model
OD	Open Detonation
OEHHA	Office of Environmental Health Hazard Assessment
Pb	Lead
PCDF	Polychlorinated dibenzofuran
PCDP	Polychlorinated dibenzopdioxin
PETN	Pentaerythritol tetranitrate
PRG	Preliminary Remediation Goal
PST	Pacific Standard Time
RCRA	Resource Conservation and Recovery Act
RDX	Research Department explosive (cyclotrimethylenetrinitramine)
REL	Reference Exposure Levels
rep	reptile
RfD	Reference dose
RREI	Representative receptor of ecological interest
RWBB	Red-Winged Black Bird
SF	Scaling factor
SO_2	Sulfur dioxide
SVOC	Semi-volatile organic compound
TCDD	2,3,7,8-Tetrachlorodibenzo-p-dioxin
TCDF	2,3,7,8-Tetrachlorodibenzofuran
TEF	Toxicity equivalency factor

TNT	Trinitrotoluene
TPHCWG	Total Petroleum Hydrocarbon Criteria Working Group
TRV	Toxic reference value
U.S.	United States
UF	Uncertainty factor
UT	Utah
veg	vegetation
VOC	Volatile organic compound
wlf	wildlife
Zn	Zinc

Appendix A. Integration of OBODM into the HARP

As stated in the main body of this risk assessment, the standard approach for human health risk assessment is a four-step process stated by the National Academy of Sciences in *Risk Assessment in the Federal Government: Managing the Process* (NAS, 1983) and reiterated in *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments* (OEHHA, 2003). The four steps in the process are (1) hazard identification, (2) exposure assessment, (3) dose-response assessment, and (4) risk characterization.

For this risk assessment for the EWTF, the DTSC recommended the use of the Open Burn Open Detonation Dispersion Model (OBODM; Bjorklund et al., 1998). Region III of the U.S. EPA (2002) also recommends its use. The OBODM has components that allow completion of steps 1 and 2 (i.e., it contains emissions factors for many chemicals based on tests of 39 types of munitions [see also Mitchell and Suggs, 1998]); and it contains a Gaussian-plume air dispersion model developed specifically for short-term episodic releases, such as open burns and open detonations. The OBODM emission factors have been widely used to estimate the hazards from OB/OD and similar operations.[3] It is more common for a risk assessor to identify the hazards through developing source-specific information and/or through the use of approved emissions factors not specifically included in the air dispersion model. Unfortunately, the OBODM only allows the estimation of one released chemical for each treated material for each model run. If, for example, an OB/OD treatment involved the release of ten materials, the OBODM would have to be run ten times. Because the model is linear with respect to the initial released chemical, the OBODM could also be run once, and a scaling factor could then be used to scale the result up or down, depending on the ratio of the initial chemical to the chemical in question. (For example, if chemical A has an emission factor of 1, and chemical B has an emission factor of 2, the OBODM could be run for chemical A, and the air concentrations would then be used without adjustment for chemical A and would be multiplied by 2 for chemical B.)

To complete this risk assessment, the Hotspot Analysis Reporting Program (HARP) (CARB, 2003) was used. The OEHHA and the California Air Resources Board (CARB)

---

[3] For example, OBODM emission factors have been used by the U.S. Navy and affirmed by the Agency for Toxic Substances Disease Registry (ATSDR) in evaluating emissions from Isla de Vieques, Puerto Rico, bombing range (http://www.atsdr.cdc.gov/HAC/PHA/vieques4/vbr_p5.html): "The Navy contractor used emission factors derived from Bangbox studies to estimate emissions of chemical by-products of bombing activities. These emission factors have been widely used to assess environmental impacts from open burning and open detonation activities. For instance, the Open Burn/Open Detonation Model (OBODM), available from EPA's clearinghouse of dispersion models on the agency's technology transfer network, also estimates air emissions from the Bangbox emission factors. ATSDR acknowledges that the representativeness of static detonation tests to live bombing exercises has not been established. However, source testing (or emissions measurements) during live bombing exercises is an extremely complicated endeavor, given the potential safety hazards associated with placing field surveying equipment in the proximity of bombing targets. In the absence of such source testing results, ATSDR believes the Bangbox emission factors are reasonable indicators of chemical releases from explosions."

developed this model for compliance with the AB2588 Hotspots reporting requirements. The HARP provides assistance with steps 2, 3 and 4 of risk assessment: (2) exposure assessment, (3) dose-response assessment, and (4) risk characterization. The HARP model is available in two formats: a free, self-contained version and a commercial version (called HARPExpress) that relies on Microsoft Excel to provide a user-friendly interface for entering information into the program. This risk assessment used HARPExpress; however, this risk assessment refers to the model as "HARP."

To accomplish the exposure assessment portion of the risk assessment, the HARP incorporates the Industrial Source Code, Short Term (ISCST) model. ISCST is the U.S. EPA regulatory model most commonly used in permitting actions. It includes the common assumptions that emissions are continuous and that they are vented through a stack. Consequently, the air dispersion modeling output of the HARP could not be used (at least not without some manipulation). However, the HARP is quite robust in its treatment of dose-response assessment and risk characterization. It allows modeling of many chemicals at the same time (in this case, 51) and is limited only by the availability of toxicological information.

The problem that arose in this risk assessment was how to integrate the source term and the atmospheric modeling capabilities of the OBODM together with the exposure assessment, dose response and risk characterization attributes of the HARP.

The integration of the emissions factors information was straightforward. The emissions factors from the OBODM were read into a Microsoft Access database file. The database file was queried for the munitions that were identified as those representative of waste Forms 1 through 4, and the highest emission factor for each emitted chemical was selected. These emissions factors were multiplied by the amount of material treated, and the emissions estimates for each chemical for each waste form were copied into the HARP.

The integration of the air dispersion modeling was somewhat more complex. First, it is important to remember that the HARP is written in a modular form and that the modules operate independently. The HARP modules are the source term calculations, the air dispersion calculations (which is the ISCST model), and the risk and hazard calculations. However, only the air dispersion modeling of the HARP needed to be changed from ISCST output to the OBODM output.

Fortunately (from the point of view of inserting the OBODM results into the HARP), ISCST (within the HARP) begins all of its air dispersion calculations from the assumption that 1 gram per second (1 g/s) is being released from a facility. It does not use the actual emissions until later in the modeling code. From the starting point of a 1-g/s release (also called a unit-source release), ISCST then calculates the concentrations at all the receptor locations identified in the input file, in micrograms per cubic meter of air ($\mu g/m^3$) for that 1-g/s release. The result is called the unit source "X/Q," where "X" (the Greek letter "chi") is the concentration at the receptor location, and "Q" is the emission rate for the material of interest. The X/Q data are located in an ISCST file named "filename.XOQ" where "filename" represents the file name of the particular model run.

Therefore, to incorporate the OBODM results into the HARP, the modeler needs to acquire a unit source "X/Q" from the OBODM for all receptor locations and substitute that data into the filename.XOQ file. After the substitution is made, the risk and the hazard assessments modules of the HARP can be run based on OBODM X/Q data. The OBODM does not have an intermediate "X/Q" file that is obviously accessible. However, the OBODM primary output, ground-level concentrations, can be used with the input emissions concentrations to calculate the X/Q for each location. This was the approach that was taken. It was used for both maximum hourly X/Q and annual average X/Q.

The chemical barium was selected for the calculation because it had an emission factor for all four waste forms. The emission factor for barium for Forms 1 and 2 was 0.0082, and the emission factor for Forms 3 and 4 was 0.000086. The OBODM model was run for each of these emission factors for all four forms. Because a "unit" X/Q was being calculated, the results should be the same without regard to the initial emission factor. The use of actual emission factors enabled checking the concentration of barium for each of the waste forms in the HARP after the substitution was made.

To reiterate, the concentration output of the OBODM model must be divided by the emission rate for each of the waste forms to yield a unit source X/Q. However, this step requires the availability of the source emission rates. These emission rates were calculated from the estimated masses of the quantities emitted per second. The calculations and the resulting emission rates are shown in Table A-1. Table A-2 shows the unit source X/Q calculations based on the 0.0082 barium emission factor, and Table A-3 shows the unit source X/Q calculations based on the 0.000086 barium emission factor. A comparison of Tables A-2 and A-3 shows that the unit source X/Qs are calculated to be the same to five significant digits. Exact agreement to more significant digits was not expected because only three significant digits are presented in the OBODM output. It should be noted that the source order in Tables A-2 and A-3 are as follows: source 1 is the burn pan, source 2 is the burn cage (Form 3), source 3 is the burn cage (Form 4), and source 4 is the detonation pad. The same source order was implemented in the HARP.

Table A-4 shows the modified .XOQ file after the annual average and maximum hourly values were updated with OBODM X/Q values. The validity of the approach was checked by comparing the concentrations calculated by the HARP for barium with those calculated by the OBODM. The results were equal, confirming that the .XOQ file had been modified appropriately. This confirmatory calculation was carried out independently by two of the authors of this report; both of whom obtained the same results. The calculations are shown in Table A-5, where the appropriate ground-level concentrations for each of the sources are summed for the total annual average concentration and the maximum 1-hour concentration for each modeled receptor location. Figure A-1 is a screen shot of the annual average and maximum hourly ground-level concentrations calculated by the HARP.

Table A-1. Calculation of unit source values for two barium emission factors.

	Burn pan	Burn cage (form 3)	Burn cage (form 4)	Detonation pad
Barium factor 0.0082	**Annual average emission rate**			
Pounds per event	100	50	260	350
Events per year	100	100	100	100
Total pounds per year	10000	5000	26000	35000
Total grams per year	4535923	2267962	11793400	15875731
Total seconds per year	31536000	31536000	31536000	31536000
Annual average g/s	0.144	0.072	0.374	0.503
Barium emission factor	0.0082	0.0082	0.0082	0.0082
Barium annual average emission rate (g/s)	0.00118	0.00059	0.00307	0.00413
	Maximum hourly emission rate			
Pounds per event	100	50	260	350
Events per hour	1	1	1	1
Total pounds per hour	100	50	260	350
Total grams per hour	45359	22680	117934	158757
Total seconds per hour	3600	3600	3600	3600
Hourly g/s	12.6	6.3	32.8	44.1
Barium emission factor	0.0082	0.0082	0.0082	0.0082
Barium maximum hourly emission rate (g/s)	0.103	0.052	0.269	0.362
Barium factor 0.000086	**Annual average emission rate**			
Pounds per event	100	50	260	350
Events per year	100	100	100	100
Total pounds per year	10000	5000	26000	35000
Total grams per year	4535923	2267962	11793400	15875731
Total seconds per year	31536000	31536000	31536000	31536000
Annual average g/s	0.144	0.072	0.374	0.503
Barium emission factor	0.000086	0.000086	0.000086	0.000086
Barium annual average emission rate (g/s)	0.0000124	0.0000062	0.0000322	0.0000433
	Maximum hourly emission rate			
Pounds per event	100	50	260	350
Events per hour	1	1	1	1
Total pounds per hour	100	50	260	350
Total grams per hour	45359	22680	117934	158757
Total seconds per hour	3600	3600	3600	3600

	Burn pan	Burn cage (form 3)	Burn cage (form 4)	Detonation pad
Hourly g/s	12.6	6.3	32.8	44.1
Barium emission factor	0.000086	0.000086	0.000086	0.000086
Barium maximum hourly emission rate (g/s)	0.00108	0.00054	0.00282	0.00379

Table A-2. Calculations of X/Q based on barium emission factor of 0.0082.

Emission factor 0.0082 (form12out)		OB Pan	OB Cage 3	OB Cage 4	OD	factors by which to divide Ba emissions to derive unit chi/Q
	annual ave	1.18E-03	5.90E-04	3.07E-03	4.13E-03	
	mxhrly	1.03E-01	5.17E-02	2.69E-01	3.62E-01	

Annual Average Barium Time-Average {1-hr} Concentration (Micrograms/Cubic Meter)
(Due to source group 1, sources: 1) Burn Pan
(Maximum = .13365E+00 at X,Y,Z = 629500.00,4168500.00,383.90)

X (Meters)	Y (Meters)	Z (Meters)	Time-Avg. Con.	chi/Q	chi/Q for .XOQ file	
633000	4170500	273.9	1.00E-03	8.52E-01	.8515709E+00	Pasture
628681.5	4165968	201	9.67E-04	8.19E-01	.8194978E+00	Carnegie
632976.6	4166183	158.4	4.68E-04	3.97E-01	.3965510E+00	Ranch
629950	4168674	309.4	1.72E-02	1.46E+01	.1455489E+02	B812
630020	4168179	379.3	1.61E-02	1.36E+01	.1364920E+02	B895
633000	4170500	273.9	1.00E-03	8.52E-01	.8515709E+00	Pasture repeat
629500	4168500	383.9	1.34E-01	1.13E+02	.1133045E+03	Ecological

Table 3
Annual Average Barium Time-Average {1-hr} Concentration (Micrograms/Cubic Meter)
(Due to source group 2, sources: 2) Burn Cage (form 3)
(Maximum = .66794E-01 at X,Y,Z = 629500.00,4168500.00,383.90)

X (Meters)	Y (Meters)	Z (Meters)	Time-Avg. Con.	chi/Q	chi/Q for .XOQ file	
633000	4170500	273.9	4.99E-04	8.47E-01	.8469687E+00	Pasture
628681.5	4165968	201	5.69E-04	9.65E-01	.9646185E+00	Carnegie
632976.6	4166183	158.4	2.67E-04	4.52E-01	.4524008E+00	Ranch
629950	4168674	309.4	1.05E-02	1.78E+01	.1782248E+02	B812
630020	4168179	379.3	8.92E-03	1.51E+01	.1511857E+02	B895
633000	4170500	273.9	4.99E-04	8.47E-01	.8469687E+00	Pasture repeat
629500	4168500	383.9	6.68E-02	1.13E+02	.1132647E+03	Ecological

Table 4
Annual Average Barium Time-Average {1-hr} Concentration (Micrograms/Cubic Meter)
(Due to source group 3, sources: 3) Burn Cage (form 4)
(Maximum = .30209E+00 at X,Y,Z = 629500.00,4168500.00,383.90)

X (Meters)	Y (Meters)	Z (Meters)	Time-Avg. Con.	chi/Q	chi/Q for .XOQ file	
633000	4170500	273.9	2.55E-03	8.33E-01	.8327705E+00	Pasture
628681.5	4165968	201	2.80E-03	9.14E-01	.9135818E+00	Carnegie
632976.6	4166183	158.4	1.34E-03	4.37E-01	.4366443E+00	Ranch
629950	4168674	309.4	4.49E-02	1.46E+01	.1463560E+02	B812
630020	4168179	379.3	4.28E-02	1.39E+01	.1394625E+02	B895
633000	4170500	273.9	2.55E-03	8.33E-01	.8327705E+00	Pasture repeat
629500	4168500	383.9	3.02E-01	9.85E+01	.9851385E+02	Ecological

Table A-2. Calculations of X/Q based on barium emission factor of 0.0082 (continued).

Table 5
Annual Average Barium Time-Average {1-hr} Concentration (Micrograms/Cubic Meter)
(Due to source group 4, sources: 4) Detonation Pad
(Maximum = .12371E+00 at X,Y,Z = 629500.00,4168500.00,383.90)

X (Meters)	Y (Meters)	Z (Meters)	Time-Avg. Con.	chi/Q	chi/Q for .XOQ file	
633000	4170500	273.9	2.10E-03	5.08E-01	.5081017E+00	Pasture
628681.5	4165968	201	2.19E-03	5.31E-01	.5313550E+00	Carnegie
632976.6	4166183	158.4	1.27E-03	3.07E-01	.3067384E+00	Ranch
629950	4168674	309.4	1.72E-02	4.17E+00	.4165249E+01	B812
630020	4168179	379.3	2.44E-02	5.90E+00	.5900564E+01	B895
633000	4170500	273.9	2.10E-03	5.08E-01	.5081017E+00	Pasture repeat
629500	4168500	383.9	1.24E-01	3.00E+01	.2996745E+02	Ecological

Table 6
Highest Barium Time-Average {1-hr} Concentration (Micrograms/Cubic Meter)
(Due to source group 1, sources: 1) Burn Pan
(Maximum = 11.877 at X,Y,Z =629500.00,4168500.00,383.90)

X (Meters)	Y (Meters)	Z (Meters)	Time-Avg. Con.	chi/Q	chi/Q for .XOQ file	Mo/	Dy/	Yr	Jdy	Hr
633000	4170500	273.9	0.12558	1.22E+00	.1215468E+01	3	26	0	68	800
628681.5	4165968	201	0.223714	2.17E+00	.2165290E+01	9	13	1	86	800
632976.6	4166183	158.4	0.114005	1.10E+00	.1103435E+01	3	6	3	65	800
629950	4168674	309.4	2.8726	2.78E+01	.2780341E+02	11	6	2	310	800
630020	4168179	379.3	2.95159	2.86E+01	.2856795E+02	12	20	4	355	800
633000	4170500	273.9	0.12558	1.22E+00	.1215468E+01	3	26	0	86	800
629500	4168500	383.9	11.877	1.15E+02	.1149555E+03	9	11	2	254	800

Table 8
Highest Barium Time-Average {1-hr} Concentration (Micrograms/Cubic Meter)
(Due to source group 2, sources: 2) Burn Cage (form 3)
(Maximum = 5.0540 at X,Y,Z = 629500.00,4168500.00,383.90)

X (Meters)	Y (Meters)	Z (Meters)	Time-Avg. Con.	chi/Q	chi/Q for .XOQ file	Mo/	Dy/	Yr	Jdy	Hr
633000	4170500	273.9	0.050014	9.68E-01	.9681504E+00	12	6	2	340	800
628681.5	4165968	201	8.33E-02	1.61E+00	.1612033E+01	9	13	1	256	800
632976.6	4166183	158.4	0.040661	7.87E-01	.7870981E+00	3	6	3	65	800
629950	4168674	309.4	1.3717	2.66E+01	.2655291E+02	1	19	4	19	900
630020	4168179	379.3	1.17555	2.28E+01	.2275590E+02	11	25	0	330	800
633000	4170500	273.9	0.050014	9.68E-01	.9681504E+00	12	6	2	340	800
629500	4168500	383.9	5.05396	9.78E+01	.9783286E+02	9	11	2	254	800

Table A-2. Calculations of X/Q based on barium emission factor of 0.0082 (continued).

Table 10
Highest Barium Time-Average {1-hr} Concentration (Micrograms/Cubic Meter)
(Due to source group 3, sources: 3) Burn Cage (form 4)
(Maximum = 21.001 at X,Y,Z = 629500.00,4168500.00,383.90)

X (Meters)	Y (Meters)	Z (Meters)	Time-Avg. Con.	chi/Q	chi/Q for .XOQ file	Mo/	Dy/	Yr	Jdy	Hr
633000	4170500	273.9	0.246753	9.19E-01	.9185696E+00	12	6	2	340	800
628681.5	4165968	201	0.391287	1.46E+00	.1456616E+01	9	13	1	256	800
632976.6	4166183	158.4	0.198177	7.38E-01	.7377392E+00	3	6	3	65	800
629950	4168674	309.4	4.95688	1.85E+01	.1845262E+02	1	19	4	19	900
630020	4168179	379.3	5.4473	2.03E+01	.2027827E+02	11	25	0	330	900
633000	4170500	273.9	0.246753	9.19E-01	.9185696E+00	12	6	2	340	800
629500	4168500	383.9	21.0008	7.82E+01	.7817816E+02	9	11	2	254	800

Table 12
Highest Barium Time-Average {1-hr} Concentration (Micrograms/Cubic Meter)
(Due to source group 4, sources: 4) Detonation Pad
(Maximum = 18.767 at X,Y,Z =629500.00,4168500.00,383.90)

X (Meters)	Y (Meters)	Z (Meters)	Time-Avg. Con.	chi/Q	chi/Q for .XOQ file	Mo/	Dy/	Yr	Jdy	Hr
633000	4170500	273.9	0.591244	1.64E+00	.1635015E+01	12	8	0	343	900
628681.5	4165968	201	0.435929	1.21E+00	.1205510E+01	9	13	1	256	800
632976.6	4166183	158.4	0.373553	1.03E+00	.1033016E+01	10	16	1	289	800
629950	4168674	309.4	1.92837	5.33E+00	.5332677E+01	1	1	0	1	900
630020	4168179	379.3	8.25488	2.28E+01	.2282789E+02	3	6	3	65	800
633000	4170500	273.9	0.591244	1.64E+00	.1635015E+01	12	8	0	343	900
629500	4168500	383.9	18.767	5.19E+01	.5189790E+02	2	18	0	49	800

Table A-3. Calculations of X/Q based on barium emission factor of 0.000086.

Emission factor 0.000086 (form34out)		OB Pan	OB Cage 3	OB Cage 4	OD	factors by which to divide Ba emissions to derive unit chi/Q
	annual ave	1.24E-05	6.18E-06	3.22E-05	4.33E-05	
	mxhrly	1.08E-03	5.42E-04	2.82E-03	3.79E-03	

Annual Average Barium Time-Average {1-hr} Concentration (Micrograms/Cubic Meter)
(Due to source group 1, sources: 1) Burn Pan
(Maximum = .14015E-02 at X,Y,Z = 629500.00,4168500.00,383.90)

X (Meters)	Y (Meters)	Z (Meters)	Time-Avg. Con.	chi/Q	chi/Q for .XOQ file	
633000	4170500	273.9	1.05E-05	8.52E-01	.8515679E+00	Pasture
628681.5	4165968	201	1.01E-05	8.19E-01	.8194975E+00	Carnegie
632976.6	4166183	158.4	4.91E-06	3.97E-01	.3965511E+00	Ranch
629950	4168674	309.4	1.80E-04	1.46E+01	.1455489E+02	B812
630020	4168179	379.3	1.69E-04	1.36E+01	.1364921E+02	B895
633000	4170500	273.9	1.05E-05	8.52E-01	.8515679E+00	Pasture repeat
629500	4168500	383.9	1.40E-03	1.13E+02	.1133047E+03	Ecological

Table 3
Annual Average Barium Time-Average {1-hr} Concentration (Micrograms/Cubic Meter)
(Due to source group 2, sources: 2) Burn Cage (form 3)
(Maximum = .70052E-03 at X,Y,Z = 629500.00,4168500.00,383.90)

X (Meters)	Y (Meters)	Z (Meters)	Time-Avg. Con.	chi/Q	chi/Q for .XOQ file	
633000	4170500	273.9	5.24E-06	8.47E-01	.8469696E+00	Pasture
628681.5	4165968	201	5.97E-06	9.65E-01	.9646204E+00	Carnegie
632976.6	4166183	158.4	2.80E-06	4.52E-01	.4524023E+00	Ranch
629950	4168674	309.4	1.10E-04	1.78E+01	.1782249E+02	B812
630020	4168179	379.3	9.35E-05	1.51E+01	.1511861E+02	B895
633000	4170500	273.9	5.24E-06	8.47E-01	.8469696E+00	Pasture repeat
629500	4168500	383.9	7.01E-04	1.13E+02	.1132646E+03	Ecological

Table 4
Annual Average Barium Time-Average {1-hr} Concentration (Micrograms/Cubic Meter)
(Due to source group 3, sources: 3) Burn Cage (form 4)
(Maximum = .31683E-02 at X,Y,Z = 629500.00,4168500.00,383.90)

X (Meters)	Y (Meters)	Z (Meters)	Time-Avg. Con.	chi/Q	chi/Q for .XOQ file	
633000	4170500	273.9	2.68E-05	8.33E-01	.8327701E+00	Pasture
628681.5	4165968	201	2.94E-05	9.14E-01	.9135820E+00	Carnegie
632976.6	4166183	158.4	1.40E-05	4.37E-01	.4366424E+00	Ranch
629950	4168674	309.4	4.71E-04	1.46E+01	.1463560E+02	B812
630020	4168179	379.3	4.49E-04	1.39E+01	.1394629E+02	B895
633000	4170500	273.9	2.68E-05	8.33E-01	.8327701E+00	Pasture repeat
629500	4168500	383.9	3.17E-03	9.85E+01	.9851374E+02	Ecological

Table A-3. Calculations of X/Q based on barium emission factor of 0.000086 (continued).

Table 5
Annual Average Barium Time-Average {1-hr} Concentration (Micrograms/Cubic Meter)
(Due to source group 4, sources: 4) Detonation Pad
(Maximum = .12974E-02 at X,Y,Z = 629500.00,4168500.00,383.90)

X (Meters)	Y (Meters)	Z (Meters)	Time-Avg. Con.	chi/Q	chi/Q for .XOQ file	
633000	4170500	273.9	2.20E-05	5.08E-01	.5081029E+00	Pasture
628681.5	4165968	201	2.30E-05	5.31E-01	.5313557E+00	Carnegie
632976.6	4166183	158.4	1.33E-05	3.07E-01	.3067369E+00	Ranch
629950	4168674	309.4	1.80E-04	4.17E+00	.4165263E+01	B812
630020	4168179	379.3	2.55E-04	5.90E+00	.5900570E+01	B895
633000	4170500	273.9	2.20E-05	5.08E-01	.5081029E+00	Pasture repeat
629500	4168500	383.9	1.30E-03	3.00E+01	.2996758E+02	Ecological

Table 6
Highest Barium Time-Average {1-hr} Concentration (Micrograms/Cubic Meter)
(Due to source group 1, sources: 1) Burn Pan
(Maximum = .12456E+00 at X,Y,Z = 629500.00,4168500.00,383.90)

X (Meters)	Y (Meters)	Z (Meters)	Time-Avg. Con.	chi/Q	chi/Q for .XOQ file	Mo/	Dy/	Yr	Jdy	Hr
633000	4170500	273.9	1.32E-03	1.22E+00	.1215469E+01	3	26	0	86	800
628681.5	4165968	201	2.35E-03	2.17E+00	.2165291E+01	9	13	1	256	800
632976.6	4166183	158.4	1.20E-03	1.10E+00	.1103433E+01	3	6	3	65	800
629950	4168674	309.4	3.01E-02	2.78E+01	.2780344E+02	11	6	2	310	800
630020	4168179	379.3	3.10E-02	2.86E+01	.2856795E+02	12	20	4	355	800
633000	4170500	273.9	1.32E-03	1.22E+00	.1215469E+01	3	26	0	86	800
629500	4168500	383.9	1.25E-01	1.15E+02	.1149549E+03	9	11	2	254	800

Table 8
Highest Barium Time-Average {1-hr} Concentration (Micrograms/Cubic Meter)
(Due to source group 2, sources: 2) Burn Cage (form 3)
(Maximum = .53005E-01 at X,Y,Z = 629500.00,4168500.00,383.90)

X (Meters)	Y (Meters)	Z (Meters)	Time-Avg. Con.	chi/Q	chi/Q for .XOQ file	Mo/	Dy/	Yr	Jdy	Hr
633000	4170500	273.9	5.25E-04	9.68E-01	.9681504E+00	12	6	2	340	800
628681.5	4165968	201	8.73E-04	1.61E+00	.1612032E+01	9	13	1	256	800
632976.6	4166183	158.4	4.26E-04	7.87E-01	.7870972E+00	3	6	3	65	800
629950	4168674	309.4	1.44E-02	2.66E+01	.2655287E+02	1	19	4	19	900
630020	4168179	379.3	1.23E-02	2.28E+01	.2275583E+02	11	25	0	330	800
633000	4170500	273.9	5.25E-04	9.68E-01	.9681504E+00	12	6	2	340	800
629500	4168500	383.9	5.30E-02	9.78E+01	.9783278E+02	9	11	2	254	800

Table A-3. Calculations of X/Q based on barium emission factor of 0.000086 (continued).

Table 10

Highest Barium Time-Average {1-hr} Concentration (Micrograms/Cubic Meter)

(Due to source group 3, sources: 3) Burn Cage (form 4)

(Maximum = .22025E+00 at X,Y,Z = 629500.00,4168500.00,383.90)

X (Meters)	Y (Meters)	Z (Meters)	Time-Avg. Con.	chi/Q	chi/Q for .XOQ file	Mo/	Dy/	Yr	Jdy	Hr
633000	4170500	273.9	2.59E-03	9.19E-01	.9185706E+00	12	6	2	340	800
628681.5	4165968	201	4.10E-03	1.46E+00	.1456615E+01	9	13	1	256	800
632976.6	4166183	158.4	2.08E-03	7.38E-01	.7377422E+00	3	6	3	65	800
629950	4168674	309.4	5.20E-02	1.85E+01	.1845262E+02	1	19	4	19	900
630020	4168179	379.3	5.71E-02	2.03E+01	.2027826E+02	11	25	0	330	800
633000	4170500	273.9	2.59E-03	9.19E-01	.9185706E+00	12	6	2	340	800
629500	4168500	383.9	2.20E-01	7.82E+01	.7817806E+02	9	11	2	254	800

Table 12

Highest Barium Time-Average {1-hr} Concentration (Micrograms/Cubic Meter)

(Due to source group 4, sources: 4) Detonation Pad

(Maximum = .19682E+00 at X,Y,Z = 629500.00,4168500.00,383.90)

X (Meters)	Y (Meters)	Z (Meters)	Time-Avg. Con.	chi/Q	chi/Q for .XOQ file	Mo/	Dy/	Yr	Jdy	Hr
633000	4170500	273.9	6.20E-03	1.64E+00	.1635014E+01	12	8	0	343	900
628681.5	4165968	201	4.57E-03	1.21E+00	.1205510E+01	9	13	1	256	800
632976.6	4166183	158.4	3.92E-03	1.03E+00	.1033016E+01	10	16	1	289	800
629950	4168674	309.4	2.02E-02	5.33E+00	.5332686E+01	1	1	0	1	900
630020	4168179	379.3	8.66E-02	2.28E+01	.2282787E+02	3	6	3	65	800
633000	4170500	273.9	6.20E-03	1.64E+00	.1635014E+01	12	8	0	343	900
629500	4168500	383.9	1.97E-01	5.19E+01	.5189800E+02	2	18	0	49	800

Table A-4. Modified .XOQ file after the annual average and maximum hourly values were updated with OBODM X/Q values. (Other values in .XOQ files were not used in this risk assessment).

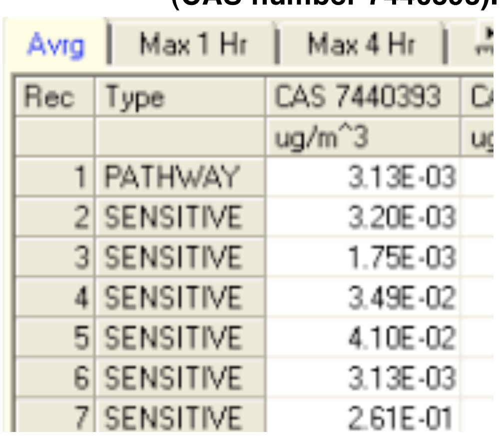
SRC	REC	UNUSED	AVERAGE	1HR_MAX	. . .(additional columns, not used in this assessment)
1	1	0.3961217E+00	0.8515709E+00	0.1215468E+01	. . .
1	2	0.2721988E-02	0.8194978E+00	0.2165290E+01	. . .
1	3	0.2719286E-02	0.3965510E+00	0.1103435E+01	. . .
1	4	0.2839895E-02	0.1455489E+02	0.2780341E+02	. . .
1	5	0.3750449E-01	0.1364920E+02	0.2856795E+02	. . .
1	6	0.2341939E-01	0.8515709E+00	0.1215468E+01	. . .
1	7	0.2341939E-01	0.1133045E+03	0.1149555E+03	. . .
2	1	0.4261317E+00	0.8469687E+00	0.9681504E+00	. . .
2	2	0.3105313E-02	0.9646185E+00	0.1612033E+01	. . .
2	3	0.4173856E-01	0.4524008E+00	0.7870981E+00	. . .
2	4	0.2657336E-01	0.1782248E+02	0.2655291E+02	. . .
2	5	0.8583720E+00	0.1511857E+02	0.2275590E+02	. . .
2	6	0.1174408E+01	0.8469687E+00	0.9681504E+00	. . .
2	7	0.2341939E-01	0.1132647E+03	0.9783286E+02	. . .
3	1	0.4261317E+00	0.8327705E+00	0.9185696E+00	. . .
3	2	0.3105313E-02	0.9135818E+00	0.1456616E+01	. . .
3	3	0.4173856E-01	0.4366443E+00	0.7377392E+00	. . .
3	4	0.2657336E-01	0.1463560E+02	0.1845262E+02	. . .
3	5	0.8583720E+00	0.1394625E+02	0.2027827E+02	. . .
3	6	0.1174408E+01	0.8327705E+00	0.9185696E+00	. . .
3	7	0.2341939E-01	0.9851385E+02	0.7817816E+02	. . .
4	1	0.2331261E+00	0.5051017E+00	0.1635015E+01	. . .
4	2	0.2328404E-02	0.5313550E+00	0.1205510E+01	. . .
4	3	0.3221262E-01	0.3067384E+00	0.1033016E+01	. . .
4	4	0.1822067E-01	0.4165249E+01	0.5332677E+01	. . .
4	5	0.7229874E+00	0.5900564E+01	0.2282789E+02	. . .
4	6	0.9328276E+00	0.5081017E+00	0.1635015E+01	. . .
4	7	0.2341939E-01	0.2996745E+02	0.5189790E+02	. . .

Table A-5. Total ground level concentration of barium for all four sources by receptor location[a].

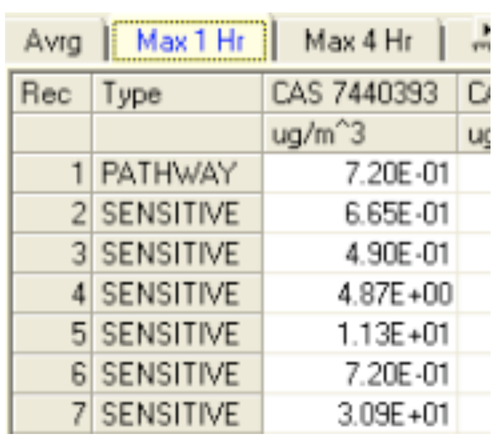
Annual average				
Location	X (UTM East) (Meters)	Y (UTM North) (Meters)	Z (Elevation) (Meters)	Ground Level Concentration µg/m3
Pasture	633000	4170500	273.9	3.13E-03
Carnegie	628681.5	4165968	201	3.20E-03
Ranch	632976.6	4166183	158.4	1.75E-03
B812	629950	4168674	309.4	3.49E-02
B895	630020	4168179	379.3	4.10E-02
Pasture repeat	633000	4170500	273.9	3.13E-03
Ecological	629500	4168500	383.9	2.61E-01
Maximum 1 hour				
Location	X (UTM East) (Meters)	Y (UTM North) (Meters)	Z (Elevation) (Meters)	Ground Level Concentration µg/m3
Pasture	633000	4170500	273.9	7.20E-01
Carnegie	628681.5	4165968	201	6.65E-01
Ranch	632976.6	4166183	158.4	4.90E-01
B812	629950	4168674	309.4	4.87E+00
B895	630020	4168179	379.3	1.13E+01
Pasture repeat	633000	4170500	273.9	7.20E-01
Ecological	629500	4168500	383.9	3.09E+01

[a] the burn pan (source 1) and detonation pad (source 4) values are obtained from Table A-2, and the burn cage/Form 3 (source 2) and burn cage/Form 4 (source 3) values are obtained from Table A-3.

Figure A-1. Screen captures of total ground level concentrations for the HARP for barium (CAS number 7440393).



Rec	Type	CAS 7440393 ug/m^3
1	PATHWAY	3.13E-03
2	SENSITIVE	3.20E-03
3	SENSITIVE	1.75E-03
4	SENSITIVE	3.49E-02
5	SENSITIVE	4.10E-02
6	SENSITIVE	3.13E-03
7	SENSITIVE	2.61E-01



Rec	Type	CAS 7440393 ug/m^3
1	PATHWAY	7.20E-01
2	SENSITIVE	6.65E-01
3	SENSITIVE	4.90E-01
4	SENSITIVE	4.87E+00
5	SENSITIVE	1.13E+01
6	SENSITIVE	7.20E-01
7	SENSITIVE	3.09E+01

Note: The pathway location (for the beef ingestion pathway) was repeated as the number 6 “sensitive” location (for a person) in the HARP to assure that the final result was a risk value for a person at that location, and not some other type of receptor, e.g., a cow. The pathway location was necessary for the HARP to calculate a human ingestion dose from the beef pathway.

Appendix B. Ecological Risk Assessment in Support of Renewal of Permit for the Explosive Waste Treatment Facility (EWTF) at Site 300 of Lawrence Livermore National Laboratory

B.1 Introduction

This ecological risk assessment (ERA) is a supplement to the human health risk assessment (HRA) for the Explosive Waste Treatment Facility (EWTF). The EWTF is located near the center of Site 300 in a small, isolated canyon (see Figures 2 through 6 in the text). The ERA described in detail in this Appendix was prepared in accordance with guidance on currently accepted practice provided by the Human and Ecological Risk Division (HERD) at the Department of Toxic Substances Control (DSTC) of the State of California Environmental Protection Agency (CalEPA) in Sacramento, California. A separate document describes the spreadsheet calculations for populating the data tables in this appendix, which pertain to the ERA analysis (Daniels, 2007).

The technical basis for this ERA is an analysis that involves a series of screening calculations to assess each of 21 contaminants of potential ecological concern (CPECs) for its potential to produce an adverse ecological impact in particular wildlife species, including vegetation, considered representative receptors of ecological interest (RREI) in the trophic levels of the food network at Site 300. This series of screening calculations is designed to illustrate whether CPECs identified as being of possible consequence in the most conservative screening calculation actually may be of lesser or no significance when more information is considered in subsequent screening calculations.

All of the series of screening calculations are based on a ratio between a soil concentration for a CPEC at a specific location (mg_{CPEC}/kg_{soil}) and a corresponding location-specific ecological soil screening level ($ESSL_{LS}$; mg_{CPEC}/kg_{soil}). Such a ratio of concentration values for a CPEC is the location-specific ecological hazard quotient (EHQ_{LS}) for that CPEC. Any EHQ_{LS} that exceeds one indicates that the CPEC may be of possible consequence; however, the $ESSL_{LS}$ used as the denominator of the EHQ_{LS} ratio may either be applicable to an individual RREI, or be a *most* conservative (lowest) value $ESSL_{LS}$ selected from among all of the $ESSL_{LS}$ values derived for each of the members of each RREI category (e.g., animal wildlife organisms, consisting of mammals, birds, reptiles, and invertebrates; or vegetation, consisting of all plants). In this latter case, the EHQ_{LS} will be the most conservative one (i.e., the lowest $ESSL_{LS}$ will appear as the denominator in each of the EHQ_{LS} calculations). Specifically, the location-specific most conservative (lowest) minimum ecological soil screening level ($ESSL_{LS\text{-}min}$) value for a CPEC is that one selected from all of the $ESSL_{LS\text{-}min}$ values derived for each RREI, and each individual $ESSL_{LS\text{-}min}$ value for an RREI applicable to a particular CPEC is obtained using either the lowest toxic reference value (TRV_{Lo}) available for that CPEC with respect to that RREI or an $ESSL_{LS\text{-}min}$ already available in the literature. In this case, using this most conservative (lowest) $ESSL_{LS\text{-}min}$ as the denominator of the EHQ_{LS} equation for a CPEC will yield an $EHQ_{LS\text{-}max}$ value for that CPEC that is the most conservative for the category of RREIs (e.g., animal wildlife organisms). Thus, any

CPEC with an $EHQ_{LS\text{-}max} > 1$ suggests it may be of potential consequence to an RREI or the food web and so that CPEC deserves further assessment.

The food network at Site 300 consists of nine different wildlife organisms plus vegetation, which represent a total of 10 individual RREIs across the different trophic levels. The nine RREIs composing wildlife organisms are one category of RREI and vegetation is another, due primarily to limitations in data with respect to deriving $ESSL_{LS}$ values for CPECs for vegetation.

There are seven steps involved in performing the series of screening analyses that constitute this ERA analysis. A summary of the details involved in performing each step follows:

1) Each CPEC in emissions from the Open Burn/Open Detonation (OB/OD) operations at the Site 300 EWTF was identified, and its soil concentration over a 6-inch (15-cm) depth (mg_{CPEC}/kg_{soil}) was predicted for a receptor location of interest based on atmospheric dispersion and deposition modeling. This ERA analysis addresses 21 CPECs with respect to the RREIs of interest.

2) The RREIs of interest were selected from among the trophic levels of the applicable wildlife food web in the habitat of interest. A reasonable approximation of total daily dietary matter intake (DMI-total/d) was obtained from the literature for each vertebrate RREI and quantified per unit body weight (i.e., mammal, avian, and reptile; $mg_{DMI\text{-}total}/[kg_{bw}\ d]$). Also obtained from the literature for these vertebrate RREIs were dietary fractions for consumption of specific dietary matter intake (DMI-specific) and bioaccumulation factors (BAFs; $mg_{CPEC}/kg_{DMI\text{-}specific}$ per mg_{CPEC}/kg_{soil}) for such specific dietary matter intake, all of which are then used with a CPEC-specific toxicity reference value (TRV) applicable to an RREI to derive a CPEC-specific $ESSL_{LS}$ value for that RREI. A lowest observed adverse effect concentration (LOAEC; mg_{CPEC}/kg_{soil}), obtained for the earthworm from data in the literature, was considered applicable to soil invertebrates and found suitable for use as an $ESSL_{LS\text{-}min}$ for this RREI. Plants were also evaluated as a separate vegetation category of RREI, and an LOAEC (mg_{CPEC}/kg_{soil}) generalizeable to all plants for a CPEC was obtained from the literature where available and found suitable for use as an $ESSL_{LS\text{-}min}$ for this RREI. There is an assumption in the ecological risk assessment process (Suter et al., 2000) that as long as a LOAEC is not significantly exceeded for plants and an earthworm (soil invertebrate) (i.e., the ecological hazard quotient [EHQ] is less than one), the plant and invertebrate community is protected.

3) For the 21 CPECs to be assessed there is a TRV_{Lo} ($mg_{CPEC}/(kg_{bw}\ d)$) value for a mammalian experimental test species (ETS), and in some cases for an avian ETS too. Each such TRV_{Lo} value represents a no observed adverse effect level (NOAEL) for the respective CPEC and ETS. The TRV_{Lo} value for each CPEC that is associated with a mammalian ETS is converted to both a TRV_{Lo} value for that CPEC that is associated with a specific mammalian-wildlife RREI, and also to a mammal-based TRV_{Lo} for that CPEC that is associated with the reptilian-wildlife RREI (because no reptile ETS is available in the literature to derive TRV_{Lo} values for a reptile for any of

the CPECs). The TRV_{Lo} value for each CPEC that is associated with an avian ETS is converted to both a TRV_{Lo} value for that CPEC that is associated with a specific avian-wildlife RREI, and also to an avian-based TRV_{Lo} for that CPEC that is associated with the reptilian-wildlife RREI (again, because no reptile ETS was available to derive TRV_{Lo} values for a reptile for any of the CPECs). By analogy, each TRV_{Lo} for a CPEC and wildlife RREI also equates to a NOAEL (with the understanding that it is the lowest TRV_{Lo} between the mammal- and avian-based reptilian TRV_{Lo} that is considered applicable to a reptile; albeit, the avian and reptile have more metabolic and physiological similarities than the mammal and reptile). In either case the mammal-based and avian-based derivation of an $ESSL_{LS}$ for a reptile will be quite uncertain.

4) The TRV_{Lo} for a CPEC and wildlife RREI then serves as the basis for deriving a CPEC-specific $ESSL_{LS\text{-}min}$ for that wildlife RREI at a location. As already mentioned, for invertebrates and plants an LOAEC available from the literature is interpreted to represent the $ESSL_{LS\text{-}min}$ for the invertebrate RREI and vegetation RREI. In all cases, each respective $ESSL_{LS\text{-}min}$ value corresponds to a CPEC-specific concentration in soil at a location and is considered to be protective of a particular category of wildlife receptor (e.g., mammal, bird, reptile, invertebrate, or plant) that might have direct or indirect contact with such soil. From among the CPEC-specific $ESSL_{LS\text{-}min}$ values applicable to each of the animal wildlife RREI (i.e., eight vertebrate—five different mammals, two different birds, one reptile—and one soil invertebrate RREI) at a location, the most conservative (lowest) $ESSL_{LS\text{-}min}$ is selected. This lowest $ESSL_{LS\text{-}min}$ value is then used as the denominator of a quotient that has the model-predicted soil concentration for that location as the numerator. Because the denominator of this quotient is the most conservative (lowest) $ESSL_{LS\text{-}min}$, this quotient is then the most conservative (maximum) location-specific ecological hazard quotient ($EHQ_{LS\text{-}max}$) at a location. Where such a conservatively derived $EHQ_{LS\text{-}max}$ exceeds one, that CPEC is considered to be of possible consequence to one or more of the nine organisms composing the animal wildlife in the food network at Site 300. Therefore, each CPEC, if any, with an $EHQ_{LS\text{-}max}$ exceeding one, would "not be filtered" from further consideration in this conservative screening process and so would deserve further assessment. Similarly, if a cumulative $EHQ_{LS\text{-}max}$, represented by the sum of $EHQ_{LS\text{-}max}$ values for those CPECs with similar toxic action, if any, exceeds one, then the CPECs in that category also would deserve further evaluation, as they would "not be filtered" from further consideration by this conservative screening process.

5) The next series of calculations looks specifically at $EHQ_{LS\text{-}max}$ values computed at different receptor locations from model-predicted soil concentrations for two vertebrate species of particular concern at Site 300—the San Joaquin Kit Fox and the Burrowing Owl. Each of these CPEC-specific $EHQ_{LS\text{-}max}$ values at a different location is calculated using $ESSL_{LS\text{-}min}$ values derived specifically for each one of these organisms that are of particular concern (and either of these $ESSL_{LS\text{-}min}$ values may or may not equate to the most conservative [lowest] $ESSL_{LS\text{-}min}$ obtained from those determined for all nine animal organisms). This screening is performed to determine if any CPEC-specific $EHQ_{LS\text{-}max}$ or a particular cumulative (summed) $EHQ_{LS\text{-}max}$ for any group of CPECs exceeds one for either or both organisms, and

which, if any, CPEC or category of CPECs would deserve further examination especially with regard to one or both of these organisms.

6) Because ecological soil screening levels applicable to vegetation exist only for the CPECs that are metals, and soil concentration measurements from across Site 300, which can be considered background, are available for only seven of the eight metals among the 21 CPECs that are being assessed, the vegetation-RREI category is addressed separately. In this screening calculation the most conservative LOAEC with respect to plants that is applicable to a metal CPEC with a background soil concentration measurement available for Site 300 is used. This LOAEC is then considered the $ESSL_{LS\text{-}min}$ for plants in the vegetation RREI at Site 300. A Site 300 $EHQ_{LS\text{-}max}$ for vegetation is then derived for each metal CPEC as the ratio of the soil (considered background) concentration of the CPEC metal measured at Site 300 to the $ESSL_{LS\text{-}min}$ represented by the most conservative (lowest) LOAEC for that metal. Where any CPEC-specific $EHQ_{LS\text{-}max}$ for Site 300 exceeds one, or the total cumulative (summed) $EHQ_{LS\text{-}max}$ for all metal CPECs measured at Site 300 exceeds one, the CPEC or category of CPEC would "not be filtered" from further consideration by this conservative screening process, and a possibility for ecological impact on vegetation from such metal or metals deserves further evaluation.

   Additional calculations are performed to determine metal CPEC-specific $EHQ_{LS\text{-}max}$ values that are based on ratios of location-specific model-predicted soil concentrations for each metal and the corresponding $ESSL_{LS\text{-}min}$ represented by the most conservative (lowest) LOAEC for each CPEC metal. Where any of these $EHQ_{LS\text{-}max}$ values for a metal CPEC at a location exceed one, or a total cumulative (summed) $EHQ_{LS\text{-}max}$ for all metal CPECs at a location exceeds one, it is perhaps more reasonable that such a metal CPEC or category of metal CPECs may be of consequence with respect to impacting vegetation. This is examined even further by also looking at the ratios of the modeled to measured $EHQ_{LS\text{-}max}$ values for each CPEC, and also at the contribution to the total cumulative (summed) $EHQ_{LS\text{-}max}$ value derived for measured (background) soil concentrations at Site 300 that may be made by the total cumulative (summed) $EHQ_{LS\text{-}max}$ derived for model-predicted soil concentrations. Where either a ratio of these $EHQ_{LS\text{-}max}$ values for a CPEC is substantial, or a contribution to a cumulative (summed) $EHQ_{LS\text{-}max}$ for background by a cumulative (summed) $EHQ_{LS\text{-}max}$ for model-predicted soil concentrations at a location is substantial, there is more reason to look at one or more of the metal CPECs with respect to potential impact on vegetation.

7) For vertebrate wildlife, where $ESSL_{LS\text{-}min}$ values are derived from TRV_{Lo} values representing NOAELs (and do not represent LOAEC values as were used for invertebrates and plants), further screening is then performed on those CPECs (or CPECs in a category) for which a most conservative $EHQ_{LS\text{-}max}$ value (or cumulative $EHQ_{LS\text{-}max}$) exceeds one. This additional screening is conducted in two phases. In the first phase CPECs not filtered from further consideration from among the 21 CPECs screened conservatively with respect to model-predicted soil concentrations and all of the vertebrate wildlife RREIs at Site 300 locations are examined. This analysis involves the use of $EHQ_{LS\text{-}min}$ values derived from model-predicted soil

concentrations and TRV_{Hi}-based $ESSL_{LS\text{-}max}$ values for these CPECs. Also in this first phase of screening, these same CPECs are evaluated with respect to the two vertebrate species of particular concern at Site 300, the San Joaquin Kit Fox and Burrowing Owl, and this evaluation is performed with respect to these CPECs and organisms using $EHQ_{LS\text{-}min}$ values. In the second phase of screening, those 7 CPEC metals for which measurement of soil concentrations exist at Site 300 (and are considered to be background levels) are examined with regard to potential impact on animal wildlife RREIs. The screening of these 7 metal CPECs is performed first with respect to $EHQ_{LS\text{-}max}$ values for all animal wildlife. Then, additional screening is performed with respect to any CPECs not filtered from further consideration by this process. For this additional screening thresholds for soil screening level concentrations for these particular CPECs are derived from lowest observed adverse effect levels (LOAELs), which are represented by available highest toxic reference values (TRV_{Hi} s). Thus, the location-specific soil screening level that is used to evaluate each of these metals will be applicable to a vertebrate RREI, and will have a value greater than the $ESSL_{LS\text{-}min}$ used previously for a vertebrate RREI. Consequently, each ecological soil screening level used for purposes of this additional screening is going to be a maximum ($ESSL_{LS\text{-}max}$), and because this $ESSL_{LS\text{-}max}$ is used in the denominator of the ecological hazard quotient (EHQ), the result will be a minimum (i.e., $EHQ_{LS\text{-}min}$). In concluding this second phase of screening, all 7 metal CPECs for which measurement data exists for Site 300 are then evaluated with respect to the two organisms of particular concern at Site 300 (the San Joaquin Kit Fox and the Burrowing Owl) and this is done by first using $EHQ_{LS\text{-}max}$ values and then $EHQ_{LS\text{-}min}$ values specific to these two organisms and all 7 CPEC metals measured at Site 300.

Forty-five potential contaminants (including surrogates, such as Research Department Explosive (RDX), which represents both RDX and pentaerythritol tetranitrate [PETN]) are considered to be produced from OB/OD operations at the EWTF. Among these 45 substances, 24 are not addressed in this ERA because they are gaseous or gaseous upon emission. These emissions disperse significantly into the atmosphere and do not pose a problem as potential soil contaminants. The 24 emissions falling into this "gaseous emission" category are carbon monoxide (CO), chlorine (Cl), hydrogen chloride (HCl), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and 19 additional volatile organic compounds (VOCs)—allyl chloride; benzene; 1,3-butadiene; carbon tetrachloride; chloroform; cyclohexane; ethylbenzene; ethyl chloride; isopropylbenzene; methyl chloride (or chloromethane); methyl chloroform (or 1,1,1-trichloroethane); methyl cyclohexane; methyl chloride; n-hexane; propene; styrene; tetrachloroethylene (1,1,2,2-tetrchloroethane); toluene; and vinyl chloride. The 21 remaining substances were considered CPECs and consisted of five polychlorinated dibenzofurans (PCDFs), three energetic or other thermally labile compounds, eight metals, and five semi-volatile organic compounds (SVOCs).

This ERA evaluated deposited emissions with respect to impacts on plants and the nine different animal RREIs identified below:

- Soil invertebrate (represented by the earthworm).

- Ominvorous bird (represented by the Savannah Sparrow [*Passerculus sandwichensis*]).
- Carnivorous bird (represented by the Burrowing Owl [*Athene cunicularia*]).
- Insectivorous reptile (represented by the Side-Blotched Lizard [*Uta stansubriana*]).
- Omnivorous small mammal (Deer Mouse [*Permyscus maniculatus*]).
- Granivorous small mammal (California Ground Squirrel [*Spermophilus beecheyi*]).
- Herbivorous small mammal (Pocket Gopher [*Thomomys bottae*]).
- Herbivorous large mammal (Black-Tailed [Mule] Deer [*Odocoileus hemionus columbianus*]).
- Carnivorous mammal (San Joaquin Kit Fox [*Vulpes macrotis mutica*]).

Each animal RREI (except for the soil invertebrate) has a distinct diet at its particular level of the food web (conceptualized in Figure B-1).

B.1.1 Source Term

The EWTF OB/OD operations at Site 300 represent the source term. As described in the risk assessment text, these operations involve:

- Open detonation of Waste Form 1 (waste explosives that otherwise might detonate during open burning).
- Open burning in a burn pan of Waste Form 2 (waste explosives or explosive parts).
- Open burning in a burn cage of either Waste Form 3 (waste explosives that are wetted in processing or as a result of removal from waste water as sludge from weirs and settling basins or on wetted expendable filters) or Waste Form 4 (explosives-contaminated waste materials, including paper, rags, plastic tubing, gloves and personal protective equipment).

Emissions were estimated based on the planned quantities of materials to be treated annually (see Table 1 in the text):

- Waste Form 1 (OD treatment) is considered to involve 100 annual treatments of 350 pounds (159 kg) each.
- Waste Form 2 (OB pan) is considered to involve 100 annual treatments of 100 pounds (45 kg) each.
- Waste Form 3 (OB cage) is considered to involve 100 annual treatments of 50 pounds (23 kg) each.
- Waste Form 4 (OB cage) is considered to involve 100 annual treatments of 260 pounds (118 kg) each.

For this ERA, the Open Burn/Open Detonation Dispersion Model (OBODM) and HotSpots Analysis and Reporting Program (HARP) models (see Bjorklund et al., 1998; CARB, 2003) were linked to estimate maximum annual soil concentrations for each of the 21 CPECs over a depth of 6 inches (15 cm) at six different receptor locations in the habitat of Site 300, including one location near the OD pad, OB burn pan, and OB burn cage (all of which are in close proximity) at the EWTF site (shown in Figure 6 of the main text).

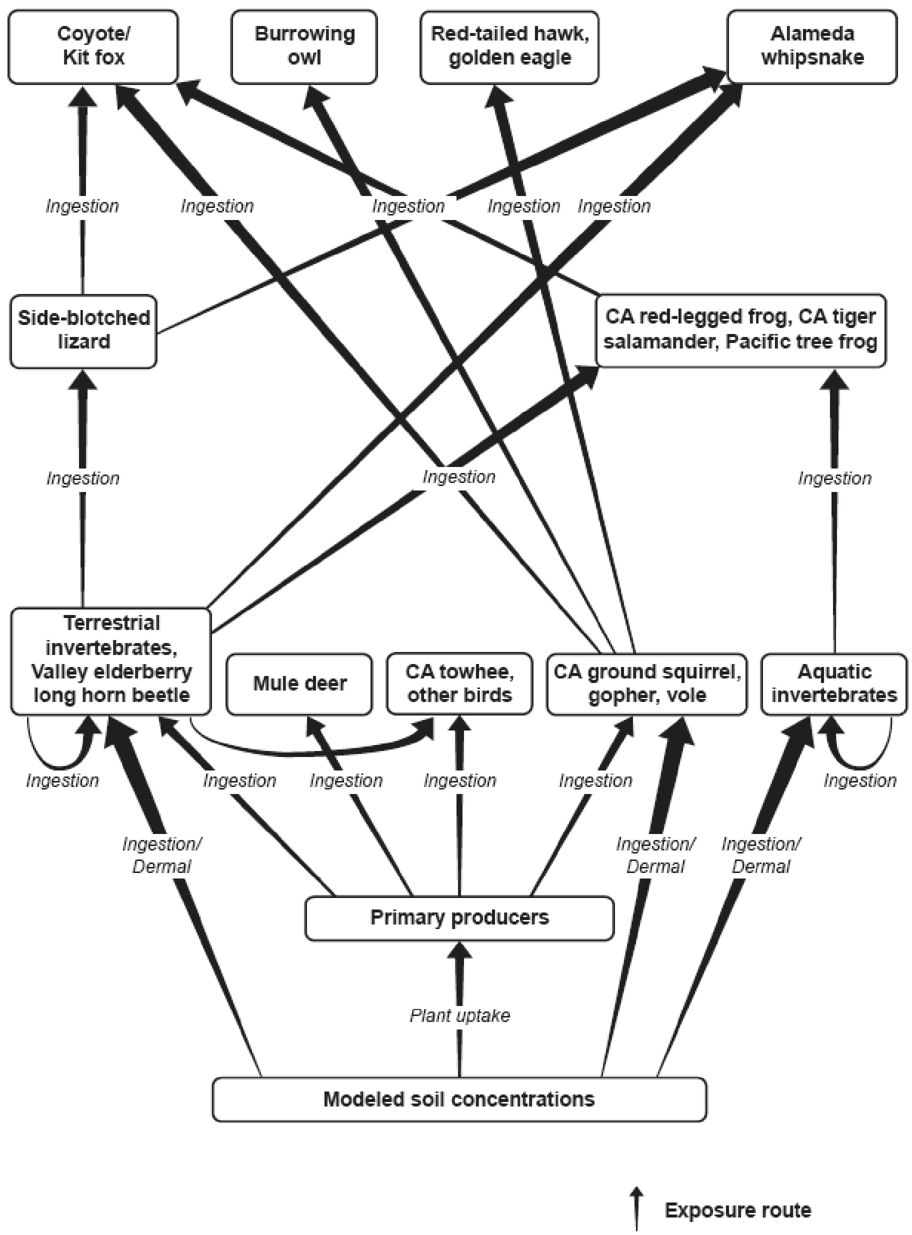


Figure B-1. RREIs of concern in relation to conceptualized food web.

B.1.2 Relevant Exposure Pathways for Each RREI

Only the ingestion exposure pathway was considered for each animal RREI. "Ingestion" is defined as dry-matter intake (DMI) of the proportion of vegetation, invertebrate prey and/or vertebrate prey as well as incidental soil ingestion considered representative of the diet of a particular RREI. Potential inhalation and dermal absorption of CPEC-contaminated soil as a result of particulate resuspension into air or contact with soil on the ground or in burrows were considered to contribute significantly lower doses than those associated with the ingestion pathway. The intake of contaminated water by an RREI also was not addressed in this ERA as water contamination is not considered especially relevant for the receptor locations.

For purposes of conservatism, all animal RREI living, foraging, prey capturing, and subject to incidental soil ingestion were considered to occur at the selected receptor sites, including that habitat nearest OB/OD operations, where modeling predicted that the highest concentrations of each CPEC are deposited. In addition, concentrations of CPECs were calculated over a depth of 6 inches (15 cm). Although 2 feet (60 cm) is a common depth for evaluating the effects on fossorial animals (DTSC, 1998), that depth was not used. One conservative reason for not using a depth greater than 6 inches (15 cm) is that the source of contamination is air deposition; therefore, the soil at depth is not expected to be at as high a level of contamination as that soil which is present at or near the surface. Another conservative reason for not considering contamination to a greater depth than 6 inches is that the assumption is made that the absorption fraction of each CPEC from the intestinal tract of each RREI is considered to be 100 percent. Therefore, the combination of these factors makes considering contamination to only a 6-in (15-cm) depth sufficiently conservative to be justified.

B.1.3 Habitat

Site 300 itself is hilly, natural grassland habitat. Only about 5 percent of this 11-square-mile (28-sq-km) site is even developed. Put into perspective, the vast majority of this site is undeveloped and consists mostly of undisturbed land with diverse wildlife. In fact, Site 300 is a high explosives testing area, has no public access, and is subject to controlled burns. Indeed, these factors all combine to prevent impacts from grazing and contribute to natural biodiversity (U.S. Department of Energy/National Nuclear Security Administration [DOE/NNSA], 2005).

B.1.4 Identification of CPECs and RREIs

Table B-1 contains the list of the 21 CPECs, along with their Chemical Abstract Service registry identification numbers (CAS ID), applicable toxicity equivalency factors (TEF), and the low toxicity reference values (TRV_{Lo}) obtained experimentally for mammalian and avian test species, as well as the body weight associated with each experimental test species (ETS). These TRV_{Lo} values will be translated to ones applicable to analogous animal wildlife RREI and a reptile. The 21 CPECs are divided among four chemical categories:

- Five polychlorinated dibenzofurans (PCDFs).

- Three energetic and thermally labile compounds.
- Eight metals.
- Five SVOCs.

For each of the five PCDF congeners, the TEFs that are applicable to humans and mammals with respect to 2,3,7,8 tetrachlorodibenzo-p-dioxin (TCDD), and to birds with respect to 2,3,7,8-tetrachlorodibenzofuran (TCDF) were provided (see Van den Berg et al., 1998). Thus, a TRV that is applicable to a mammal for a particular PCDF can be multiplied by the TEF for that PCDF (i.e., the ratio of toxic dose for TCDD to that for the PCDF) to yield the TRV for the more toxic TCDD that was used to generate it. Similarly, a TRV that is applicable to birds for a particular PCDF can be multiplied by the TEF for that PCDF (i.e., the ratio of toxic dose for TCDD to that for the PCDF) to yield the TRV for the more toxic TCDF that was used to generate it. For the chemicals in the other categories, the TEF is equal to 1.0 because each TRV was derived specifically for that substance.

As a consequence of the location and the habitat of Site 300, the wildlife that were specified in this ERA as RREIs include three fossorial (i.e., burrowing) species:

- California Ground Squirrel: a small, mammalian granivore, which is generally considered to have a home range of one-quarter to one-half an acre (.1 to 0.2 ha) (CDFG, 2005a).
- San Joaquin Kit Fox: a mammalian carnivore with a general home range of 1 to 2 square miles (2.6 to 5.2 sq km) (CDFG, 2005a).
- Burrowing Owl: an avian carnivore with a general home range of 1 to 4 acres (0.4 to 1.6 ha) (CDFG, 2005b).

In addition to these organisms, wildlife also of interest in the food web of the habitat (see Figure B-1) are represented by:

- An insectivorous reptile (Side-blotched Lizard).
- An omnivorous bird (Savannah Sparrow).
- An herbivorous small mammal (Pocket Gopher).
- An herbivorous large mammal (Black-tailed [Mule] Deer with a general home range of one-third to 1 square mile [1 to 3 sq km])(CDFG, 2005a).
- An omnivorous small mammal (Deer Mouse).
- The earthworm, a terrestrial soil invertebrate.

The physiological characteristics, including body weight, total dry-matter dietary intake, and proportion of diet from other trophic levels applicable to each of these organisms, except, of course, the earthworm, appear in Table B-2.

Vegetation is also addressed as an RREI category that is part of the food web. However, it is evaluated separately from the animal wildlife RREI.

B.1.5 Estimating Location-specific Ecological Soil Screening Level ($ESSL_{LS}$) Values for a CPEC Applicable to an RREI and Corresponding Ecological Hazard Quotients (EHQ_{LS})

The procedure followed for estimating a CPEC-specific $ESSL_{LS}$ for the animal wildlife RREIs involved two steps:

1) CPEC-specific low or high toxicity reference values (i.e., TRVs in units of $mg/(kg_{bw}\ d)$) for an experimental test species (ETS) were converted to either a low or high TRV (TRV_{Lo} or TRV_{Hi}) for each animal wildlife RREI to be used in deriving $ESSL_{LS\text{-}max}$ and $ESSL_{LS\text{-}min}$ values (in units of mg_{CPEC}/kg_{soil}), respectively. The only exception was for the soil invertebrate, for which an $ESSL_{LS\text{-}min}$ value was obtained directly from the literature as a lowest observed adverse effect concentration (LOAEC) in soil.

2) A CPEC-specific $ESSL_{LS\text{-}min}$ or $ESSL_{LS\text{-}max}$ is then derived by dividing the TRV_{Lo} or TRV_{Hi} by the sum of products of dietary-matter intake specific fraction, the total dry-matter intake daily per unit body weight ($mg_{DMI\text{-}total}/kg_{bw}\ d$), and a corresponding bioaccumulation factor (BAF; $mg_{CPEC}/kg_{DMI\text{-}specific}$ per mg_{CPCE}/kg_{soil}). Generally, dietary fractions are assumed values subject to interpretation, but the ones identified and used are considered to be reasonable approximations, including a conservative default fraction of 1.0. The BAF is the uptake ratio between the concentration of a CPEC in consumed dietary matter intake stated specifically (i.e., DMI-specific, where specific is described as either vegetation, invertebrate, or small mammal) and the concentration of that CPEC in soil.

For situations where the body weight of the wildlife RREI (wlf) is within two orders of magnitude of the body weight of the experimental test species (i.e., when $BW_{ETS}/BWwlf < 100$ or $BW_{ETS}/BWwlf > 0.01$), the TRV_{Lo} or TRV_{Hi} for wildlife is equal to the quotient of the TRV_{ETS} (low or high, respectively) divided by the TEF and any uncertainty factor (UF) that is different from 1.0 (e.g., for a PCDF, it would be the TRV_{ETS} for TCDD for mammals or TCDF for birds divided by the applicable TEF for the respective PCDF, as the UF in this case is considered to be 1.0). For the situation where the body weight of the wildlife is at least two orders of magnitude different from that of the ETS ($BW_{ETS}/BWwlf \geq 100$ or $BW_{ETS}/BWwlf \leq 0.01$), allometric scaling is required to derive the TRV_{Lo} or TRV_{Hi} for wildlife (wlf), and the following equation is used:

$$TRV_{wlf}\ (mg/[kg_{bw}\ d]) = [TRV_{ETS}/(TEF \times UFs)] \times (BW_{ETS}/BW_{wlf})^{1-b}\ ,$$

where TEF is the toxicity equivalency factor, UF is the applicable uncertainty factor, and "b" in the exponent is the allometric scaling factor (SF) (Sample and Arenal, 1999).

Table B-3 contains the UFs and SFs for mammalian and avian species used to derive the CPEC-specific (low or high) TRVs for each of these animal wildlife RREIs. The CPEC-specific TRV_{Lo} values for the wildlife representing each of these RREIs are presented in Table B-4. Table B-5a contains the regression coefficients or median values used for determining the BAFs for those CPECs for which a BAF is not assigned a default value of 1.0. The regression coefficients are inserted into the following equation, as applicable, to compute a BAF:

$$BAF = \frac{\exp\left[B_0 + B_1\left(\ln C_{soil}\right)\right]}{C_{soil}},$$

where C_{soil} is the concentration of the CPEC in soil.

Table B-5b contains the values of BAFs applicable to the plants, invertebrates, and mammals consumed as dietary intake by mammals and birds.

An $ESSL_{LS}$ is a locations-specific ecological soil screening level value that is a minimum or maximum depending on whether it is derived using a TRV_{wlf} that is a low or high value. In addition to a TRV, dietary fractions (DF) of specific dietary matter intake that is consumed as vegetation (veg), invertebrates (inv), reptiles (rep), mammals (mam) and/or soil; the total dietary dry-matter intake daily per unit body weight (DMI-total; $mg_{DMI\text{-}total}/(kg_{bw\ d})$); and BAFs are needed to calculate the $ESSL_{LS}$. The DF and DMI-total data appear in Table B-2. The BAFs appear in Table B-5 and are expressed in units of ($mg_{CPEC}/kg_{DMI\text{-}specific}$ per mg_{CPEC}/kg_{soil}).

Applying dimensional analysis to the equation for deriving the CPEC-specific $ESSL_{LS\text{-}min}$ value makes transparent how the TRV_{Lo} for a wildlife RREI is converted to a corresponding location-specific minimum soil concentration ($ESSL_{LS\text{-}min}$) for a CPEC that is suitable for screening purposes:

$$\left[\frac{mg_{CPEC}}{kg_{soil}}\right]_{ESSL_{LS-min}} = \frac{\left[mg_{CPEC}\big/\left(kg_{bw}\times d\right)\right]_{TRV_{Lo}}}{\sum\left[\left(\frac{mg_{CPEC}/kg_{DMI\text{-}specific}}{mg_{CPEC}/kg_{soil}}\right)_{BAF} \times \left(\frac{kg_{DMI\text{-}specific}/d}{kg_{DMI\text{-}TOTAL}/d}\right)_{DF} \times \left(\frac{kg_{DMI\text{-}TOTAL}}{\left(kg_{bw}\times d\right)}\right)_{DDI}\right]},$$

where TRV_{Lo} = lowest toxicity reference value; BAF = bioaccumulation factor or uptake ratio of CPEC in specific dietary matter to concentration in soil; DF = dietary fraction that is a function of specific to total daily dietary matter intake; and DDI = total daily dietary matter intake per unit body weight.

Similarly, replacing the TRV_{Lo} for a wildlife RREI (in the numerator of the fraction at the right of the equal sign) with the respective TRV_{Hi} produces a corresponding CPEC-specific $ESSL_{LS\text{-}max}$ value, which is a location-specific maximum soil concentration for a CPEC that is also suitable for use in further screening analyses.

Tables B-6a and 6b list the CPEC-specific $ESSL_{LS\text{-}min}$ values for each animal wildlife RREI, including the earthworm, for the EWTF and the Ranch locations (the two locations that are the furthest distances apart). The two parts of Table B-6 (a and b) illustrate for each location the $ESSL_{LS\text{-}min}$ values from which a most conservative (lowest) $ESSL_{LS\text{-}min}$ for each CPEC at that location is selected. Each model-predicted soil concentration for a CPEC at a location may then be divided by the most conservative $ESSL_{LS\text{-}min}$ value for the CPEC at that location to obtain a most conservative CPEC-specific $EHQ_{LS\text{-}max}$ at that location. Table B-7 contains the most conservative (lowest) $ESSL_{LS\text{-}min}$ for each CPEC at each receptor location of interest, and indicates the animal wildlife organism with which each of the most conservative CPEC-specific $ESSL_{LS\text{-}min}$ values at each location is associated.

The model-predicted soil concentrations for each receptor location appear in Table B-8. Table B-9 contains the CPEC-specific $EHQ_{LS\text{-}max}$ values derived for these receptor locations. As previously noted, the $EHQ_{LS\text{-}max}$ values appearing in Table B-9 are obtained by dividing each CPEC-specific soil concentration at each location by the most conservative $ESSL_{LS\text{-}min}$ value for that location (see Table B-7 for $ESSL_{LS\text{-}min}$ values that are most conservative at each location; and see Tables B-6a and B-6b with respect to examples of how selection is made using EWTF and Ranch data).

There are $EHQ_{LS\text{-}max}$ values appearing in Table B-9 that do exceed one. For example, the $EHQ_{LS\text{-}max}$ values for lead suggest a potential to produce ecological impact at all receptor locations for which a soil concentration was predicted. Similarly, the $EHQ_{LS\text{-}max}$ values for cadmium suggest a potential for ecological impact at the location of the EWTF and also possibly at the Building 812 and Building 895 receptor locations. However, these $EHQ_{LS\text{-}max}$ values in excess of one are based on the most conservative TRVs, which correspond to NOAEL values. In fact, the TRVs for cadmium and lead derived by U.S. EPA for these compounds in Ecological Soil Screening Level documents (U.S. EPA, 2005c,d), still represent NOAEL levels, but they are not as conservative as those presented by DTSC (2000). These U.S. EPA documents identify the avian wildlife TRV for cadmium as being a geometric mean value (i.e., 1.47), and the highest bounded NOAEL below the lowest bounded LOAEL as being the mammalian TRV for cadmium (i.e., 0.77) as well as the avian and mammalian TRVs for lead (i.e., 1.63 and 4.70, respectively). Following use of the more conservative TRVs for cadmium and lead from DTSC, the $EHQ_{LS\text{-}max}$ values at the EWTF for cadmium and lead are 4.27 and 78.5, respectively (see Table B-9). However, the $EHQ_{LS\text{-}max}$ values that were derived using the TRVs from U.S. EPA (2005c,d) are actually lower than one (i.e., 0.03 for cadmium and 0.67 for lead). Even the cumulative (sum) $EHQ_{LS\text{-}max}$ value applicable to cadmium and lead, because of similar toxic action, only reaches one at the ETWF for these CPECs when the U.S. EPA TRVs are used. These results suggest that there is uncertainty with respect to those CPECs with $EHQ_{LS\text{-}max}$ values exceeding one in Table B-9 and these CPECs deserve further evaluation.

Another comparison was made between the predicted soil concentrations at the EWTF and the $ESSL_{LS\text{-}max}$ values specific to two wildlife species considered to be of particular concern at Site 300—the San Joaquin Kit Fox and the Burrowing Owl (because they are identified to be endangered or sensitive species). These results appear in Table B-10 (a and b). For the Kit Fox, only aluminum may represent a potential impact and only at the EWTF location (i.e., $EHQ_{LS\text{-}max} > 1$). Interestingly, the U.S. EPA regards aluminum only as a CPEC if soil pH is less than 5.5 (U.S. EPA, 2003). The soil pH at Site 300 is greater than 5.5 (unreported measurements have ranged from 6.9 to 9, where these unreported measurements of pH at Sit 300 were collected as part of remedial investigation work supporting the Comprehensive Environmental Response, Compensation, and Liability Act [CERCLA], which is commonly know as Superfund, and these data are maintained in electronic archives for informational purposes and have not been published in technical reports); therefore, aluminum should not be of concern. However, for the Burrowing Owl, the $EHQ_{LS\text{-}max}$ for lead and copper exceeds one at the EWTF, and for lead, the $EHQ_{LS\text{-}max}$ exceeds one at all other locations. As stated previously, the U.S. EPA has derived less conservative TRV values for mammalian and avian wildlife than has DTSC (2000). (The U.S. EPA values are 5.60 for mammalian and 4.05 for avian wildlife for copper, see recently revised and published U.S. EPA, 2007a; and 4.70 for mammalian and 1.63 for avian wildlife for lead, see U.S. EPA, 2005d.) Therefore, applying these U.S. EPA TRVs for copper and lead to the Kit Fox and Burrowing Owl will lead to lower values than those $EHQ_{LS\text{-}max}$ values described in Table B-9. Also, the assumption that all soils to which these two fossorial animals are exposed have the same concentration as predicted over a depth of 6 inches (15 cm) is conservative. If the estimated concentrations were adjusted to include uncontaminated soils at deeper levels, the calculated $EHQ_{LS\text{-}max}$ could be reduced by a factor of 4 or more. The cumulative $EHQ_{LS\text{-}max}$ for cadmium and lead due to similar toxic action that is applicable to the Kit Fox does not exceed one at any location; this same cumulative $EHQ_{LS\text{-}max}$ for the Burrowing Owl exceeds one at all locations (due overwhelmingly to lead).

Additionally, neither TRVs nor separate $ESSL_{LS}$ values have been developed by regulatory agencies for amphibians, such as the California red-legged frog (*Rana aurora draytonii*) and the California tiger salamander (*Ambystoma californiense*) that may be present near the EWTF. However, in a technical report prepared for the Naval Facility Engineering Command in Port Hueneme, CA, by ENSR International (2004; Table 3-7, p. 3-17), a range for the NOECs in sediments that correspond to sub-lethal endpoints (e.g., growth) applicable to the leopard frog (*Rana* [likely *pipiens*]) were presented for the heavy metals Cd, Cu, Pb, and Zn. For all four of these elements, the lowest sediment NOEC value in the range provided for each element (i.e., Cd = 0.46 mg/kg; Cu = 64 mg/kg; Pb = 2000 mg/kg; and Zn = 900 mg/kg) was always greater than the soil concentration predicted near the EWTF from atmospheric dispersion and deposition modeling (i.e., Cd = 0.05 mg/kg; Cu = 29 mg/kg; Pb = 8.9 mg/kg; and Zn = 1.7 mg/kg). On the basis of these results, and assuming *Rana* (likely *pipiens*) to be a suitable surrogate for *Rana aurora draytonii* and *Ambystoma californiense* serious impacts from these elements to amphibians in the area of the EWTF (as well as a distances further away) would appear to be unlikely.

Plants were evaluated separately from wildlife on the basis of available measured soil concentrations of CPECs at Site 300 and corresponding $ESSL_{LS\text{-}min}$ values based on LOAECs for plants available in the literature. These measured soil concentrations and the corresponding $ESSL_{LS\text{-}min}$ values applicable to plants exist only for heavy metals.

The corresponding $ESSL_{LS-min}$ values were obtained either from U.S. EPA (2005c,d) or from Efroymson et al. (1997). Where $ESSL_{LS-min}$ values applicable to measured soil concentrations for CPECs at Site 300 are provided by both sources, the U.S. EPA data took precedent. In Table B-11, $ESSL_{LS-min}$ values are compared first to the measured soil concentrations applicable to Site 300, and then to predicted values from modeling at the different receptor locations. The EHQ_{LS-max} determined from the ratio of measured values to $ESSL_{LS-min}$ suggest only total chromium and zinc may be of potential concern for Site 300, although the total cumulative EHQ_{LS-max} for all measured soil concentrations of metals (considered to be an estimate of background) does exceed one. These results suggest further evaluation be performed with respect to these CPECs and plants. However, the EHQ_{LS-max} values at each location developed from modeling predicted concentrations of these CPECs at each location are all less than one, as is the total cumulative EHQ_{LS-max} at any location. Further the ratio of the modeled to measured EHQ_{LS-max} is less than one at all locations, and the contribution to the fraction of the cumulative EHQ_{LS-max} at each location that corresponds to a predicted concentration is exceptionally low (also see Table B-11).

Data appearing in Tables B-12, B-13a, B-13b, and B-14 are applicable to vertebrate animals and complement the information appearing in Tables B-1, B-4, B-6a, B-6b, and B-7, with the exception that these data are now applicable only to the CPECs for which EHQ_{LS-max} values exceeded one in Table B-9 and that were constructed using a most conservative $ESSL_{LS-min}$ value, which could be selected from among those derived from a TRV_{Lo} value and for which a $ESSL_{LS-min}$ could be obtained directly. Resulting values for a location specific minimum ecological hazard quotient (EHQ_{LS-min}) based on model-predicted concentrations of these eight CPECs—three PCDFs and five heavy metals—appear in Table B-15 for each location. These results indicate that none of these EHQ_{LS-min} values exceed one, and only for the EWTF location will the cumulative EHQ_{LS-min} summed for PCDDs/PCDFs exceed one. Furthermore, Table B-16a indicates that both CPEC-specific EHQ_{LS-min} values and cumulative EHQ_{LS-min} values derived specifically for application to the Kit Fox do not exceed one at any location. Table 16b indicates similar results for the Burrowing Owl with respect to both CPEC-specific EHQ_{LS-min} values and cumulative EHQ_{LS-min} values.

Results for plants and invertebrates were obtained with respect to $ESSL_{LS-min}$ values equating to LOAECs reported in the literature. Because the assumption is made in the ecological risk assessment process that as long as the LOAEC is not significantly exceeded for plants or invertebrates these communities are protected (Suter et al. 2000), no further analysis was performed. It should be noted that some background levels of metals yielded EHQ_{LS-max} values for plants exceeding one, which indicates that further development of the science of ecological risk assessment is warranted.

Moreover, some information on chlorophenols and the polycyclic aromatic hydrocarbons fluoranthene and naphthalene is emerging, although it appears to be limited at this time. For completeness, a summary of this information follows for plants and soil invertebrates as the data currently remain uncertain.

The chlorophenol identified as a result of atmospheric dispersion and deposition modeling to be a CPEC for Site 300 is specifically identified as 2-chlorophenol. A soil-based screening benchmark concentration for phytotoxicity in soil of 7 mg/kg_{soil} is provided by Efroymson et al. (1997) only for 3-chlorophenol. Additionally, phenol is considered to be a CPEC for Site 300 and is also identified by Efroymson et al. (1997) to have a soil-based screening benchmark concentration for phytotoxicity in soil of 70 mg/kg_{soil}. Nevertheless, in both cases it appears soil-screening concentrations remain uncertain.

For fluoranthene, Sverdrup et al. (2003) indicate that a potential soil-screening concentration for vegetation based on phytotoxicity may range from 140 to 650 mg/kg_{soil}. This would probably apply to naphthalene too, based on an assumption of similar toxic action in receptors. However, it is important to note that U.S. EPA (2007b) made the decision that at this time ecological soil screening levels for PAHs cannot be derived for plants because the data that would be used for such a derivation are not sufficient.

In a series of other reports, Sverdrup et al. (2001, 2002a,b,c) also suggest that fluoranthene may produce toxicity in soil invertebrates, including a small wingless (jumping) insect (collembolan *Folsomia fimetaria* L.), an enchytraeid worm (*Enchytraeus crypticus*), and the earthworm *Eisenia veneta*. The range in soil-screening concentration that would be applicable would appear to be from 15 to 37 mg/kg_{soil}. It also seems reasonable that such a range would apply to naphthalene (individually or together with fluoranthene) because of assumed similar toxic action. However, it should be noted that toxicity actually might be governed by the concentration in pore water because a soluble fraction (amount in pore water) may be more bioavailable. Nevertheless, such a range is consistent with one of 18 to 29 mg/kg_{soil} suggested by U.S. EPA (2007b) as an ecological soil screening level for soil invertebrates for polycyclic aromatic hydrocarbons (PAHs) over all molecular weights (i.e., both low and high).

For purposes of further comparisons, most conservative $EHQ_{LS\text{-}max}$ values were then derived for all animal wildlife RREI based on measured soil concentrations for Site 300 applicable to the seven heavy metals for which measurement data are available: antimony (Sb), barium (Ba), cadmium (Cd), total chromium (Cr; assumed to be sixfold greater than hexavalent chromium), copper (Cu), lead (Pb), and zinc (Zn). To calculate the applicable $ESSL_{LS}$ values for the vertebrate RREI needed to derive the $EHQ_{LS\text{-}max}$, BAFs, for which a median BAF was not readily available in the literature, were derived based on the measured soil concentrations for these metals. Unlike median values for BAFs of CPECs, the derived BAFs for CPECs change with soil concentration according to regression equations specified in the footnotes of Table B-5a. All BAFs are provided in Table B-17a, including those constituting median values. The $ESSL_{LS\text{-}min}$ applicable to soil invertebrates is an LOAEC value, and for this reason an $ESSL_{LS\text{-}max}$ for invertebrates is not applicable. Table B-17b provides the $ESSL_{LS\text{-}min}$ and $ESSL_{LS\text{-}max}$ values for all RREI, where TRV_{Lo} and TRV_{Hi} values and respective BAF data are used for vertebrate RREI. Thus, Table B-17b contains the $ESSL_{LS\text{-}min}$ and $ESSL_{LS\text{-}max}$ values that are complementary to the information presented in Tables B-6a and B-6b (derived for vertebrate RREI using

TRV_{Lo} values) and Table B-13b (derived for vertebrate RREI using TRV_{Hi} values), with the exception that the BAFs used in Table B-17b for computing these $ESSL_{LS\text{-}min}$ and $ESSL_{LS\text{-}max}$ values for the vertebrate RREIs are based on values applicable to the soil concentrations for heavy metals measured at Site 300 (Peterson et al., 2006).

Table B-18 applies to all animal wildlife RREIs, but is constructed similar to Table B-11 for plants. Thus, in Table B-18 the most conservative (lowest) $ESSL_{LS\text{-}min}$ appears along with the corresponding $EHQ_{LS\text{-}max}$ values for the soil concentrations for CPECs measured for Site 300. The resulting $EHQ_{LS\text{-}max}$ values suggest that the measured soil concentrations, considered to be background levels, may pose a problem for animal wildlife RREI for all seven metals for which soil measurements exist at Site 300, including individually and cumulatively with respect to cadmium and lead, because of similar toxic action (i.e., all of these $EHQ_{LS\text{-}max}$ values exceed one). However, additional data provided in Table B-18 for model-predicted soil concentrations indicate that for individual CPECs, $EHQ_{LS\text{-}max}$ values from model-predicted data are small fractions of the $EHQ_{LS\text{-}max}$ values determined from the measured soil concentrations. Furthermore, the contribution of the cumulative $EHQ_{LS\text{-}max}$ determined for a model-predicted soil concentration at any location to that cumulative $EHQ_{LS\text{-}max}$ determined from measured soil concentration for Site 300 is no more than about 18% of the cumulative $EHQ_{LS\text{-}max}$ due to measured soil concentrations, and then only in the region of the EWTF (the contribution at all other locations is much less than 18%).

Table B-19 is constructed similar to Table B-18, except that only those measured metals that were not screened out in Table B-9 are considered, and the most conservative (lowest) $ESSL_{LS\text{-}max}$ for a CPEC is used to derive a corresponding $EHQ_{LS\text{-}min}$ with respect to measured soil concentrations and for comparison with $EHQ_{LS\text{-}min}$ values for CPECs derived for a model-predicted soil concentration at a receptor location. The data in Table B-19 applies to vertebrate RREI only because no $ESSL_{LS\text{-}max}$ for invertebrate RREI is applicable. The results presented in Table B-19 indicate that background soil concentrations measured at Site 300 may not pose a significant problem for any vertebrate wildlife RREI, but the cumulative $EHQ_{LS\text{-}min}$ does exceed one for cadmium and lead, because of a similar toxic action. These results suggest that together these two metals may need further attention. However, the contribution of the $EHQ_{LS\text{-}min}$ determined for model-predicted data to the $EHQ_{LS\text{-}min}$ derived for measured data is at most 14% (for the EWTF location), and even less at the locations further from the EWTF.

Tables B-20 through B-23 contain the $EHQ_{LS\text{-}max}$ and $EHQ_{LS\text{-}min}$ for the Kit Fox and Burrowing Owl applicable to the measured soil concentrations of metals for Site 300. Accordingly information in Tables B-20 through B-23 is similar in content to data in Tables B-10a, B-10b, B-16a, and B-16b. However, in this case the data are for measured soil concentrations. The results in Table B-20 suggest that the Kit Fox may be impacted by background levels of cadmium and lead, and the cumulative $EHQ_{LS\text{-}min}$ for cadmium and lead based on the Site 300 measurement data also suggests further evaluation be performed of these CPECs. A similar situation is apparent for the Burrowing Owl, as can be seen from data in Table B-21, which indicates all available individual $EHQ_{LS\text{-}min}$

values exceed one. However, when a TRV_{Hi} is employed to derive $ESSL_{LS\text{-}max}$ values for the measured concentrations at Site 300 for the Kit Fox (Table B-22), there appears to be no impact from background concentrations nor is a potential impact reflected in the cumulative $EHQ_{LS\text{-}min}$ that is applicable to cadmium and lead, based on similar toxic action. A similar condition exists for the Burrowing Owl with respect to both individual $EHQ_{LS\text{-}min}$ values being less than one, and the cumulative $EHQ_{LS\text{-}min}$ being less than one (see Table B-23).

B.2 ERA Conclusions

Quantification of the ecological risk posed by release of a particular contaminant to a specific habitat is complicated by many uncertainties related to limited data. However, this ERA employed very conservative values for wildlife TRVs, especially for avian RREI with respect to cadmium and lead (see avian BTAG values presented in DTSC [2000]).

The TRVs published by the U.S. EPA (2005 c,d) are more recent than the more conservative BTAG values and are based on extensive literature reviews with literally hundreds of data points. The calculated EHQ_{LS} values that suggest potential impacts may occur are most likely overly conservative, and the Burrowing Owl and other wildlife are unlikely to be impacted organisms. Thus, the possibility exists that all $EHQ_{LS\text{-}min}$ for all CPECs and for each RREI at the EWTF are all actually less than one, and that it is unlikely that adverse ecological impacts are going to occur. This is clear from looking at the most conservative analyses based on the measured background concentrations, yet the food web does not seem to be suffering from such background levels of measured concentrations.

This ERA focused on developing $EHQ_{LS\text{-}max}$ and $EHQ_{LS\text{-}min}$ values for an individual organism in one or more species (and most often only for adults due to data limitations) in the affected habitat; any impact to an individual of a particular species may translate to an impact to the population and, by inference, to a potential impact on the entire local ecosystem. Following this approach, this ERA examined the potential for impact from a CPEC for an individual RREI from more than one species, with each species considered to be at a different trophic level in the local ecosystem near the EWTF. Additional conservatism was added to these ERA calculations by maximizing the amount of material deposited (by considering a habitat location at Site 300 quite close to the OB/OD operations—the source of emissions—and calculating exposure of animals at soil concentrations estimated over a 6-inch [15-cm] depth); optimizing the RREI behavior to maximize exposures (i.e., living, foraging, and capturing prey exclusively in that immediate habitat); and fixing the absorption fraction of each CPEC from the intestinal tract of each RREI at 100 percent. Adding these conservatisms acts to address uncertainty because they increase the likelihood that each calculated EHQ_{LS} will be an overestimate, and so there is a degree of confidence that the substances screened from further consideration using the $EHQ_{LS\text{-}max}$ are unlikely to pose a problem ecologically.

B.3 References

Agency for Toxic Substances and Disease Registry (ATSDR) (1998), *Toxicological Profile for 2,4- and 2,6-Dinitrotoluene,* Division of Toxicology, Agency for Toxic Substances and Disease Registry, Public Health Service, United States Department of Health and Human Services, Atlanta, GA, URL: http://www.atsdr.cdc.gov/toxprofiles/tp109.html (See p. 81).

Bechtel Jacobs Company LLC (1998), *Empirical Models for the Uptake of Inorganic Chemicals from Soil by Plants*, Bechtel Jacobs Company LLC, Oak Ridge, TN, BJC/OR-133 (see Tables 7 and D-1); URL: http://www.esd.ornl.gov/programs/ecorisk/biological_uptake.html#reports.

Bjorklund, J.R., J. F. Bowers, G. C. Dodd and J. M. White (1998), O*pen Burn/Open Detonation Dispersion Model (OBODM), User's Guide,* West Desert Test Center, Dugway Proving Ground, Dugway, UT (DPG Document No. DPG-TR-96-008a).

California Environmental Protection Agency, Air Resources Board (CARB) (2003), *HotSpots Analysis and Reporting Program User Guide,* developed by Dillingham Software Engineering, Inc., Air Resources Board, Stationary Source Division, Sacramento, CA.

California Department of Fish and Game (CDFG) (2005a), *California's Wildlife: Volume III. Mammals*, State of California Department of Fish and Game, Wildlife Habitat Data Analysis Branch, Sacramento, CA, URL: http://www.dfg.ca.gov/whdab/html/lifehistmammal.html.

California Department of Fish and Game (CDFG) (2005b), *California's Wildlife: Volume II. Birds*, State of California Department of Fish and Game, Wildlife Habitat Data Analysis Branch, Sacramento, CA, URL: http://www.dfg.ca.gov/whdab/html/lifehistbirds.html

Carlsen, T.M. (1996), "Ecological Risks to Fossorial Vertebrates from Volatile Organic Compounds in Soil," *Risk Analysis* 16(2), 211–219.

Daniels, J.I. (2007), *Description of Spreadsheet Calculations for Populating Data Tables of the Ecological Risk Assessment (Appendix B of the Human Health and Ecological Risk Assessment Document) for the Explosive Waste Treatment Facility (EWTF) at Site 300*, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-TR-235449.

Denton, J.E. (2003), *Memorandum to W.H. Hickox, Secretary for California Environmental Protection Agency: Adoption of the Revised Toxicity Equivalency Factors (*$TEF_{WHO\text{-}97}$*) for PCDDs, PCDFs and Dioxin-Like PCBs,* State of California Environmental Protection Agency, Director of the Office of Health Hazard Assessment, Sacramento, CA, August 29, 2003, see Attachment, URL: http://www.oehha.ca.gov/air/hot_spots/pdf/adoptionwhotefs.pdf.

Department of Toxic Substances Control (1996), *Guidance for Ecological Risk Assessment at Hazardous Waste Sites and Permitted Facilities: Part A. Overview,* Health and Ecological Risk Division (HERD), Department of Toxic Substances Control, State of California Environmental Protection Agency, Sacramento, CA, URL: http://www.dtsc.ca.gov/AssessingRisk/upload/overview.pdf (see p. 22).

Department of Toxic Substances Control (DTSC) (1998), *Depth of Soil Samples Used to Set Exposure Point Concentration for Burrowing Mammals and Burrow-Dwelling Birds in an Ecological Risk Assessments,* State of California Environmental Protection Agency (CalEPA), Department of Toxic Substances Control (DTSC), Sacramento, CA, Human and Ecological Risk Division (HERD) Ecological Risk Assessment (ERA) Note Number 1 (EcoNote1), May 15, 1998, URL: http://165.235.111.242/AssessingRisk/eco.cfm#EcoNOTE5.

Department of Toxic Substances Control (DTSC) (2000), *Use of Navy/U.S. Environmental Protection Agency (U.S. EPA) Region 9 Biological Technical Assistance Group (BTAG) Toxicity Reference Values (TRVs) for Ecological Risk Assessment,* State of California Environmental Protection Agency (CalEPA), Department of Toxic Substances Control (DTSC), Sacramento, CA, Human and Ecological Risk Division (HERD) Ecological Risk Assessment (ERA) Note Number 4 (EcoNote4), December 8, 2000, URL: http://165.235.111.242/AssessingRisk/eco.cfm#EcoNOTE5 (see Table 1 [p. 6]).

Department of Toxic Substances Control (DTSC) (2002a), Revised U.S. Environmental Protection Agency (U.S. EPA) Region 9 Biological Technical Assistance Group (BTAG) Mammalian Toxicity Reference Value (TRV) for Lead: Justification and Rationale, State of California Environmental Protection Agency (CalEPA), Department of Toxic Substances Control (DTSC), Sacramento, CA, Human and Ecological Risk Division (HERD) Ecological Risk Assessment (ERA) Note Number 5 (EcoNote5), November 21, 2002, URL: http://165.235.111.242/AssessingRisk/eco.cfm#EcoNOTE5

Department of Toxic Substances Control (DTSC) (2002b), *Currently Recommended U.S. Environmental Protection Agency Region 9 Biological Technical Assistance Group (BTAG) Mammalian and Avian Toxicity Reference Values (TRVs),* State of California Environmental Protection Agency (CalEPA), Department of Toxic Substances Control (DTSC), Sacramento, CA, November 21, 2002; two data tables and accompanying references, URL: http://165.235.111.242/AssessingRisk/eco.cfm#EcoNOTE5.

Department of Toxic Substances Control (2005), "Toxicity Reference Values for Dioxins and Furans for Mammalian and Avian Species Submitted from Vandenberg Air Force Base (VAFB), California, to the Health and Ecological Risk Division (HERD) as 'Final Toxicity Profiles,'" were provided and recommended for use by Michael J. Anderson, Staff Toxicologist, at HERD in a facsimile correspondence received 13 Dec 2005 at the Lawrence Livermore National Laboratory from M.J. Anderson at HERD, Department of Toxic Substances Control (DTSC), State of California Environmental Protection Agency (CalEPA), Sacramento, CA (see §7.1, §7.2 and §7.4 of *VAFB Final Toxicity Profiles for the Ecological Risk Assessments* obtained from M.J. Anderson, PhD).

Dibley, V., T. Carlsen, S. Chamberlain, W. Daily, Z. Demir, M. Denton, R. Goodrich, S. Gregory, V. Madrid, M. Taffett, J. Valett (2005), *2004 Annual Compliance Monitoring Report, Lawrence Livermore National Laboratory, Site 300*, Environmental Protection Department, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-AR-2006319-04; see §4.2. Ecological Risk and Hazard Management, pp. 41–44.

Efroymson, R.A., M.E. Will, G.W. Suter, II, A.C. Wooten (1997), *Toxicological Benchmarks for Screening Contaminants fo Potential Concern for Effects on Terrestrial Plants: 1997 Revision*, Lockheed Martin Energy Systems, Inc, managing Oak Ridge National Laboratory, Oak Ridge, TN, ES/ER/TM-85/R3 (see Table 1., p. 2-5); URL: http://www.esd.ornl.gov/programs/ecorisk/benchmark_reports.html.

Engineering Field Activity West (EFA West) (1998), *Development of Toxicity Reference Values for Conducting Ecological Risk Assessment at Naval Facilities in California, Interim Final,* EFA West, Naval Facilities Engineering Command, United States Navy, San Bruno, CA, September 1998, URL: http://www.epa.gov/Region8/r8risk/eco_toxicity.html#chem (see category: Wildlife TRVs for Ingestion of Contaminants).

ENSR International (2004), *Development of a Standardized Approach for Assessing Potential Risks to Amphibians Exposed to Sediment and Hydric Soils,* Naval Facilities Engineering Services Center, Port Hueneme, CA, TR-2245-ENV (prepared by J. Bleier, D. Pillard, D. Barclift, A. Hawkins and J.Speicher, ENSR International, Westford, MA), see Table 3-7 on pp. 3-17, URL: http://web.ead.anl.gov/ecorisk/methtool/pdf/TR-2245-ENV.pdf.

Nagy, K.A. (2001), "Food Requirements of Wild Animals: Predictive Equations for Free-Living Mammals, Reptiles, and Birds," *Nutrition Abstracts and Reviews, Series B:* 71, 21R-31R, URL: http://www.obee.ucla.edu/Faculty/Nagy/NutrAbsRev2001ps.pdf.

Peterson, S.R., D. Armstrong, N.A. Bertoldo, S. Brigdon, R.A. Brown, C.G. Campbell, S. Cerruti, C.L. Conrado, A.R. Grayson, H.E. Jones, J. Karachewski, D.H. MacQeen, S. Mathews, L. Paterson, M.A. Revelli, D. Rueppel, L. Sanchez, B. Schad, M.J. Taffet, K. Wilson, J. Woollett (2006), *Environmental Report 2005*, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-50027-05 (in preparation).

Sample, B.E., D.M. Opresko and G.W. Suter, II (1996), *Toxicological Benchmarks for Wildlife: 1996 Revision,* Oak Ridge National Laboratory, Oak Ridge, TN, ES/ER/TM-86/R3.

Sample, B.E., J.J. Beauchamp, R.A. Efroymson, G.W. Suter, II, and T.L. Ashwood (1998a), *Development and Validation of Bioaccumulation Models for Earthworms,* Oak Ridge National Laboratory, Oak Ridge TN, ES/ER/TM-220 (see Table 12); URL: http://www.esd.ornl.gov/programs/ecorisk/biological_uptake.html#reports.

Sample, B. E., J. J. Beauchamp, R. A. Efroymson, and G. W. Suter, II (1998b), *Development and Validation of Bioaccumulation Models for Small Mammals,* Oak Ridge National Laboratory, Oak Ridge TN ES/ER/TM-219 (see Tables 7 through 9); URL: http://www.esd.ornl.gov/programs/ecorisk/biological_uptake.html#reports.

Sample, B.E., and C.A. Arenal (1999), "Allometric Models for Interspecies Extrapolation of Wildlife Toxicity Data," *Bull. Env. Contamin. Toxicol. 62,* 653–663.

Schafer, E.W., Jr., W.A. Bowles and J. Hurlbut (1983), "The Acute Oral Toxicity, Repellency, and Hazard Potential of 998 Chemicals to One or More Species of Wild and Domestic Birds," *Arch. Environ. Contam. Toxicol.* 12, 355–382 (see Table 2 [p. 363]).

Suter, G.W., II, R.A. Efroymson, B.E. Sample, and D.S. Jones (2000), *Ecological Risk Asssessment for Contaminated Sites,* Lewis Publishers, CRC Press, Washington, DC.

Sverdrup, L.E., A.E. Kelley, P.H. Krogh, T. Nielsen, J. Jensen, J.J. Scott-Fordsmand, and J. Stenersen (2001), Effects of Eight Polycyclic Aromatic Compounds on the Survival And Reproduction of the Springtail *Folsomia Fimetaria* L. (Collembola, Isotomidae)," *Environ. Toxicol. Chem. 20*(6), 1332–1338.

Sverdrup, L.E., T. Nielsen, and P.H. Krogh (2002a), "Soil Ecotoxicity of Polycyclic Aromatic Hydrocarbons in Relation to Soil Sorption, Lipophilicity, and Water Solubility," *Environ. Sci. Technol. 36* (11), 2429–2435.

Sverdrup, L.E., J.Jensen, A.E. Kelley, P.H. Krogh and J. Stenersen (2002b), "Effects of Eight Polycyclic Aromatic Compounds on the Survival and Reproduction of *Enchytraeus Crypticus* (Oligochaeta, Clitellata)", *Environ. Toxicol. Chem.* 21(1), 109-114.

Sverdrup, L.E., P.H. Krogh, T. Nielsen, and J. Stenersen (2002c), "Relative Sensitivity of Three Terrestrial Invertebrate Tests to Polycyclic Aromatic Compounds," *Environ. Toxicol. Chem. 21*(9), 1927–1933.

Sverdrup, L.E., P.H. Krogh, T. Nielsend, C. Kjær, and J. Stenersen (2003), "Toxicity of Eight Polycyclic Aromatic Compounds to Red Clover (*Trifolium pratense*), Ryegrass (*Lolium perenne*), and Mustard (*Sinapsis alba*)," *Chemosphere 53*(8), 993–1003.

Talmage, S.S., D.M. Opresko, C.J. Maxwell, C.J.E. Welsh, F.M. Cretella, P.H. Reno, and F.B. Daniel (1999), "Nitroaromatic Munition Compounds: Environmental Effects and Screening Values," *Rev. Environ. Contam. Toxicol.* 161, 1–156.

Thomsen, L. (1971), Behaviour and Ecology of Burrowing Owls on the Oakland Municipal Airport, *The Condo* 73:177-192 (Table 6, average of survivors and siblings).

United States Department of Energy National Nuclear Security Administration (DOE/NNSA) (2005), *Final Site-Wide Environmental Impact Statement for Continued Operation of Lawrence Livermore National Laboratory and Supplemental Stockpile Stewardship and Management Programmatic Environmental Impact Statement,* National Nuclear Security Administration, Livermore, CA (DOE/EIS-0348 and DOE/EIS-0226-S3)

United States Environmental Protection Agency (U.S. EPA) (1998), *Reregistration Eligibility Decision (RED): Diphenylamine, List B, Case 2210,* Office of Pesticide Programs, Special Review and Registration Division, United States Environmental Protection Agency, Washington, DC, EPA738-R-97-010 (April 1998), URL: http://www.epa.gov/oppsrrd1/REDs/2210red.pdf (see pp. 29 and 41).

United States Environmental Protection Agency (U.S. EPA) (1999*), Screening Level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities,* Office of Solid Waste and Emergency Response, United States Environmental Protection Agency, Washington, DC, EPA530-D-99-001A (Peer Review Draft: August 1999),
URL: http://www.epa.gov/region6/6pd/rcra_c/protocol/slerap.htm (see Appendix E).

United States Environmental Protection Agency (U.S. EPA) (2003), *Ecological Soil Screening Levels forAluminum, Interim Final*, Office of Solid Waste and Emergency Response, United States Environmental Protection Agency, Washington, DC, OSWER Directive 9285.7–60, URL: http://www.epa.gov/ecotox/ecossl/pdf/eco-ssl_aluminum.pdf.

United States Environmental Protection Agency (U.S. EPA) (2004), *Region 9 Preliminary Remediation Goal Table* (U.S. Environmental Protection Agency, Region 9, San Francisco, CA, October 2004), URL: http://www.epagov/region09/waste/sfund/prg

United States Environmental Protection Agency (U.S. EPA) (2005a), *Ecological Soil Screening Levels for Antimony, Interim Final*, Office of Solid Waste and Emergency Response, United States Environmental Protection Agency, Washington, DC, OSWER Directive 9285.7–61, URL: http://www.epa.gov/ecotox/ecossl/pdf/eco-ssl_antimony.pdf.

United States Environmental Protection Agency (U.S. EPA) (2005b), *Ecological Soil Screening Levels for Barium, Interim Final*, Office of Solid Waste and Emergency Response, United States Environmental Protection Agency, Washington, DC, OSWER Directive 9285.7–63, URL: http://www.epa.gov/ecotox/ecossl/pdf/eco-ssl_barium.pdf.

United States Environmental Protection Agency (U.S. EPA) (2005c), *Ecological Soil Screening Levels for Cadmium, Interim Final*, Office of Solid Waste and Emergency Response,United States Environmental Protection Agency, Washington, DC, OSWER Directive 9285.7–65, URL: http://www.epa.gov/ecotox/ecossl/pdf/eco-ssl_cadmium.pdf.

United States Environmental Protection Agency (U.S. EPA) (2005d), *Ecological Soil Screening Levels for Lead, Interim Final*, Office of Solid Waste and Emergency Response, United States Environmental Protection Agency, Washington, DC, OSWER Directive 9285.7–70, URL: http://www.epa.gov/ecotox/ecossl/pdf/eco-ssl_lead.pdf.

U.S. Environmental Protection Agency (U.S. EPA) (2006 *access date*), Integrated Risk Information System (IRIS), Office of Research and Development, National Center for Environmental Assessment, United States Environmental Protection Agency, Washington, DC, URL: http://www.epa.gov/iris/search.htm.

United States Environmental Protection Agency (U.S. EPA) (2007a), *Ecological Soil Screening Levels for Copper, Interim Final*, Office of Solid Waste and Emergency Response, United States Environmental Protection Agency, Washington, DC, OSWER Directive 9285.7–68, URL: http://www.epa.gov/ecotox/ecossl/pdf/eco-ssl_copper.pdf.

United States Environmental Protection Agency (U.S. EPA) (2007b), *Ecological Soil Screening Levels for Polycyclic Aromatic Hydrocarbons (PAHs), Interim Final*, Office of Solid Waste and Emergency Response, United States Environmental Protection Agency, Washington, DC, OSWER Directive 9285.7–78, URL: http://cfpub.epa.gov/ecotox/ .

Van den Berg, M., L. Birnbaum, A.T.C. Bosveld, B. Brunström, P. Cook, M. Feeley, J.P. Giesy, A. Hanberg, R. Hasgawa, S.W. Kennedy, T. Kubiak, J.C. Larsen, F.X.R. van Leeuwen, A.K. Djien Liem, C. Nolt, R.E. Peterson, L. Poellinger, S. Safe, D. Schrenk, D. Tillitt, M. Tysklind, M. Younes, F. Wærn and T. Zacharewski (1998), "Review: Toxic Equivalency Factors (TEFs) for PCBs, PCDDs, PCDFs for Humans and Wildlife," *Environ. Health Perspect* 106(12), 775–7, URL: http://ehponline.org/members/1998/106p775-792vandenberg/abstract.html (see Table 5).

Zarn, M. (1974), *Report No. 11: Habitat Management Series for Unique or Endangered Species,* U.S. Department of Interior, Bureau of Land Management, Denver, CO, Technical Note 250.

Table B-1. Chemicals of potential ecological concern (CPECs) with respect to emissions from the EWTF along with their corresponding Chemical Abstracts Service registry identification numbers (CAS IDs), toxicity equivalency factors (TEFs), and the available lowest mammalian and avian toxicity reference values (TRV-Low) for identified experimental test species (ETS) with specified body weights (BW).

Chemical	CAS ID	TEF[a]	Mammal ETS	Mammal BW[b] (kg_{bw})	Mammal $TRV_{ETS\text{-}Low}$[c] [mg/(kg d)]	Avian ETS	Avian BW[d] (kg_{bw})	Avian $TRV_{ETS\text{-}Low}$[e] [mg/(kg d)]
PCDFs								
1-4, 6-8 HpCDF	67562-39-4	0.01	Rat	0.35	1×10^{-5}	Chicken	1.5	1×10^{-3}
1-4, 7-9 HpCDF	55673-89-7	0.01	Rat	0.35	1×10^{-5}	Chicken	1.5	1×10^{-3}
1-4, 7, 8 HxCDF	70648-26-9	0.1	Rat	0.35	1×10^{-6}	Chicken	1.5	1×10^{-4}
1-3, 6-8 HxCDF	57117-44-9	0.1	Rat	0.35	1×10^{-6}	Chicken	1.5	1×10^{-4}
1-9 OCDF	39001-02-0	0.0001	Rat	0.35	1×10^{-3}	Chicken	1.5	1×10^{-1}
Energetics and other thermally labile compounds								
2,4-Dinitrotoluene	121-14-2	1.0	Dog	14	0.2	Not Available[f]		
2,6-Dinitrotoluene	606-20-2	1.0	Dog	14	0.4	Not Available[f]		
RDX	121-82-4	1.0	Rat	0.35	10	Not Available[f]		
Metals								
Aluminum	7429-90-5	1.0	Mouse	0.03	1.93	Ringed dove	0.155	109.7
Antimony	7440-36-0	1.0	Shrew	0.044	0.059	Not Available[f]		
Barium	7440-39-3	1.0	Shrew	0.044	51.8	Chick	0.121	20.8
Cadmium	7440-43-9	1.0	Mouse	0.0322	0.06	Mallard duck	1.153	0.08
Chromium	7440-47-3	1.0	Rat	0.35	1468	Not Available[f]		
Copper	7440-50-8	1.0	Mouse	0.03	2.67	Chicken	1.5	2.3
Lead	7439-92-1	1.0	Rat	0.35	1.0	Quail	0.014	0.014
Zinc	7440-66-6	1.0	Mouse	0.0255	9.6	Mallard duck	1.153	17.2
SVOCs								
2-Chlorophenol	95-57-8	1.0	Rat	0.35	5	Not Available[f]		
Diphenylamine	122-39-4	1.0	Dog	14	2.5	Practically Non-toxic[e]		
Fluoranthene	206-44-0	1.0	Mouse	0.03	125	Not Available[f]		

Chemical	CAS ID	TEF[a]	Mammal ETS	Mammal BW[b] (kg_{bw})	Mammal $TRV_{ETS\text{-}Low}$ [c] [mg/(kg d)]	Avian ETS	Avian BW[d] (kg_{bw})	Avian $TRV_{ETS\text{-}Low}$ [e] [mg/(kg d)]
Naphthalene	91-20-3	1.0	Rat	0.2765	50	Not Available[f]		
Phenol	108-95-2	1.0	Rat	0.35	60	RWBB[e]	0.096	113

[a] Toxicity equivalency factors (TEFs) for PCDFs from Van den Berg et al. (1998; Table 5) and Denton (2003) for mammalian species; Van den Berg et al. (1998; Table 5) for avian species; experimental test species and body weight for TCDD and TCDF evaluations were taken from Sample et al. (1996) and from DTSC (2005) data submitted for Vandenberg Air Force Base, California.

[b] Experimental test species and corresponding body weight data for mammals taken from ATSDR (1998) for 2,4-dinitrotoluene; and from U.S. EPA (1999) for 2,6-dinitrotoluene; from Talmage et al. (1999) for RDX; from Sample et al., (1996) for Al; from U.S. EPA (2005a,b) for Sb and Ba; from EFA West (1998) for Cd, Cu, Zn, and naphthalene; from the U.S. EPA Integrated Risk Information System (IRIS) database (U.S. EPA, 2006 accessed) for Cr, 2-chlorophenol, diphenylamine, fluoranthene, and phenol; and from DTSC (2002a) for Pb.

[c] Toxicity reference values (TRVs) for mammals that are applicable to Cd, Cu, Pb, Zn, and naphthalene are TRV-lows taken from DTSC (2002a,b); those that are applicable to Sb and Ba are taken from U.S. EPA (2005a,b); and the remainder are derived from literature values.

[d] Experimental test species and corresponding body weight data for avian organisms taken from DTSC (2005) for PCDF congeners, from Sample et al. (1996) for Al, Ba, and Zn; from EFA West (1998) for Cd, Cu, and Pb; and from Schafer et al. (1983) for phenol.

[e] Toxicity reference values for avian organisms were obtained for Al and Ba from Sample et al. (1996); for Cd, Cu, Pb, and Zn from DTSC (2002b); diphenylamine was declared practically non-toxic for avian species by U.S. EPA (1998); and the toxicity reference value for phenol was derived from data taken from Schafer et al. (1983) applicable to the Red-winged Blackbird (RWBB).

[f] Avian data for this substance is not available.

Table B-2. Representative receptors of ecological interest (RREI) and respective physiological characteristics, including body weight (BW) and dietary dry-matter intake (DMI).

Organism	BW[a] (kg)	Daily dietary dry-matter intake (kg_{dmi}/d)	Daily dietary dry-matter intake per unit body weight (kg_{dmi}/d per kg_{bw})	Fraction of total dietary dry-matter intake (DMI)[b]				
				Vege-tation	Inverte-brate	Reptile	Mammal	Soil[c]
Mammals								
Omnivorous small mammal (Deer Mouse)	0.0179	0.00381	0.2128	0.7	0.3	0	0	0.1
Granivorous small mammal (Ground Squirrel)	0.56	0.0383	0.0683	1	0	0	0	0.077
Herbivorous small mammal (Pocket Gopher)	0.104	0.013	0.1250	1	0	0	0	0.1
Herbivorous large mammal [Black-Tailed (Mule) Deer]	39.1	1.565	0.04	1	0	0	0	0.02
Carnivorous mammal (San Joaquin Kit Fox)	1.48	0.0702	0.0474	0	0	0.5	0.5	0.028
Reptile								
Insectivorous reptile (Side-Blotched Lizard)	0.0032	0.000037	0.011563	0	1	0	0	0.1
Birds								
Omnivorous bird (Savannah Sparrow)	0.0187	0.00574	0.3070	0.39	0.61	0	0	0.04
Carnviorous bird (Burrowing Owl)	0.157[d]	0.024	0.154	0	0.333	0.333	0.333	0.05

[a] Body weight (BW) and dietary dry-matter intake (DMI) for the wildlife organisms are taken directly from Nagy (2001) for the Deer Mouse, Pocket Gopher, Black-Tailed (Mule) Deer, Kit Fox, Side-Blotched Lizard, and Savannah Sparrow. The body weights of the Burrowing Owl and Ground Squirrel come from Thomsen (1971) and Carlsen (1996), and dietary dry-matter intake (DMI) for these two organisms is computed from wet weight intake for Ground Squirrel given by Carlsen (1996) to dry-matter intake using relationships described Nagy (2001; p. 2-R) and from body weight for Burrowing Owl derived from Thomsen (1971) using allometric scaling described by Nagy (2001; p. 9-R).

[b] Fraction of total dietary dry-matter intake represented by vegetation (plants), invertebrates, reptiles, mammals, and soil provides reasonable conservative default estimates for the organisms being evaluated.

[c] Data from Carlsen (1996) for Ground Squirrel, Mule Deer, and San Joaquin Kit Fox; and Zarn (1974) for Burrowing Owl. Default values that are considered conservative approximations are used for Deer Mouse, Pocket Gopher, Side-Blotched Lizard, and Savannah Sparrow.

[d] Thomsen (1971; Table 6), average of survivors and siblings.

Note: The soil invertebrate category does not appear because an ESSL for that organism (earthworm) was taken directly from literature values (see Tables B-6a and B-6b.

Table B-3. Chemicals of potential ecological concern (CPEC) and factors used for deriving applicable mammalian and avian wildlife toxicity reference values (TRV_{wlf}) from those determined for experimental test species (i.e., TRV_{ETS}).

Chemical	CAS ID	Mammal uncertainty factor (UF_M)	Mammal Scaling factor (SF_M)[a]	Avian uncertainty factor (UF_A)	Avian scaling factor (SF_A)[a]
1-4, 6-8 HpCDF	67562-39-4	1	0.537	1	1.19
1-4, 7-9 HpCDF	55673-89-7	1	0.537	1	1.19
1-4, 7, 8 HxCDF	70648-26-9	1	0.537	1	1.19
1-3, 6-8 HxCDF	57117-44-9	1	0.537	1	1.19
1-9 OCDF	39001-02-0	1	0.537	1	1.19
2,4-Dinitrotoluene	121-14-2	1	0.940	Not Available[b]	Not Available[b]
2,6-Dinitrotoluene	606-20-2	1	0.940	Not Available[b]	Not Available[b]
RDX	121-82-4	1	0.940	Not Available[b]	Not Available[b]
Aluminum	7429-90-5	1	0.940	1	1.19
Antimony	7440-36-0	1	0.940	Not Available[b]	Not Available[b]
Barium	7440-39-3	1	0.746	1	1.19
Cadmium	7440-43-9	1	0.440	1	1.19
Chromium	7440-47-3	1	0.940	Not Available[b]	Not Available[b]
Copper	7440-50-8	1	0.940	1	1.19
Lead	7439-92-1	1	0.940	1	1.19
Zinc	7440-66-6	1	0.851	1	1.19
2-Chlorophenol	95-57-8	1	0.940	Not Available[b]	Not Available[b]
Diphenylamine	122-39-4	1	0.940	Not Available[b]	Not Available[b]
Fluoranthene	206-44-0	2[c]	0.940	Not Available[b]	Not Available[b]
Naphthalene	91-20-3	1	0.940	Not Available[b]	Not Available[b]
Phenol	108-95-2	1	0.940	100[c]	1.19

[a] Allometric scaling is applied only if the difference in body weight between an experimental test species and a wildlife RREI is more than two orders of magnitude apart. If applied, it is done so according to the equation recommended by Sample and Arenal (1999), where $TRVwlf = [TRV_{ETS}/(TEF \times UFs)] \times (BW_{ETS}/BWwlf)^{1-b}$ and the specified scaling factors for b that appear in the fourth and last columns for mammals and avian organisms, respectively.

[b] Uncertainty and scaling factors applicable to avian species were not available for this substance.

[c] Uncertainty factors (UFs) greater than 1 are applied as noted to convert TRV_{ETS} to a TRV for wildlife in Table B-4. Application of safety factors is described in DTSC (1996), such that a UF = 2 is used when it is necessary to extrapolate from subchronic to chronic exposure studies, and an UF = 5 is applied when extrapolating from lowest observed adverse effect to no observed adverse effect. Additional factors of safety can also be applied and the product can equal 100.

Table B-4. Low toxicity reference values derived for wildlife (TRV-Low) for chemicals of potential ecological concern (CPEC).[a]

Chemical	Toxicity reference values (TRVs) derived from experimental test species for respective wildlife species								
	Omnivorous small mammal (Deer Mouse)	Granivorous small mammal (Ground Squirrel)	Herbivorous small mammal (Pocket Gopher)	Herbivorous large mammal (Black-Tailed [Mule] Deer)	Carnivorous mammal (San Joaquin Kit Fox)	Mammal-based insectivorous reptile (Side-Blotched Lizard)	Omnivorous bird (Savannah Sparrow)	Carnivorous bird (Burrowing Owl)	Avian-based insectivorous reptile (Side-Blotched Lizard)
PCDDs/PCDFs									
1-4, 6-8 HpCDF	1.00E-05	1.00E-05	1.00E-05	1.13E-06[b]	1.00E-05	8.79E-05[b]	1.00E-03	1.00E-03	3.11E-04
1-4, 7-9 HpCDF	1.00E-05	1.00E-05	1.00E-05	1.13E-06[b]	1.00E-05	8.79E-05[b]	1.00E-03	1.00E-03	3.11E-04
1-4, 7, 8 HxCDF	1.00E-06	1.00E-06	1.00E-06	1.13E-07[b]	1.00E-06	8.79E-06[b]	1.00E-04	1.00E-04	3.11E-05
1-3, 6-8 HxCDF	1.00E-06	1.00E-06	1.00E-06	1.13E-07[b]	1.00E-06	8.79E-06[b]	1.00E-04	1.00E-04	3.11E-05
1-9 OCDF	1.00E-03	1.00E-03	1.00E-03	1.13E-04[b]	1.00E-03	8.79E-03[b]	1.00E-01	1.00E-01	3.11E-02
Energetics and other thermally labile compounds									
2,4-Dinitrotoluene	2.98E-01[b]	2.00E-01	2.68E-01[b]	2.00E-01	2.00E-01	3.31E-01[b]	Not Available[c]	Not Available[c]	Not Available[c]
2,6-Dinitrotoluene	5.97E-01[b]	4.00E-01	5.37E-01[b]	4.00E-01	4.00E-01	6.61E-01[b]	Not Available[c]	Not Available[c]	Not Available[c]
RDX	1.00E+01	1.00E+01	1.00E+01	7.54E+00[b]	1.00E+01	1.33E+01[b]	Not Available[c]	Not Available[c]	Not Available[c]
Metals									
Aluminum	1.93E+00	1.93E+00	1.93E+00	1.26E+00[b]	1.93E+00	1.93E+00	1.10E+02	1.10E+02	1.1E+02
Antimony	5.90E-02	5.90E-02	5.90E-02	3.93E-02[b]	5.90E-02	5.90E-02	Not Available[c]	Not Available[c]	Not Available[c]
Barium	5.18E+01	5.18E+01	5.18E+01	9.23E+00[b]	5.18E+01	5.18E+01	2.08E+01	2.08E+01	2.08E+01
Cadmium	6.00E-02	6.00E-02	6.00E-02	1.12E-03[b]	6.00E-02	6.00E-02	8.00E-02	8.00E-02	2.61E-02
Chromium	1.47E+03	1.47E+03	1.47E+03	1.11E+03	1.47E+03	1.95E+03[b]	Not Available[c]	Not Available[c]	Not Available[c]
Copper	2.67E+00	2.67E+00	2.67E+00	1.74E+00[b]	2.67E+00	2.67E+00	2.30E+00	2.30E+00	7.15E-01
Lead	1.00E+00	1.00E+00	1.00E+00	7.54E-01	1.00E+00	1.33E+00[b]	1.40E-02	1.40E-02	1.40E-02

Chemical	Toxicity reference values (TRVs) derived from experimental test species for respective wildlife species								
	Omnivorous small mammal (Deer Mouse)	Granivorous small mammal (Ground Squirrel)	Herbivorous small mammal (Pocket Gopher)	Herbivorous large mammal (Black-Tailed [Mule] Deer)	Carnivorous mammal (San Joaquin Kit Fox)	Mammal-based insectivorous reptile (Side-Blotched Lizard)	Omnivorous bird (Savannah Sparrow)	Carnivorous bird (Burrowing Owl)	Avian-based insectivorous reptile (Side-Blotched Lizard)
Zinc	9.60E+00	9.60E+00	9.60E+00	3.22E+00[b]	9.60E+00	9.60E+00	1.72E+01	1.72E+01	5.62E+00
SVOCs									
2-Chlorophenol	5.00E+00	5.00E+00	5.00E+00	3.77E+00[b]	5.00E+00	6.63E+00[b]	Not Available[c]	Not Available[c]	Not Available[c]
Diphenylamine	3.73E+00[b]	2.50E+00	3.35E+00	2.50E+00	2.50E+00	4.13E+00	Not toxic[d]	Not toxic[d]	Not toxic[d]
Fluoranthene	6.25E+01[e]	6.25E+01[e]	6.25E+01[e]	4.06E+01[b]	6.25E+01[e]	6.25E+01[e]	Not Available[c]	Not Available[c]	Not Available[c]
Naphthalene	5.00E+01	5.00E+01	5.00E+01	3.71E+01[b]	5.00E+01	5.00E+01[b]	Not Available[c]	Not Available[c]	Not Available[c]
Phenol	6.00E+01	6.00E+01	6.00E+01	4.52E+01[b]	6.00E+01	7.95E+01[b]	1.13E+00[e]	1.13E+00[e]	1.13E+00

[a] TRV_{wlf} was derived from TRV_{ETS} using applicable uncertainty and scaling factors appearing in Table B-3.

[b] Allometric scaling applied based on ratio of ETS body weight to wlf body weight exceeding two orders of magnitude (see equation in footnote “a” of Table B-3 and body weight information in Tables B-1 and B-2).

[c] TRV_{wlf} applicable to avian species for this chemical could not be computed because derivation depends on data that are not available (see Table B-1).

[d] Diphenylamine was declared practically non-toxic for avian species by the U.S. EPA (1998).

[e] See footnote “c” in Table B-3, which identifies uncertainty factors greater than 1 for avian species and uncertainty factor greater than 1 for mammalian species (also applied to insectivorous reptile).