Technical Memorandum
Air Emissions from Incidental Ordnance Detonation During a Prescribed Burn on Ranges 43 through 48
Former Fort Ord, California

Prepared for

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November 9, 2001

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EXECUTIVE SUMMARY

From 1917 to 1993, the U.S. Department of the Army (Army) used Fort Ord, California, as a training and staging area for infantry troops. Among the activities conducted at Fort Ord prior to its closure in September 1994 were the firing and use of various projectiles, rockets, mortars, hand grenades, land mines, pyrotechnics, bombs, detonators, and other explosive materials. These ordnance and explosives (OE) were used at various sites in two main areas known as the Multi-Range Area (MRA) and the Inland Training Ranges. Both of these areas today contain sites where unexploded ordnance (UXO) are known or are suspected to exist. The location and removal of these OE is necessary before the land can be safely transferred to public use.

Central maritime chaparral is the dominant natural plant community in the MRA and the Inland Training Ranges. In areas such as at the former Fort Ord where natural fires are suppressed by human intervention, the central maritime chaparral tends to form a dense canopy of intertwined stems that can become nearly impenetrable. Investigation and removal for OE requires the use of sensors such as magnetometers that need to be swept over the ground close to the surface and are limited from effectively functioning in the dense thickets of mature chaparral. Also, the visibility of potential OE items on the ground is blocked by dense vegetation, increasing the hazard to which ordnance removal crews are exposed and making the sampling and removal process less effective.

Prescribed burning is utilized where the use of alternative vegetation clearance methods is significantly limited because the site is located in a habitat area and/or where surface UXO prevents workers from safely utilizing manual and mechanical vegetation clearance methods. Such is the case for the proposed burn polygon in Ranges 43 through 48.

The intense fire associated with prescribed burn conditions may result in the detonation of surface or near-surface OE items. Detonation of OE has the potential to release air pollutants to the atmosphere. These air emissions may potentially include combustion products, volatile or semivolatile organic compounds, unburned or incompletely burned energetic material, and particulate metals and metal compounds from chemical components of the OE items. At issue is whether the type or quantity of air emissions from incidental detonation of OE in Ranges 43 through 48 is significant in comparison to air emissions from prescribed burning of vegetation (biomass) in the same area, or is significant in absolute magnitude.

This Technical Memorandum has been prepared in consultation with the U.S. Environmental Protection Agency (USEPA) Region IX, California Environmental Protection Agency Department of Toxic Substances Control (CalEPA/DTSC), U.S. Army Corps of Engineers (USACE) Sacramento District, and the Department of the Army (Army) to (1) quantify a reasonable upper bound estimate of air emissions from incidental detonation of OE in Ranges 43 through 48, (2) compare those emissions with those expected from burning of biomass, and (3) compare screening level estimates of pollutant concentrations from OE to health-protective regulatory screening values. Data from this investigation may also be used to guide the development of an appropriate ambient air monitoring program to be implemented during a prescribed burn at Ranges 43 through 48 if such a prescribed burn is performed. This Technical Memorandum does not address the issue of possible human health effects from biomass burning.

Summary of Findings. The results of this investigation reveal that reasonable upper bound estimates of air emissions from incidental OE detonation for combustion products and volatile organic compounds are much less than 0.1% (i.e., one one-thousandth) of the corresponding emissions from biomass burning in Ranges 43 through 48. The only exception is for dioxin/furan toxicity equivalent emissions for which the reasonable upper bound OE contribution is about 1% (i.e., one one-hundredth) of that from biomass.

Reasonable upper bound emissions of all particulate metals except Beryllium from incidental OE detonation are equal to or less than 10% (i.e., one-tenth) those from biomass burning. For all pollutants evaluated in this investigation, including Beryllium and those pollutants for which there are no corresponding biomass emissions for comparison, screening model estimates of pollutant concentrations are much less than health-protective regulatory screening values.

The conclusion of this investigation is that air pollutant emissions from incidental OE detonation during a prescribed burn in Ranges 43 through 48 will be minor compared to emissions contributed directly by biomass burning, and will result in pollutant concentrations well below health-protective regulatory screening levels.

1.0 INTRODUCTION

The Army is evaluating vegetation clearance methods, including prescribed burning of approximately 555 acres in Ranges 43 through 48 of the former Fort Ord, to facilitate the subsequent removal of OE. The intense fire associated with prescribed burn conditions may result in the detonation of surface or near-surface OE items. Detonation of OE has the potential to release air pollutants to the atmosphere. These air emissions may potentially include combustion products, volatile or semivolatile organic compounds, unburned or incompletely burned energetic material, and particulate metals and metal compounds from the OE items. At issue is whether the type or quantity of air emissions from incidental detonation of OE in Ranges 43 through 48 is a significant human health risk in comparison to air emissions from prescribed burning of vegetation (biomass) in the same area, or is significant in absolute magnitude.

This Technical Memorandum has been prepared in consultation with the U.S. Environmental Protection Agency (USEPA) Region IX, California Environmental Protection Agency Department of Toxic Substances Control (CalEPA/DTSC), U.S. Army Corps of Engineers (USACE) Sacramento District, and the Department of the Army (Army) to (1) quantify a "reasonable upper bound" estimate of air emissions from incidental detonation of OE in Ranges 43 through 48, (2) compare those emissions with those expected from burning of biomass, and (3) compare screening level estimates of pollutant concentrations from OE to health-protective regulatory screening values. To develop a "reasonable upper bound" estimate, Harding ESE relied on Fort Ord-specific data where available and used health-protective assumptions where site-specific data do not exist. The OE emission estimates presented herein therefore represent amounts that are unlikely to be exceeded under real conditions of a prescribed burn in Ranges 43 through 48.

The following sections of this Technical Memorandum describe the approaches used to identify and quantify the air emissions from both incidental OE detonation and biomass burning. These emission estimates are then compared and discussed in terms of the potential significance of the OE emission contribution.

2.0 TECHNICAL APPROACH

The technical approach involved identifying the nature and quantity of air emissions from biomass burning and OE detonation. For biomass burning, emissions arise from the combustion process and depend largely on the type and amount of biomass present in the burn area. Emissions from OE, on the other hand, may arise from three distinct processes:

- Detonation of the item
- Vaporization of structural metal components
- Leaching of metals into the soil, where they are taken up by biomass and released as air emissions when the biomass is burned.

Each of these air emission processes was examined and are described in the following sections.

2.1 Pollutants of Interest

Several references were reviewed to develop a list of pollutants of interest from biomass burning and OE detonation. A great deal of research has been conducted by the U.S. Forest Service and other agencies involved with the use of prescribed burns for wildland management. Peterson and Ward (*1989*) have summarized the results of a number of field and laboratory prescribed burn smoke sampling programs, and have provided a method for estimating the nature and quantity of air emissions produced from prescribed burns for a variety of fuel types. The California Air Resources Board (*CARB, 1996*) has investigated the nature and quantity of air emissions from open burning of agricultural and forest biomass.

For OE emissions, a series of seven field studies funded by the U.S. Department of Defense (DoD) have been conducted to identify and quantify the pollutant species released to the air from detonating or burning energetic materials. These studies are commonly referred to as BangBox studies, because the tests were conducted inside large chambers. A total of 16 energetic materials were burned and 23 were detonated in the BangBox studies. An August 1998 USEPA report entitled "Emission Factors for the Disposal of Energetic Materials by Open Burning and Open Detonation (OB/OD)" (*USEPA, 1998*) provides an analysis and summary of all the BangBox studies. Air samples from the BangBox tests were analyzed for more than 275 individual compounds, including volatile organic compounds (VOCs), energetic and other semivolatile organic compounds (SVOCs), particulate metals, and chlorinated dioxins and furans. Many of those compounds (103 of 108 SVOCs and over 65% of the VOCs) were never detected in any of the BangBox tests. Further, many of the analytes that were detected were observed at concentrations less than background or below the minimum quantitation limit (MQL), and were therefore considered “not detected” in the report. Of the 83 analytes for which emission factors are reported, a few are criteria air pollutants or their precursors, but most are non-hazardous compounds commonly found in ambient air.

The USEPA report was reviewed to identify those analytes which were associated with the types of OE at the former Fort Ord. Emission factors that were reported for analytes associated only with open burning of propellant wastes and other items or processes not encountered at the former Fort Ord are not considered relevant to the identification of air pollutant emissions from OE detonation at this location and were excluded from the list. However, because the BangBox report was inconclusive with regard to particulate metal emissions from OE, the OE analyte list used in this study was supplemented with a list of metals known to be present in the chemical composition of OE items (*U.S. Army Defense Ammunition Center, 2001*). The combined list of OE analytes was then compared to the list of biomass analytes to

develop the list of air pollutants of interest for this investigation. Shown below are the 38 pollutants selected for inclusion in this investigation and their rationale for selection.

Pollutants Common to Both the Biomass and OE Analyte Lists	OE-Specific Pollutants With Established Acute Toxicity Criteria	Residual Energetic Materials	Metals Present In OE Chemical Compositions
Carbon Monoxide	Vinyl Chloride	RDX	Aluminum
Carbon Dioxide	Tetrachloroethylene	HMX	Antimony
Nitrogen Oxides	Carbon Tetrachloride	PETN	Arsenic
Non-Methane Hydrocarbons	Methylene Chloride	TNT	Barium
Particulate Matter less than 10 microns			Beryllium
1,3-Butadiene			Cadmium
n-Hexane			Chromium
Methyl Chloride			Cobalt
Benzene			Copper
Toluene			Lead
Dioxin/Furan Toxicity Equivalent			Manganese
			Mercury
			Molybdenum
			Nickel
			Selenium
			Silver
			Titanium
			Zinc
			Zirconium

2.2 Air Emissions from Biomass Burning

Prescribed fire is an extremely diverse source and its emissions are therefore difficult to quantify. The diversity in the type and quantity of combustion products is due to many factors, including fuel (biomass) type and quantity, moisture content, and the diversity of combustion processes which occur simultaneously within a fire. The primary combustion processes include flaming, smoldering, and glowing combustion.

Fortunately, there are substantial site-specific data at the former Fort Ord on which to base emission estimates. The following subsections describe the data and methods used to estimate air emissions from biomass burning at Ranges 43 through 48.

2.2.1 Biomass Make-Up and Distribution

Of the many factors noted above which affect the estimation of air emissions from biomass burning, the most important factor is fuel type and quantity (density). Age classes and biomass density within the Range 43 through 48 burn polygon were determined based on available information regarding the past management and maintenance of habitat within the burn polygon.

Stands of chaparral within the burn polygon have been subjected to different, sometimes random methods of vegetation removal during active military use and following base closure. In addition, methods of vegetation removal have been both deliberate and accidental. Deliberate vegetation removal typically occurred within the range fans of an existing range during active military use to facilitate clearing that range of unexploded ordnance and OE scrap or to establish a new range. Methods of vegetation removal during active use of the base included mechanical or manual means. Accidental vegetation removal was typically the result of exploding ordnance starting a fire in adjacent vegetation. The amount of vegetation effectively removed in a given area varied drastically depending on the timing and method of removal. For example, a hot fire burning during the height of the dry season would have removed significantly more vegetative biomass than a colder burning fire that occurred during the wet season. The amount of vegetation removed through manual or mechanical methods varied as well depending on the specific method and level of effort involved. Because the type and timing of vegetation removal during active use of the base is not known, it is difficult to truly assess the age or the relative biomass of a given stand. That being said, some assumptions were made in this estimate of chaparral age and biomass density.

Information sources utilized in this estimate include:

- Aerial photographs
- Transect (survey) data
- USACE data on recent past burns within the Range 43 through 48 burn polygon
- Unpublished chaparral biomass density data generated by Lars Pierce, CSU Monterey Bay.
- *Forest Ecology, Third Edition*. Spurr, S.H. and B.V. Barnes. 1992.

Maritime Chaparral age class estimates are based on visual inspection of aerial photographs containing the Range 43 through 48 burn polygon portion of former Fort Ord. Use of aerial photographs was limited due to photographic updates of the base occurring approximately every five years. Aerial photographs utilized were from the following years: 1978, 1986, 1989, 1994, and 1999. Aerials were visually inspected to determine the last observable evidence of vegetation removal in a given location within the burn polygon boundaries. The year of the photograph that displays the last known clearance of a given area is then considered the minimum age of that particular stand of chaparral. The age class is then determined by rounding up to the next highest five-year increment of age, with the exception of an area that is known to have been cleared three years ago. Estimates were rounded up in age to account for vegetation and established root systems that remained following a clearance. In addition, vegetation and root systems remaining in an area following clearance would typically contribute to a faster, more abundant re-establishment of chaparral habitat than an area where chaparral habitat had not previously occurred.

Based on the estimated age classes of chaparral, biomass density was estimated for the following age classes: 3 years, 5 years, 10 years, 15 years, 20 years, 25 years, and 30 years. These biomass estimates are based on unpublished data collected by Lars Pierce of California State University at Monterey Bay. Mr. Pierce collected data on above ground biomass of Maritime Chaparral at Fort Ord for the following age classes: 2 years, 15 years, and 40 years. His data was recorded in grams per square meter for both standing biomass and leaf litter. Harding ESE biologists applied these data to calculate biomass in tons per acre for these three age classes. Statistical regression was then used to calculate estimated total biomass (standing and leaf litter) for 3 years, 5 years, 10 years, and so on up to 30 years. Biomass for grassland habitat is based on the mean biomass for temperate grassland habitat as documented in *Forest Ecology, Third Edition* (Spurr, et. al., 1992).

Chaparral stands of a given age class and grassland habitat were determined and delineated on an aerial photograph of the burn polygon. This data was then digitized onto a GIS-based electronic version of the aerial (Plate 1). Acreage totals for chaparral age class and grassland polygons were then extracted electronically from the GIS and added together for each respective class. Total biomass for each chaparral age class was calculated by multiplying the total acreage of each class by the respective estimated tonnage of biomass per acre. Total grassland biomass was estimated by multiplying the mean biomass per acre by the total number of acres of identified grassland. These data are shown in Table 1.

2.2.2 Emission Calculations

Emission factor data from Peterson and Ward (*1989*) and Hardy (*1996*) were applied to the biomass data from Table 1 to calculate biomass combustion emissions from the Range 43 through 48 burn polygon. The biomass emission factor for dioxin/furan toxicity equivalent was obtained from the USEPA Dioxin Reassessment Draft Documents (*USEPA, 2000*). Table 2 presents the results of the emission calculations for biomass in the Range 43 through 48 burn polygon.

2.3 Biomass Uptake of Metals

Most studies of air emissions from biomass, including those summarized in Peterson and Ward (*1989*) and Hardy (*1996*), have not included analysis of smoke for particulate metals. CARB (*1996*) did include some analysis for metals in the smoke from controlled test burns of agricultural and forest biomass, and did find some metals present. Plants may absorb metals through their root systems at widely varying rates depending on many factors, one of which is the concentration of metal in the root zone of the soil. Areas of the Range 43 through 48 burn polygon that were historically used as "target" areas may experience elevated concentrations of metals in soil due to leaching of metals from accumulation of both live and expended OE items, and thus may contribute to elevated levels of metals in biomass at those locations. When burned, this biomass may release these metals as air emissions. The following subsections describe the approach that was used to estimate metal emissions from biomass burning.

2.3.1 Identification of Target Areas

Target locations within Ranges 43 through 48 were derived from three sources including targets located during the ongoing OE sampling program, target locations mapped for the Basewide Remedial Investigation/Feasibility Study (RI/FS) (*HLA, 1994*), and from targets identified on aerial photos. Targets include tanks, personnel carriers, silhouettes, dumpsters, structures, and automobiles.

Target locations identified during the OE sampling program were field registered using a Global Positioning System (GPS). Targets identified during the Basewide RI/FS were located using maps and coordinates provided by Fort Ord Range Control, verified in the field and later hand digitized using an AutoCad program. Target locations identified during the OE sampling program and the Basewide RI/FS were confirmed using aerial photo stereo pairs and electronically scanned photos. Scanned photos were orthorectified with the Fort Ord base map and the target locations superimposed on target location maps.

The aerial photos, dating from 1986, 1989 and 1999, were used to confirm target locations present during field efforts and to identify additional target locations present prior to the field efforts. Target locations identified in the field were compared to target locations identified on aerial photos. Those targets present on aerial photos, but not yet identified in the field, were added to the target location map. This included targets observed in heavily vegetated areas and targets that were removed or relocated prior to the field efforts. Plate 1 shows the location of 90 targets identified in the Range 43 through 48 burn polygon.

2.3.2 Biomass in Target Areas

The target areas identified as described above are known to vary widely in terms of size and density of OE accumulation. In most cases, the highest surface density of accumulated OE and scrap was visually observed to be within 10 to 20 feet from the actual target. OE and scrap have been observed at rapidly decreasing surface density with distance from the target. For the purposes of this investigation, each target is assumed to be represented by a circle with a diameter of 60 feet within which the OE density is assumed to be homogeneous. The biomass within these target circles is also assumed to be homogeneous and represented by the age class within which the target is located (see Plate 1). This results in a reasonable upper bound estimate of biomass within the target areas because visual observations have noted that many of the target areas have a much less dense biomass than the immediately surrounding terrain. Table 3 presents the results of the target area biomass calculations and shows that a total of 52.8 tons of biomass is contained within the 90 targets in the Range 43 through 48 burn polygon.

2.3.3 Biomass Uptake

Calculations of plant uptake of metals from soil are described in detail in Appendix A. Data are presented for both background soil metal concentrations and elevated soil metal concentrations in the target areas.

2.3.4 Emission Calculations

Table 4 summarizes the calculations of metal concentrations in biomass for both background soil and target area soil. The plant tissue concentrations shown in Table 4 are taken from Appendix A. These data were multiplied by the total burn polygon biomass and total target area biomass, respectively, to provide the estimated total mass of metal in background and target area biomass.

It is unlikely that all of the metal contained in the biomass will be released during a prescribed burn because not all of the biomass is converted to smoke. CARB (*1996*) reported that under strictly controlled burn conditions as much as 10% of the biomass, by weight, remains behind as ash. Under prescribed fire conditions with a rapidly advancing fire, trunks and large branches are frequently left intact with only the leaves and smaller branches consumed as fuel. However, the amount of biomass left behind intact or as ash cannot be reliably estimated, so the calculations of total metal in biomass in Table 4 assume that 100 percent of the metal present in the vegetation is emitted during a prescribed burn in Ranges 43 through 48.

The following list summarizes the primary assumptions that were used to ensure a reasonable upper bound estimate of emissions from biomass uptake of metals in soil:

- 60-foot diameter impact area versus observed diameters of 20 to 40 feet
- homogenous biomass density versus very little biomass observed at many target areas
- upper 95% confidence level used for soil metal concentrations
- soil metal concentrations are not corrected for background
- all metal in biomass is emitted versus evidence that not all biomass structure is consumed by the fire.

2.4 Air Emissions from Incidental OE Detonation

The heat from a prescribed burn has the potential to cause incidental detonation of surface or near-surface OE items within the Range 43 through 48 burn polygon. The following subsections describe the approach that was used to identify the type and quantity of OE items present in the burn polygon, which items are likely to incidentally detonate, and the methods used to estimate air emissions.

2.4.1 OE Scenario on Ranges 43 through 48

A variety of OE grid sampling and firebreak clearance activities have been conducted in the Range 43 through 48 burn polygon over the past few years. Data summarized in the draft Notice of Intent (NOI) for the Range 43 through 48 prescribed burn were used to identify the type and relative quantity of OE items likely to be encountered in the burn polygon. The complete list of OE items from the draft NOI was first screened to eliminate expended items with no explosive charge (OE Scrap). The remaining list of UXO items was further screened to eliminate all items found at depths exceeding three inches below ground surface (bgs). While it is unlikely that any OE items not on the ground surface would detonate during a prescribed fire because of the insulating effects of any soil cover, OE items within the first three inches of soil were included for this analysis as a reasonable upper bound estimate.

The final list of near-surface OE items was sorted by type of item. For each item, its relative frequency of occurrence was calculated by taking the quantity of each item found during the previous sampling and clearance activity and dividing by the total number of items found. For example, seven 84mm M136 HEAT Projectiles were found out of a total of 279 items, representing a frequency of occurrence of 2.51% for that item. These data were reviewed by Mr. A. R. Smith, Ordnance and Explosives Safety Specialist with the USACE Sacramento District. Mr. Smith confirmed that the list of items was, in his experience, representative of the type of OE items expected to be found in the Range 43 through 48 burn polygon.

Again, based on site-specific experience, Mr. Smith estimated that on average over the entire Range 43 through 48 burn polygon, there will be no more than five live near-surface items per acre. That results in a total estimate of 2,580 live near-surface items in the burn polygon. The relative frequency of occurrence for each type of item was then multiplied by the total estimated number of items in the burn polygon to obtain a breakdown of the total by type of item.

The final step in developing the OE scenario was to estimate how many of each item present would detonate during a prescribed burn. OE removal activities subsequent to previous prescribed burns and range fires at the former Fort Ord have documented that many live items are still present on the surface. Most generally, these have been items with heavier casings or other features that make them less susceptible to detonation from external heat and flame. However, even smaller items with thin casings or more sensitive detonation characteristics have been found intact on the surface after a burn. The type of OE item, the speed with which the fire advances, and the position of the item with respect to dense or sparse vegetation all have an effect on the likelihood of incidental detonation.

Given those factors, a precise estimate of how many OE items will detonate incidentally is not possible. So a reasonable upper bound estimate was developed by Mr. Smith based on his experience with previous post-burn OE clearance activities. For each type of OE item, Mr. Smith provided an estimate of what percentage of the total number present would detonate. These percentages ranged from a low of 10% for some of the larger, thick-walled projectiles to a high of 75% for many of the pyrotechnic items. Using this approach, of the total 2,580 items estimated to be present, 792 are estimated to detonate during a prescribed burn. Previous (historic) burns on these ranges and ongoing OE removal activities in accessible areas of the Range 43 through 48 burn polygon have likely reduced the number of the live OE

items that may incidentally detonate during the planned burn. Mr. Smith believes that 792 is a very high estimate, and the actual number of detonating items is likely to be much smaller.

Table 5 provides the list of OE items expected to be encountered in the Range 43 through 48 burn polygon, and presents the data and calculations described above. For each item, the table also lists the make-up of the explosive charge, the net explosive weight (NEW) per item *(U.S. Army Defense Ammunition Center, 2001*), and the total NEW for all items with similar explosive charge.

The following list summarizes the primary assumptions that were used to ensure a reasonable upper bound estimate of OE that may incidentally detonate in the Range 43 through 48 burn polygon:

- used actual data on types of OE items present in the burn polygon
- included items found on the surface and up to three inches below ground surface
- high estimates used for number of live items present
- high estimates used for the percent of items that will detonate
- estimates not reduced to account for live items incidentally detonated in previous (historic) burns
- estimates not reduced to account for ongoing removal of live items from accessible areas.

2.4.2 Emissions from Structural Components

Consideration was given to the possibility that the heat of a prescribed burn may volatilize structural metal components of surface and near-surface OE items. The Forestry Handbook, Second Edition (*Society of American Foresters, 1984*), reports that vegetation fire temperature at the soil surface can vary widely from about 500 ^{o}F for a low- to moderate-intensity surface fire to 1,300 ^{o}F for a high-intensity brush or forest fire. Table 6 summarizes the melting and boiling points for the most common metals used in OE structural components. The expected fire temperature of 500 to 1,300 ^{o}F is well below the temperature at which these metals would produce any significant volatilization. Even for those metals (cadmium and zinc) with boiling points close to the highest expected fire temperature, the short duration of a moving line of fire is unlikely to heat up the mass of the OE item sufficiently to cause volatilization of the metal components. Consequently, air emissions of metals from the heat of burning vegetation acting on structural components is considered to be unlikely.

2.4.3 Emissions from Chemical Composition

Incidental detonation of OE items has the potential to create air emissions from the following processes:

- products of combustion (both complete and incomplete)
- release of particulate metals and metal compounds present in the chemical composition of the item.

Each of these processes are described below.

2.4.3.1 Products of Combustion

Emission factors for combustion products from OE detonation were developed from three sources: the BangBox emission factor report (*USEPA, 1998*), a risk assessment document for Sierra Army Depot (*SIAD, 1996*), and chemical mass balance. Table 7 summarizes the emission factors used in this

investigation and identifies the specific reference used. Emission rates for each listed pollutant were calculated by multiplying the referenced emission factor by the total mass of the explosive material (MEM) estimated to detonate in the Range 43 through 48 burn polygon. The MEM (also referred to as Net Explosive Weight, or NEW) for each energetic material comes from the summary data in Table 5.

2.4.3.2 Particulate Metals and Metal Compounds

Some OE items have small amounts of particulate metals present in the chemical composition of the energetic material. In addition to particulate metals, several metal compounds are also present in the chemical composition of many OE items. Detailed component structure data for each type of OE item expected to be present in the Range 43 through 48 burn polygon were obtained from the Munitions Items Disposition Action System (MIDAS) database (*U.S. Army Defense Ammunition Center, 2001*). These data were used to identify and quantify the particulate metals and metal compounds present in each type of OE item. The most prevalent particulate metals identified from the MIDAS database search were listed in Section 2.1 of this Tech Memo. The most prevalent metal compounds identified from the MIDAS database search are listed below:

Pb Thiocyanate	Zr Hydride
Pb Styphnate	Zn Oxide
Pb Chromate	Fe Oxide
Pb Azide	K Nitrate
Ba Nitrate	K Chlorate
Ba Chromate	K Perchlorate
Ba Stearate	K Sulfate
Triethylalumium	Mg Carbonate
Co Naphthanate	Na Nitrate
Sb Sulfide	Na Bicarbonate
Mo Trioxide	Na Oxalate
Cr Oxide	

The MIDAS database search quantified the per-item mass of each particulate metal and each metal compound present in the chemical composition of each item. For each particulate metal, the per-item mass was multiplied by the quantity of each type of item expected to detonate in the Range 43 through 48 burn polygon to calculate the total mass of each particulate metal that may be emitted to the air. For each metal compound, the chemical structure of the compound was used to calculate the weight fraction of metal in the compound (e.g., Pb Styphnate is 45.84% Pb by weight). This result was then multiplied by the per-item mass of the compound and the quantity of each item expected to detonate in the Range 43 through 48 burn polygon to calculate the total mass of metal in each metal compound that may be emitted to the air. Examples of these calculations are shown below:

Particulate Metal Calculation

(1.22E-03 lbs. Pb in each 81mm M43A1 Mortar) * (4 detonating items) = 4.88E-03 lbs. Pb

Metal Compound Calculation

(5.26E-05 lbs. Pb Styphnate in each 81mm M43A1 Mortar) * (0.4584 weight fraction of Pb in Pb Styphnate) * (4 detonating items) = 9.64E-05 lbs. Pb

The contributions of each metal from both particulate metal and from metal compounds were then added together for each type of OE item to calculate a reasonable upper bound estimate of the total mass of non-structural metal that could be emitted from the detonating items. These results are summarized in Table 8.

3.0 COMPARISON OF BIOMASS AND OE EMISSIONS

The overall results of this investigation are presented in Table 9, for those pollutants with emission estimates for both OE detonation and biomass burning, and Table 10, for those pollutants with emission estimates from OE detonation only. In Table 9, total emissions from the entire Range 43 through 48 burn polygon are listed for both OE detonation and biomass burning. For the particulate metals listed, the OE detonation emissions include emissions from both plant uptake of metals (from Table 4) and from particulate metals in the OE chemical composition (from Table 8).

The results in Table 9 show that reasonable upper bound OE detonation emission estimates for combustion products and most volatile organic compounds are much less than 0.1% (i.e., one one-thousandth) of the corresponding biomass emissions from the burn polygon. The only exception is for dioxin/furan toxicity equivalent emissions, where the OE contribution is slightly over 1% (i.e., one-one-hundredth) of that from biomass.

For the particulate metals, the data in Table 9 show that reasonable upper bound OE emissions are equal to or less than about 10% (i.e., one-tenth) of the corresponding biomass emissions from the burn polygon. The only exception is for Beryllium, for which the OE contribution is about 45% of that from biomass. However, the absolute magnitude of Beryllium emissions from OE is only 9.56E-03 pound. Beryllium is addressed further in Table 10, discussed below.

A number of pollutants evaluated in this investigation could be quantified only for OE detonation emissions and not for biomass burning, either because the pollutant would not be emitted from biomass burning (i.e., the energetic compounds RDX, HMX, PETN, and TNT) or there were no reliable emission factors for the pollutant for biomass burning. In the absence of corresponding biomass emissions for comparison, a dispersion modeling approach was used to evaluate the potential significance of these pollutant emissions from OE detonation.

Model selection for this analysis was done through joint consultation with the California Air Resources Board (CARB), the Monterey Bay Unified Air Pollution Control District (MBUAPCD), USEPA, CalEPA/DTSC, and the Army. The complexity of trying to model a large, ground-based, buoyant emission source in complex coastal terrain contributes some uncertainty to this analysis. It was agreed, however, that a "screening-level" evaluation could be made using the Industrial Source Complex Short Term Model Version 3 (ISCST3). A "screening-level" modeling evaluation uses health-protective assumptions that would generally result in model predictions that are unlikely to be reached or exceeded in real-world conditions, even considering the modeling uncertainties. Based on agency review of these screening-level results, additional modeling analysis may be considered.

The basis of the ISCST3 model is the straight-line, steady-state Gaussian plume equation. The model accepts hourly meteorological data records to define the conditions for plume rise, transport, and diffusion. The model estimates the concentration value for each source and receptor combination for each hour of input meteorology, and calculates user-selected short-term averages. These model-predicted concentrations can then be compared to appropriate regulatory screening criteria.

For this investigation, five years of surface meteorological data from Monterey, California were combined with regional upper air data to construct the necessary meteorological data input file for ISCST3. A series of ten point sources each 20-meters in diameter and spaced over a 90-acre area were used to simulate a ground-based prescribed burn (assuming a homogeneous burn rate and a total burn time of 6 hours, approximately 90 acres would be consumed in each hour of the burn). Other model input parameters were as follows:

- "Regulatory Default" option was selected
- "Rural" environment was selected
- Receptor grid = 15.0 by 17.5 kilometers, with 500-meter spacing
- Unit emission rate of 1 gram per second (g/s) was used (0.1 g/s for each of the 10 sources)
- Averaging period = 1 hour
- Source height = 0.0 meters (ground-based release)
- Source exit temperature = 1200 ^{o}F
- Source exit velocity = 1.72 m/s (from *Hardy, 1996*).

Even though a prescribed burn on Ranges 43 through 48 would occur only during the daylight hours in the summer or fall seasons, the model investigation was not limited to those hours. Concentration estimates were modeled for all hours and for all seasons in the five-year meteorological database.

The model was run on all five years of meteorological data using the unit emission rate of 1 g/s, and the highest predicted hourly-average concentration was identified. The actual emission rate for each pollutant evaluated in this study was then calculated by dividing each pollutant's total emission by an assumed burn duration of six hours (although the burn in Ranges 43 through 48 is expected to take up to eight hours to complete, a value of six hours was used here because it provided conservatively higher emission rates). Concentrations for each individual pollutant were then calculated by multiplying the model-predicted highest 1-hour concentration by the ratio of each pollutant's actual emission rate to the unit emission rate used in the model.

Table 10 summarizes the OE detonation emission estimates for those pollutants with no corresponding biomass emissions as well as for all pollutants in Table 9, and shows the calculated maximum 1-hour air concentration for each pollutant using the ISCST3 model approach described above. Table 10 also lists an air screening level appropriate for comparison to the 1-hour model concentration for each pollutant.

The data in Table 10 show that for 27 of the 38 pollutants included in this investigation, the screening level estimates of pollutant concentrations are substantially less than 0.1% (i.e., one one-thousandth) of the regulatory screening value. Of the other 11 pollutants, 4 are less than 1% (i.e., one one-hundredth) and 6 are more than 1% but less than 10% (i.e., one-tenth) of the regulatory screening value. Only one pollutant (Cadmium) is more than 10% of the corresponding screening level, but is still well below the health-protective values.

4.0 CONCLUSIONS

This investigation used site-specific data, relevant emission factor reports, and reasonable upper bound health-protective assumptions to calculate air emissions from biomass burning and from incidental detonation of OE items in the Range 43 through 48 burn polygon. This Technical Memorandum does not address the issue of possible human health effects from biomass burning.

The results of this investigation show that for those pollutants of interest where both OE and biomass emissions can be estimated, the OE contribution is a minor fraction of biomass emissions. For all pollutants of interest, screening model estimates of pollutant concentrations from OE emissions are much less than health-protective regulatory screening values.

The conclusion of this investigation is that air pollutant emissions from incidental OE detonation during a prescribed burn in Ranges 43 through 48 will be minor compared to emissions contributed directly by biomass burning, and will result in pollutant concentrations well below health-protective regulatory screening values.

5.0 REFERENCES

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TABLES

Table 1. Estimated Biomass of Maritime Chaparral and Grassland Habitat In Burn Polygon Ranges 43 through 48 Former Fort Ord, California

Maritime Chaparral Age Class	Biomass Density [1] (tons/acre)	Total Area (acres)	Total Biomass for Each Age Class (tons)
3 Year	2.1	56.09	117.8
5 Year	3.9	68.89	268.7
10 Year	8.4	41.14	345.6
15 Year	13.4	78.48	1,051.6
20 Year	17.4	135.32	2,354.6
25 Year	21.9	122.75	2,688.2
30 Year	26.4	13.23	349.3
Sub-Total		515.9	7,175.7
Grassland	1.6	28.93	46.3
Bare Ground	NA	9.79	NA
Total		**554.62**	**7,222.0**

[1] Unpublished data from Lars Pierce, CSU Monterey Bay

Table 2. Estimated Air Emissions from Biomass Burning
Ranges 43 through 48
Former Fort Ord, California

Air Contaminant	Emission Factor	Emissions from Biomass Burning (kg)	(lbs)
CO	76.9 [a]	503,822	1,110,726
CO_2	1629 [a]	10,672,644	23,528,912
NO_x	70 [b]	15,446	34,052
NMHC	9.8 [a]	64,206	141,549
PM_{10}	10.1 [a]	66,172	145,882
C_4H_6	2.2 [b]	485	1,070
C_6H_{14}	0.2 [b]	44	97
CH_3Cl	148 [b]	32,657	71,996
C_6H_6	5.9 [b]	1,302	2,870
$C_6H_5CH_3$	5.8 [b]	1,280	2,821
TEQ_{DF}	2 [c]	1.31E-05	2.89E-05

CO: Carbon Monoxide
NO_x: Nitrogen Oxides
NMHC: Non-Methane Hydrocarbons
PM_{10}: Particulate Matter less than 10 microns
C_4H_6: 1,3-Butadiene
C_6H_{14}: n-Hexane
CH_3Cl: Methyl chloride
C_6H_6: Benzene
$C_6H_5CH_3$: Toluene
TEQ_{DF}: Dioxin/Furan Toxicity Equivalent

[a] Source: USDA Forest Service Emission Factor Report (*Hardy, 1996*)
Emission factor units are grams of pollutant per kilogram of biomass (g/kg).
Emissions (kg) = EF * B * 0.001

where:
EF = Emission Factor (g/kg)
B = Biomass in burn area (kg)
= 7,222 tons * 907.18 kg/ton
= 6,551,654 kg
0.001 = Conversion from grams to kg

[b] Source: USDA Forest Service Emission Factor Report (*Peterson and Ward, 1989*)
Emission factor units are kilograms of pollutant per hectare (kg/hectare).
Emissions (kg) = EF * A

where:
EF = Emission Factor (kg/hectare)
A = Area of burn (hectares, or ha)
= 544.83 acres * 0.405 hectares/acre
= 220.66
(total burn area less bare ground)

[c] Emission factor for TEQ_{DF} is 2 nanograms per kilogram (ng/kg) of biomass (*USEPA, 2000*)
Emissions (kg) = EF * B * 10^{-12}

where:
EF = Emission Factor (ng/kg)
B = Biomass in burn area (kg)
= 7,222 tons * 907.18 kg/ton
= 6,551,654 kg
10^{-12} = Conversion from ng to kg

Table 3. Estimated Biomass of Maritime Chaparral and Grassland Habitat In Target (Impact) Areas Ranges 43 through 48 Former Fort Ord, California

Maritime Chaparral Age Class	Biomass Density [1] (tons/acre)	Number of Targets	Target Size [2] (acres)	Biomass for Each Age Class (tons)
3 Year	2.1	6	0.065	0.8
5 Year	3.9	11	0.065	2.8
10 Year	8.4	9	0.065	4.9
15 Year	13.4	13	0.065	11.3
20 Year	17.4	22	0.065	24.9
25 Year	21.9	4	0.065	5.7
30 Year	26.4	0	0.065	0.0
Sub-Total		65		50.4
Grassland	1.6	23	0.065	2.4
Bare Ground	0.0	2	0.065	0.0
Total		90		52.8

[1] Unpublished data from Lars Pierce, CSU Monterey Bay

[2] Each target area is an approximate circle with 60' diameter = 0.065 acres

Table 4. Estimate of Metal Emissions from Target Area Biomass Compared to Background in the Burn Polygon Ranges 43 through 48 Former Fort Ord, California

Metal	Concentration in Plant Tissue (mg/kg) [1] Target Areas	Native Background	Total Metal in Biomass (lbs) Target Areas [2]	Native Background [3]
Aluminum	616 [4]	308	65.07	4,448.76
Antimony	0.86	0.16	0.09	2.31
Arsenic	0.28	0.17	0.03	2.50
Beryllium	0.09	0.001	0.01	0.02
Cadmium	3.75	0.40	0.40	5.77
Chromium	2.88	0.51	0.30	7.34
Copper	38.9	3.67	4.11	53.00
Lead	11.5	1.07	1.21	15.50
Mercury	0.07	0.08	0.01	1.13
Nickel	2.31	0.64	0.24	9.20
Selenium	0.30	0.14	0.03	2.02
Silver	2.32	0.19	0.25	2.80
Zinc	272	25.0	28.73	361.77

[1] From Appendix A

[2] Total Metal Mass in Target Area Biomass (lbs) = $C_{PT} * B_T * 2.20E-06$

where: C_{PT} = Concentration of Metal in Plant Tissue (mg/kg)

B_T = Total Biomass in Target Areas (kg) = 47,910.4

2.20E-06 = Conversion from mg to lbs

[3] Background Metal Mass in Burn Polygon Biomass (lbs) = $C_{PT} * B_B * 2.20E-06$

where: C_{PT} = Background Concentration of Metal in Plant Tissue (mg/kg)

B_B = Total Biomass in Burn Polygon (kg) = 6,551,673.0

2.20E-06 = Conversion from mg to lbs

[4] Aluminum was not included in the analysis for Site 39 soil samples. For the purpose of this analysis, the concentration of aluminum in the target areas is assumed to be twice that of background soil.

Table 5. Surface UXO Items Estimated to Detonate During a Prescribed Burn
Ranges 43 through 48
Former Fort Ord, California

Ordnance Item	Quantity Found in Surveys	% of Survey Total	Quantity Estimated in 516 Acres [1]	Fraction of Incidental Detonation [2]	Total Items Detonating in 516 Acres	Charge [3]	Per Item NEW (lbs) [3]	Total NEW (lbs)
HE Items:								
PROJECTILE, 84mm, HEAT, M136 (AT4) LIVE	7	2.51%	65	0.10	6	Octol	0.97	6.28
PROJECTILE, 81mm, MORTAR, HE, M43A1 & M43A1B1 LIVE	4	1.43%	37	0.10	4	Comp B	1.29	4.77
PROJECTILE, 81mm, MORTAR, HE, M362A1 & M362 LIVE	2	0.72%	18	0.10	2	Comp B	2.10	3.88
ROCKET, 66mm, INCENDIARY, TPA, M74 LIVE	33	11.83%	305	0.40	122	Triethylaluminum	1.30	158.68
ROCKET, 66mm, HEAT, M72, M72A1, M72A2 & M72A3 LIVE	10	3.58%	92	0.20	18	60/40 Octol	0.67	12.39
PROJECTILE, 60mm, MORTAR, HE, M49A3 (M49A2E1) & M49A2 LIVE	5	1.79%	46	0.10	5	Comp B	0.42	1.94
PROJECTILE, 57mm, HE, M306 AND M306A1+A507 LIVE	3	1.08%	28	0.10	3	Comp B	0.55	1.53
PROJECTILE, 40mm, HEDP, M430, M430A1 LIVE	4	1.43%	37	0.25	9	Comp A5	0.10	0.92
PROJECTILE, 40mm, HEDP, M433 LIVE	2	0.72%	18	0.25	5	Comp A5	0.08	0.37
PROJECTILE, 40mm, HE, M381 LIVE	20	7.17%	185	0.25	46	Comp B	0.07	3.24
PROJECTILE, 40mm, HE, M397 LIVE	6	2.15%	55	0.25	14	Octol	0.07	0.97
GRENADE, HAND, INCENDIARY, TH3, AN-M14 LIVE	2	0.72%	18	0.50	9	Thermite TH3	1.66	15.35
MINE, ANTI-PERSONNEL, M-18A1, CLAYMORE LIVE	1	0.36%	9	0.50	5	Comp C4	1.50	6.94
Pyrotechnic Items:								
PROJECTILE, 40mm, CANOPY, WHITE SMOKE, M680 LIVE	2	0.72%	18	0.40	7	Smoke Mixture	0.13	0.96
PROJECTILE, 40mm, GROUND MARKER GREEN SMOKE M715 LIVE *(also includes M713)*	27	9.68%	250	0.40	100	Smoke Mixture	0.17	16.98
PROJECTILE, 40mm, PARACHUTE, WHITE STAR, M583A1, GREEN STAR M661 & RED STAR, M662 LIVE	5	1.79%	46	0.75	35	Illuminant Mixture	0.21	7.28
FLARE, SURFACE, TRIP, M49A1 LIVE	1	0.36%	9	0.75	7	Illuminant Mixture	0.73	5.06
SIGNALS, ILLUMINATION, GROUND, PARACHUTE, RED STAR, M126A1 LIVE	1	0.36%	9	0.75	7	Illuminant Mixture	0.19	1.32
SIGNALS, ILLUMINATION, GROUND, CLUSTERS, GREEN STAR, M125A1,RED STAR, M158,WHITE STAR, M159 LIVE	1	0.36%	9	0.75	7	Illuminant Mixture	0.16	1.11
GRENADE, HAND, SMOKE, HC, AN-M8 LIVE	1	0.36%	9	0.25	2	Smoke (HC)	1.19	2.75

Table 5. Surface UXO Items Estimated to Detonate During a Prescribed Burn
Ranges 43 through 48
Former Fort Ord, California

Ordnance Item	Quantity Found in Surveys	% of Survey Total	Quantity Estimated in 516 Acres [1]	Fraction of Incidental Detonation [2]	Total Items Detonating in 516 Acres	Charge [3]	Per Item NEW (lbs) [3]	Total NEW (lbs)
Practice Items:								
PROJECTILE, 22mm, SUBCALIBER, PRACTICE, M744 LIVE	9	3.23%	83	0.10	8	Smoke Mixture	0.02	0.17
ROCKET, 35mm, PRACTICE, SUBCALIBER, M73 LIVE	90	32.26%	832	0.25	208	Flash Mixture	0.003	0.62
PROJECTILE, 40mm, PRACTICE, M781 LIVE	3	1.08%	28	0.10	3	Orange Dye	0.00	0.00
CARTRIDGE, 40mm, PRACTICE, M212 LIVE	3	1.08%	28	0.10	3	Flash Mixture	0.003	0.01
Miscellaneous Items:								
MISCELLANEOUS FUZES (M412 typical)	11	3.94%	102	0.50	51	Tetryl	0.01	0.63
PROJECTILE, 40mm, CS, M651 LIVE	6	2.15%	55	0.25	14	CS Irritant Mix	0.12	1.62
MISSILE,GUIDED,HEAT,M222 (DRAGON) (MOTOR IGNITERS) LIVE	20	7.17%	185	0.50	92	Lead Styphnate	0.002	0.20
TOTAL ITEMS	**279**		**2580**		**792**			

NOTES:
Comp A5 = 98.5% RDX, 1.5% Stearic Acid
Comp B = 60% RDX, 39% TNT, 1% Wax
Comp C4 = 91% RDX, 9% Plasticizer
CS Irritant Mix = CS Agent, Magnesium Carbonate, Nitrocelulose, Potassium Chlorate, Sugar
Flash Mixture (typical) = Potassium Perchlorate, Flaked Aluminum, Sulfur
Illuminant Mixture (typical) = Aluminum or Magnesium Powder, Sodium or Barium Nitrate
Octol = 70% HMX, 30% TNT (unless other specified percentage)
Smoke Mixture (typical) = Potassium Perchlorate, Aluminum Powder
Thermite = 27% Powdered Aluminum, 73% Iron Oxide

[1] Quantity in 516 acres = (% of Survey Total) * (5 items/acre) * (516 acres)
(total burn area less bare ground and grassland = 516 acres)
[2] Estimated based on experience (A.R. Smith).
[3] Source: *U.S. Army Defense Amunition Center, 2001*

TOTAL NEW BY COMPOSITION (lbs)	
Comp A5	1.29
Comp B	15.36
Comp C4	6.94
CS Irritant Mix	1.62
Flash Mixture	0.63
Illuminant Mixture	14.77
Lead Styphnate	0.20
Octol 70/30	7.25
Octol 60/40	12.39
Smoke Mixture	20.86
Tetryl	0.63
Thermite	15.35
Triethylaluminum	158.68

Table 6. Melting and Boiling Temperatures of Metals Common as OE Structural Components Former Fort Ord, California

Metal	Melting Point (°F) [1]	Boiling Point (°F) [1]
Antimony	1166	2975
Beryllium	2349	4532
Cadmium	610	1409
Chromium	3452	4788
Copper	1981	4703
Lead	621	3164
Nickel	2831	5139
Zinc	788	1666

[1] Hazardous Chemicals Desk Reference, 2nd Edition

Table 7. Air Emissions from Surface UXO Items Estimated to Detonate During a Prescribed Burn
Ranges 43 through 48
Former Fort Ord, California

Energetic Material	Total MEM (lbs) in Burn Polygon	Air Emission (lbs)																		
		CO	CO_2	NO_X	PM_{10}	NMHC	C_4H_6	C_6H_{14}	CH_3Cl	C_6H_6	$C_6H_5CH_3$	CH_2=CHCl	Cl_2C=CCl_2	CCl_4	CH_2Cl_2	TEQ_{DF}	RDX	HMX	PETN	TNT
Comp A5	1.29	3.17E-02	1.63E+00	4.74E-02	2.84E-01	1.68E-03	1.01E-05	5.87E-06	3.25E-06	1.21E-04	4.49E-05	7.47E-06	1.24E-05	2.62E-06	3.39E-04	2.32E-09	2.08E-03			
Comp B	15.36	5.72E-01	1.94E+01	4.53E-01	3.38E+00	2.00E-02	1.20E-04	6.99E-05	3.87E-05	1.44E-03	5.35E-04	8.89E-05	1.47E-04	3.12E-05	4.04E-03	2.76E-08	2.47E-02			2.71E-06
Comp C4	6.94	1.73E-01	8.74E+00	2.59E-01	1.53E+00	9.02E-03	5.44E-05	3.16E-05	1.75E-05	6.50E-04	2.42E-04	4.02E-05	6.66E-05	1.41E-05	1.83E-03	1.25E-08	1.12E-02			
70/30 Octol	7.25	2.51E-01	9.14E+00	2.29E-01	1.60E+00	9.43E-03	5.68E-05	3.30E-05	1.83E-05	6.79E-04	2.52E-04	4.20E-05	6.95E-05	1.47E-05	1.91E-03	1.31E-08		2.18E-04		1.52E-05
60/40 Octol	12.39	4.68E-01	1.56E+01	3.68E-01	2.73E+00	1.61E-02	9.71E-05	5.64E-05	3.12E-05	1.16E-03	4.31E-04	7.17E-05	1.19E-04	2.52E-05	3.26E-03	2.23E-08		3.72E-04		2.60E-05
Flash Mixture	0.63	5.23E-03	5.10E-01	2.55E-03	3.47E-01	3.84E-04	1.89E-06	4.28E-07	6.30E-07	2.84E-05	1.76E-05	9.45E-07	6.04E-06	1.28E-06	2.58E-04	1.13E-09	3.78E-05		1.01E-06	
Illuminant Mixture	14.77	2.51E-01	1.19E+01	6.72E-02	3.93E+00	1.11E-02	1.03E-04	1.41E-05	2.22E-05	4.73E-04	4.06E-04	1.83E-05	1.42E-04	3.00E-05	7.99E-04	2.66E-08	3.62E-04		1.51E-04	
Smoke Mixture	20.86	1.50E+00	8.76E+00	2.29E-01	5.42E+00	2.29E-02	2.50E-05	5.63E-05	1.19E-04	1.38E-03	1.79E-04	1.84E-05			2.50E-05					
Tetryl (Fuzes)	0.63	1.35E-02	7.37E-01	5.73E-03	2.93E-01	7.56E-04	8.06E-06	3.43E-07	2.46E-06	7.25E-05	1.73E-05	1.07E-06	6.04E-06	1.70E-06	2.68E-04	1.13E-09	1.25E-04		8.38E-06	
Thermite	15.35	5.99E-01	1.93E+01	1.46E-01	3.38E+00	2.00E-02	1.20E-04	6.98E-05	3.87E-05	1.44E-03	5.34E-04	8.89E-05	1.47E-04	3.12E-05	4.04E-03	2.76E-08				
Triethylaluminum	158.68	6.19E+00	2.00E+02	1.51E+00	3.49E+01	2.06E-01	1.24E-03	7.22E-04	4.00E-04	1.49E-02	5.52E-03	9.19E-04	1.52E-03	3.22E-04	4.17E-02	2.86E-07				
Miscellaneous Items	1.82	7.10E-02	2.29E+00	1.73E-02	4.00E-01	2.37E-03	1.43E-05	8.28E-06	4.59E-06	1.70E-04	6.33E-05	1.05E-05	1.75E-05	3.69E-06	4.79E-04	3.28E-09				
Total	**255.97**	**1.01E+01**	**2.98E+02**	**3.33E+00**	**5.82E+01**	**3.20E-01**	**1.86E-03**	**1.07E-03**	**6.96E-04**	**2.25E-02**	**8.24E-03**	**1.31E-03**	**2.25E-03**	**4.78E-04**	**5.90E-02**	**4.23E-07**	**3.85E-02**	**5.89E-04**	**1.60E-04**	**4.40E-05**

Mass Balance Worksheet A: Chemical Composition of Energetic Materials

Energetic Material	Formula	MW	C% (wt)	N% (wt)
RDX	$C_3H_6N_6O_6$	222	16.22%	37.84%
HMX	$C_4H_8N_8O_8$	296	16.22%	37.84%
PETN	$C_5H_8N_4O_{12}$	316	18.99%	17.72%
TNT	$C_7H_5N_3O_6$	227	37.00%	18.50%

Mass Balance Worksheet B: Emission Factor (EF) Calculation by Mass Balance

Energetic Material	Chemical Composition					EF (lb/lb MEM)	
	HMX	TNT	RDX	PETN	Other	CO	NO_X
Comp A5			98.5%		1.5%	2.46E-02	3.67E-02
Comp B		39%	60%		1%	3.72E-02	2.95E-02
Comp C4			91%		9%	2.50E-02	3.73E-02
70/30 Octol	70%	30%				3.46E-02	3.16E-02
60/40 Octol	60%	40%				3.78E-02	2.97E-02

Note:
(1) Mass balance is based on EPA BangBox test report (EPA/600/R-98-103) Table 5.2 conclusions:
100% C converted to CO_X and 6.6% of CO_X is CO.
3% N converted to NO_X and 97% N to N_2
(2) Assumption of 100% NO_X is NO_2 is used for mass balance

Overall average emission factors

Chemical Compounds	Formula	Emission Factor (lb/lb MEM)	Emission Factor Source
Carbon Monoxide	CO	3.90E-02	EPA BangBox study App. E
Carbon Dioxide	CO_2	1.26E+00	EPA BangBox study App. E
Nitrogen Oxides	NO_X	9.49E-03	EPA BangBox study App. E
Nonmethane Hydrocarbon	NMHC	1.30E-03	EPA BangBox study App. E
Particulate Matter	PM_{10}	2.20E-01	EPA BangBox study App. E
1,3-Butadiene	C_4H_6	7.84E-06	EPA BangBox study App. E
n-Hexane	C_6H_{14}	4.55E-06	EPA BangBox study App. E
Methyl Chloride	CH_3Cl	2.52E-06	EPA BangBox study App. E
Benzene	C_6H_6	9.36E-05	EPA BangBox study App. E
Toluene	$C_6H_5CH_3$	3.48E-05	EPA BangBox study App. E
Vinyl Chloride	CH_2=CHCl	5.79E-06	EPA BangBox study App. E
Tetrachloroethylene	Cl_2C=CCl_2	9.59E-06	EPA BangBox study App. E
Carbon Tetrachloride	CCl_4	2.03E-06	EPA BangBox study App. E
Methylene Chloride	CH_2Cl_2	2.63E-04	EPA BangBox study App. E
Dioxin/Furan	TEQ_{DF}	1.80E-09	EPA BangBox study App. E
RDX	$C_3H_6N_6O_6$	1.61E-03	EPA BangBox study Table 5.5
HMX	$C_4H_8N_8O_8$	3.00E-05	SIAD (p2-23)
PETN	$C_5H_8N_4O_{12}$	6.74E-04	EPA BangBox study Table 5.5
TNT	$C_7H_5N_3O_6$	2.10E-06	SIAD (p2-23)

OE-specific emission factors

Energetic Material	Typical Composition	Emission Factor (lb/lb MEM)																		
		CO	CO_2	NO_X	PM_{10}	NMHC	C_4H_6	C_6H_{14}	CH_3Cl	C_6H_6	$C_6H_5CH_3$	CH_2=CHCl	Cl_2C=Cl_2C	CCl_4	CH_2Cl_2	TEQ_{DF}	RDX	HMX	PETN	TNT
Flash Mixture	$KClO_4$+Al	8.30E-03	8.10E-01	4.05E-03	5.50E-01	6.10E-04	3.00E-06	6.80E-07	1.00E-06	4.50E-05	2.80E-05	1.50E-06	9.59E-06	2.03E-06	4.10E-04	1.80E-09	6.00E-05		1.60E-06	
Illuminant Mixture	Al+Mg+$Ba(NO_3)_2$	1.70E-02	8.05E-01	4.55E-03	2.66E-01	7.51E-04	6.95E-06	9.55E-07	1.50E-06	3.20E-05	2.75E-05	1.24E-06	9.59E-06	2.03E-06	5.41E-05	1.80E-09	2.45E-05		1.02E-05	
Smoke Mixture	$KClO_4$+Al	7.20E-02	4.20E-01	1.10E-02	2.60E-01	1.10E-03	1.20E-06	2.70E-06	5.70E-06	6.60E-05	8.60E-06	8.80E-07			1.20E-06					
Tetryl (Fuzes)	$C_7H_5N_5O_8$	2.15E-02	1.17E+00	9.10E-03	4.65E-01	1.20E-03	1.28E-05	5.45E-07	3.90E-06	1.15E-04	2.75E-05	1.70E-06	9.59E-06	2.70E-06	4.25E-04	1.80E-09	1.98E-04		1.33E-05	

Note:
(1) OE specific emission factors are taken from Appendix E to EPA BangBox test report (EPA/600/R-98-103) for flash mixture, illuminant mixture and fuzes
(2) OE specific emission factors are taken from Appendix D to EPA BangBox test report (EPA/600/R-98-103) for smoke mixture

MEM = Mass of Explosive Material; also referred to as Net Explosive Weight (NEW)

Table 8. Air Emissions of Metals from Surface UXO Items Estimated to Detonate During a Prescribed Burn
Ranges 43 through 48
Former Fort Ord, California

Ordnance Item	Total Mass of Non-Structural Metal in All Items Estimated to Detonate in a Prescribed Burn (lbs)															
	Aluminum Al	Antimony Sb	Barium Ba	Beryllium Be	Cadmium Cd	Chromium Cr	Copper Cu	Cobalt Co	Lead Pb	Manganese Mn	Molybdenum Mo	Nickel Ni	Selenium Se	Titanium Ti	Zirconium Zr	Zinc Zn
HE Items																
Projectile, 84mm, HEAT, M136(AT4) Live		1.46E-04	2.52E-04						4.53E-03							
Projectile, 81mm, Mortar, HE, M43A1 & M43A1B1 Live		5.65E-05	5.53E-05		2.40E-05	1.08E-04	1.62E-01	4.00E-06	6.19E-03	1.15E-01		3.96E-04				
Projectile, 81mm, Mortar, HE, M362A1 & M362 Live		6.54E-05			1.20E-05				5.88E-04							
Rocket, 66mm, Incendiary, TPA, M74 Live	3.55E+01	2.97E-03	2.91E-03						9.22E-02							
Rocket, 66mm, HEAT, M72, M72A1, M72A2 & M72A3 Live		4.39E-04	7.55E-04						1.36E-02							
Projectile, 60mm, Mortar, HE, M49A3 (M49A2E1) & M49A2 Live		1.64E-04			3.00E-05				1.47E-03							
Projectile, 57mm, HE, M306 & M306A1+A507 Live		8.45E-05	1.46E-03	3.60E-05		7.35E-03	6.75E-02	2.22E-03	1.51E-03			5.51E-03				
Projectile, 40mm HEDP, M430, M430A1 Live		1.22E-04	1.14E-03						3.55E-03			1.35E-04				
Projectile, 40mm HEDP, M433 Live		1.77E-05	5.23E-05	2.00E-05				1.50E-05	4.80E-04			3.50E-05				
Projectile, 40mm HE, M381 Live		1.62E-04	1.59E-04						4.65E-03							
Projectile, 40mm HE, M397 Live		4.94E-05	7.09E-04			1.96E-02		4.20E-05	3.44E-03			4.20E-03	7.00E-05			
Grenade, Hand, Incendiary, TH3 AN-M14 Live	3.27E+00		2.00E+00			1.14E-03			2.12E-01	5.00E-03				2.08E-01	3.87E-04	
Mine, Anti-personnel, M-18A1, Claymore Live		5.00E-06				2.50E-05			3.42E-03			5.00E-06				
Pyrotechnic Items																
Projectile, 40mm, Canopy, White Smoke, M680 Live			1.79E-02			6.77E-03										
Projectile, 40mm, Ground Marker Green Smoke M715 Live (also includes M173)			1.37E-01			1.26E-01										
Projectile, 40mm, Parachute, White Star, M583A1, Green Star M661 & Red Star M662 Live			1.61E-01			5.60E-03		1.95E-04							5.78E-02	1.73E-02
Flare, Surface, Trip, M49A1 Live	1.06E+00		1.76E+00						4.65E-05							
Signals, Illumination, ground, Parachute, Red Star, M126A1 Live	5.40E-05	9.67E-05	3.35E-03			1.13E-03		8.30E-05	1.65E-04		2.31E-04				1.11E-03	
Signals, Illumination, ground, Clusters, Green Star, M125A1, Red Star M158, White Star M159 Live	5.40E-05	9.67E-05	5.63E-02			1.13E-03		2.08E-05	1.65E-04		2.31E-04				1.21E-03	
Grenade, Hand, Smoke, HC, AN-M8 Live	2.01E-01		7.69E-05			2.53E-04			9.27E-04	1.11E-03				4.59E-05	8.59E-05	7.89E-01
Practice Items																
Projectile, 22mm, Subcaliber, Practice, M744 Live	4.44E-02															
Rocket, 35mm, Practice, Subcaliber, M73 Live	1.36E-01	2.79E-02							1.07E-02							
Projectile, 40mm, Practice, M781 Live	1.40E-05	1.01E-05	1.64E-05		4.20E-05		2.89E-03		1.36E-04							4.24E-08
Cartridge, 40mm, Practice, M212 Live		4.02E-04							1.54E-04							
Miscellaneous Items																
Projectile, 40mm, CS, M651 Live		4.95E-05	4.84E-05					4.20E-05	1.27E-03			2.80E-05				
Miscellaneous Fuzes		7.20E-04	7.05E-04						1.65E-02							
Missile, Guided, HEAT, M222 (Dragon) (Motor Igniters) Live									9.29E-02							
Total (lbs)	**4.02E+01**	**3.36E-02**	**4.14E+00**	**5.60E-05**	**1.08E-04**	**1.69E-01**	**2.32E-01**	**2.62E-03**	**4.71E-01**	**1.21E-01**	**4.62E-04**	**1.03E-02**	**7.00E-05**	**2.08E-01**	**6.06E-02**	**8.06E-01**

Table 9. Comparison of Biomass and OE Emissions
Ranges 43 through 48
Former Fort Ord, California

Air Contaminant		Total Air Emissions (lbs) Ordnance Detonation	Biomass Burning	Ordnance % of Biomass Emissions
Carbon Monoxide		1.01E+01	1.11E+06	0.001%
Carbon Dioxide		2.98E+02	2.35E+07	0.001%
Nitrogen Oxides		3.33E+00	3.41E+04	0.010%
Non-Methane Hydrocarbons		3.20E-01	1.42E+05	0.000%
Particulate Matter < 10 microns		5.82E+01	1.46E+05	0.040%
1,3-Butadiene		1.86E-03	1.07E+03	0.000%
n-Hexane		1.07E-03	9.73E+01	0.001%
Methyl Chloride		6.96E-04	7.20E+04	0.000%
Benzene		2.25E-02	2.87E+03	0.001%
Toluene		8.24E-03	2.82E+03	0.000%
Dioxin/Furan Toxicity Equivalent		4.23E-07	2.89E-05	1.465%
Metals:	Aluminum	1.05E+02	4.45E+03	2.366%
	Antimony	1.24E-01	2.31E+00	5.383%
	Arsenic	2.96E-02	2.50E+00	1.185%
	Beryllium	9.56E-03	2.11E-02	45.344%
	Cadmium	3.96E-01	5.77E+00	6.861%
	Chromium	4.73E-01	7.34E+00	6.451%
	Copper	4.34E+00	5.30E+01	8.191%
	Lead	1.69E+00	1.55E+01	10.871%
	Mercury	7.65E-03	1.13E+00	0.680%
	Nickel	2.54E-01	9.20E+00	2.764%
	Selenium	3.18E-02	2.02E+00	1.570%
	Silver	2.45E-01	2.80E+00	8.745%
	Zinc	2.95E+01	3.62E+02	8.164%

CO: Carbon Monoxide
NO_x: Nitrogen Oxides
NMHC: Non-Methane Hydrocarbons
PM_{10}: Particulate Matter less than 10 microns
C_4H_6: 1,3-Butadiene
C_6H_{14}: n-Hexane
CH_3Cl: Methyl Chloride
C_6H_6: Benzene
$C_6H_5CH_3$: Toluene

TEQ_{DF}: Dioxin/Furan Toxicity Equivalent
CH_2=CHCl: Vinyl Chloride
Cl_2C=CCl_2: Tetrachloroethylene
CCl_4: Carbon Tetrachloride
CH_2Cl_2: Methylene Chloride
$C_3H_6N_6O_6$: RDX
$C_4H_8N_8O_8$: HMX
$C_5H_8N_4O_{12}$: PETN
$C_7H_5N_3O_6$: TNT

Note: Metal emissions from OE include emissions from both detonation and plant uptake.

Table 10. ISCST3 Model Concentrations of OE Emissions Compared to Regulatory Screening Levels Ranges 43 through 48 Former Fort Ord, California

	Air Contaminant	Air Emissions (lbs) from Ordnance Detonation	Modeled Max 1-Hr Air Concentration [1] (mg/m^3)	Air Screening Level (mg/m^3)	Air Concentration as a % of the Screening Level [8]	Screening Level Reference
OE Emission Products with No Corresponding Biomass Emissions for Comparison:						
VOCs:	Vinyl Chloride	1.31E-03	1.02E-05	1.80E+05	0.0000%	OEHHA Acute REL [2]
	Tetrachloroethylene	2.25E-03	1.75E-05	2.00E+04	0.0000%	OEHHA Acute REL
	Carbon Tetrachloride	4.78E-04	3.71E-06	1.90E+03	0.0000%	OEHHA Acute REL
	Methylene Chloride	5.90E-02	4.58E-04	1.40E+04	0.0000%	OEHHA Acute REL
Energetics:	RDX	3.85E-02	2.99E-04	3.57E+00	0.0084%	MBUAPCD Rule 1000 [3]
	HMX	5.89E-04	4.58E-06	1.80E+02	0.0000%	EPA Region 9 PRG [4]
	PETN	1.60E-04	1.24E-06	1.19E+00 [5]	0.0000%	MBUAPCD Rule 1000
	TNT	4.40E-05	3.42E-07	1.19E+00	0.0000%	MBUAPCD Rule 1000
Metals:	Barium	4.14E+00	3.22E-02	1.19E+00	2.7046%	MBUAPCD Rule 1000
	Cobalt	2.62E-03	2.04E-05	1.19E-01	0.0171%	MBUAPCD Rule 1000
	Manganese	1.21E-01	9.41E-04	1.19E+01	0.0079%	MBUAPCD Rule 1000
	Molybdenum	4.62E-04	3.59E-06	2.38E+01	0.0000%	MBUAPCD Rule 1000
	Titanium	2.08E-01	1.62E-03	3.57E+01	0.0045%	MBUAPCD Rule 1000
	Zirconium	6.06E-02	4.71E-04	1.19E+01	0.0040%	MBUAPCD Rule 1000
OE Emission Products Also Compared to Biomass Emissions in Table 9:						
Combustion	Carbon Monoxide	1.01E+01	7.87E-02	2.30E+04	0.0003%	California AAQS [6]
Products	Carbon Dioxide	2.98E+02	2.31E+00	2.14E+04	0.0108%	MBUAPCD Rule 1000
and VOCs:	Nitrogen Oxides (as NO_2)	3.33E+00	2.59E-02	4.70E+02	0.0055%	California AAQS
	Non-Methane Hydrocarbons	3.20E-01	2.49E-03	N/A [7]	N/A	N/A
	Particulate Matter < 10 microns	5.82E+01	4.52E-01	5.00E+01	0.9042%	California AAQS
	1,3-Butadiene	1.86E-03	1.44E-05	5.24E+00	0.0003%	MBUAPCD Rule 1000
	n-Hexane	1.07E-03	8.30E-06	4.29E+02	0.0000%	MBUAPCD Rule 1000
	Methyl Chloride	6.96E-04	5.41E-06	2.50E+02	0.0000%	MBUAPCD Rule 1000
	Benzene	2.25E-02	1.74E-04	1.30E+03	0.0000%	OEHHA Acute REL
	Toluene	8.24E-03	6.41E-05	3.70E+04	0.0000%	OEHHA Acute REL
	Dioxin/Furan TEQ	4.23E-07	3.29E-09	4.48E-08	7.3357%	EPA Region 9 PRG [4]
Metals:	Aluminum	1.05E+02	8.18E-01	2.38E+01	3.4355%	MBUAPCD Rule 1000
	Antimony	1.24E-01	9.67E-04	1.19E+00	0.0812%	MBUAPCD Rule 1000
	Arsenic	2.96E-02	2.30E-04	1.90E-01	0.1209%	OEHHA Acute REL
	Beryllium	9.56E-03	7.43E-05	4.76E-03	1.5602%	MBUAPCD Rule 1000
	Cadmium	3.96E-01	3.08E-03	1.19E-02	25.8587%	MBUAPCD Rule 1000
	Chromium	4.73E-01	3.68E-03	1.19E+00	0.3089%	MBUAPCD Rule 1000
	Copper	4.34E+00	3.37E-02	1.00E+02	0.0337%	OEHHA Acute REL
	Lead	1.69E+00	1.31E-02	1.50E+00	0.8730%	California AAQS
	Mercury	7.65E-03	5.94E-05	1.80E+00	0.0033%	OEHHA Acute REL
	Nickel	2.54E-01	1.98E-03	6.00E+00	0.0329%	OEHHA Acute REL
	Selenium	3.18E-02	2.47E-04	4.76E-01	0.0518%	MBUAPCD Rule 1000
	Silver	2.45E-01	1.90E-03	2.38E-02	7.9968%	MBUAPCD Rule 1000
	Zinc	2.95E+01	2.29E-01	1.19E+01	1.9277%	MBUAPCD Rule 1000

[1] Maximum 1-hour average air concentrations were modeled with the ISCST3 dispersion model using 5 years of meteorological data from the Monterey Peninsula. The model predicted that maximum concentrations would occur 3,285 meters from the burn area.

[2] Office of Environmental Health Hazard Assessment Acute Reference Exposure Levels (http://www.oehha.ca.gov/air/acute_rels/allAcRELs.html)

[3] Monterey Bay Unified Air Pollution Control District Rule 1000 (screening values shown are 1/420th of the OSHA Permissible Exposure Limit)

[4] U.S. Environmental Protection Agency, Region 9, Preliminary Remediation Goals (these are chronic screening values; acute screening values are not available for these chemicals)

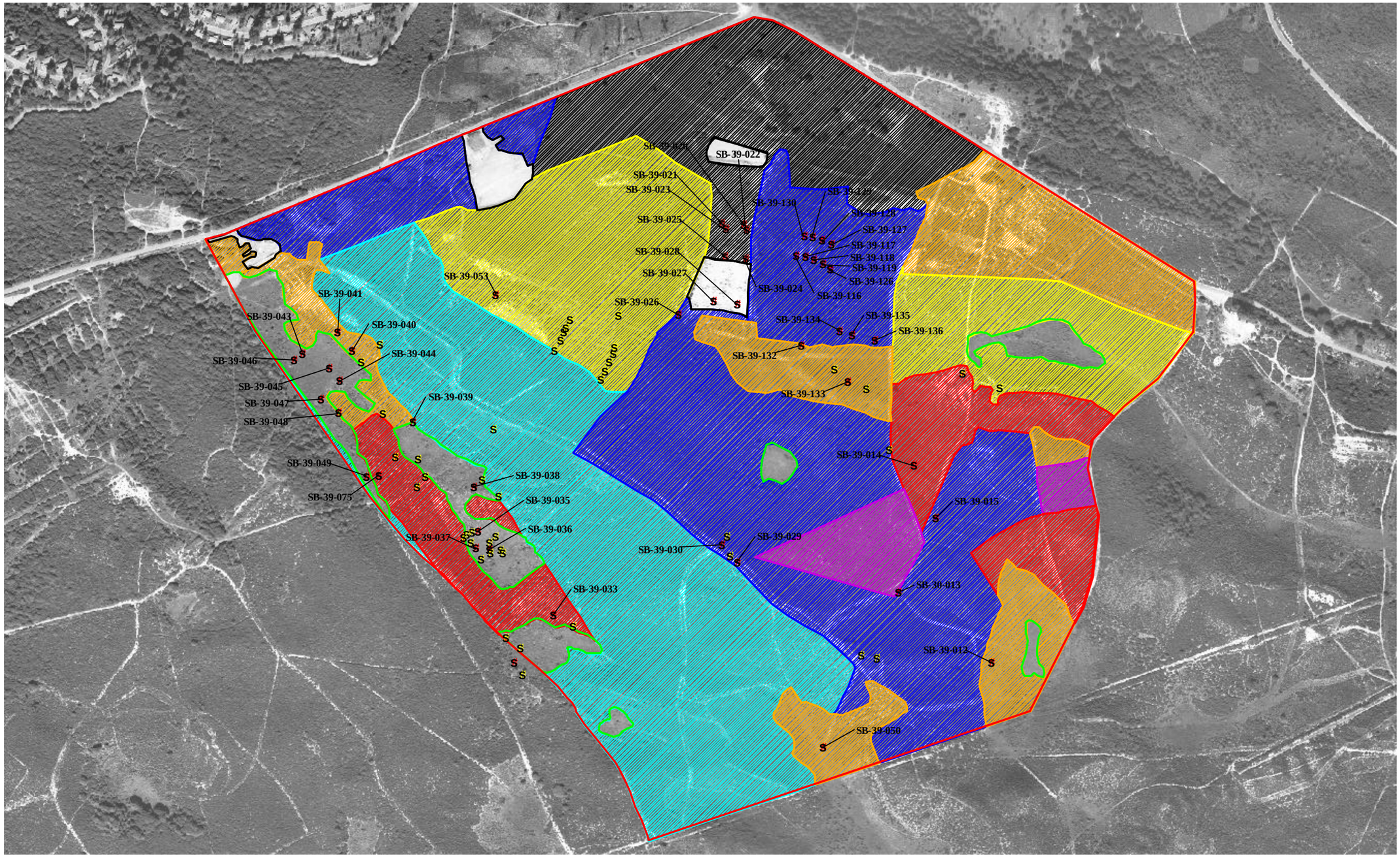
[5] A chemical-specific screening level does not exist for PETN, so the most restrictive screening level from the other energetic compounds (TNT) was used.

[6] California Ambient Air Quality Standard

[7] No screening level exists for this general class of hydrocarbons. Refer to the specific listed VOCs for screening level comparisons.

[8] (Modeled Air Concentration) / (Screening Level) * 100%. Values less than 100% indicate that the screening level will not be reached or exeeded, and adverse health effects are unlikely.

PLATES



LEGEND

- Target with Soil Boring
- Target
- Proposed Burn Area
- Bare Ground
- Grassland

Chaparral
- Less than 3 years
- 5 years Old
- 10 years Old
- 15 years Old
- 20 years Old
- 25 years Old
- 30 years Old

700 0 700 Feet

N

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Biomass Age Classes and Target Area Locations in the Range 43-48 Burn Polygon
Former Fort Ord
Monterey County, California

PLATE 1

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED DATE
JCB	46310 00117	DEC	2/01	3/01

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APPENDIX A

Harding ESE Office Memorandum: Plant Uptake of Metals at Fort Ord Site 39

OFFICE MEMORANDUM

To: Doug Cover, Vice-President

From: Genevieve DiMundo, Project Environmental Scientist

Date: May 29, 2001

Subject: Fort Ord Prescribed Burn Air SAP

Project Number: 46310.00117

This memorandum describes the methods and results of estimating concentrations of metals in plant tissue from concentrations in surface soil at Fort Ord, Site 39. Because direct measurements of metal concentrations in plant tissue were not available at the Site, models were used to predict these concentrations.

METHODOLOGY

Concentrations in plant tissue are typically modeled from soil concentrations using empirical models incorporating soil-plant uptake factors (PUFs). A PUF is the ratio of the concentration of a chemical in a plant (or portion thereof) to that in soil. For each chemical, the plant tissue concentration is derived by multiplying the soil concentration by the chemical-specific PUF. There are many uncertainties, using PUFs, however, including environmental factors and other sources of variability that are not incorporated in the model. Soil properties that affect concentrations of inorganic compounds in soil include pH, clay content, and organic matter. Because inorganic compounds (in addition to required nutrients) in soil water are passively taken up by plants, soil properties can have a great affect on how much of a chemical is absorbed into the plant tissue.

To account for many of these uncertainties, a regression equation was developed in *Empirical Models for the Uptake of Inorganic Chemicals from Soil by Plants* (*Bechtel Jacobs, 1998*). This equation is a regression of natural log (ln)-transformed plant concentration on ln-transformed soil concentration:

$$\ln(C_{plant}) = B0 + B1(\ln[C_{soil}])$$

where:

C_{plant} = Chemical concentration in plant tissue
C_{soil} = Chemical concentration in soil
B0/B1= Chemical-specific factors.

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This regression equation was used in the analysis for all metals detected at the Site and evaluated in the Bechtel Jacobs (*1998*) study. For those metals detected at the Site but not analyzed in the Bechtel Jacobs (*1998*) study, PUFs were applied, as described below.

SITE DATA

Soil samples collected for the Remedial Investigation/Feasibility Study at Site 39 were used in this assessment (*HLA, 1995*). Samples were collected from areas expected to be highly impacted by ordnance (e.g., soil near targets). These areas include the high impact area and several ranges in the northern portion of the Site. Surface soil data (0 to 2 feet below ground surface) were compiled for this assessment because chemicals in deeper soils are not expected to be readily taken up by the roots of plants. Additionally, concentrations of metals in soil at Site 39 are higher in surface soils. A statistical data summary for metals detected in surface soil at the Site is presented in Table 1 and includes the following values: number of detections, number of analyses, frequency of detection, minimum detected value, maximum detected value, arithmetic mean, standard deviation, and 95 percent upper confidence limit on the arithmetic mean (95% UCL).

For comparative purposes, background data collected from 0 to 2 feet bgs were also included in the assessment. The 95% UCL background concentrations were compiled from the *Draft Final Basewide Background Soil Investigation, Fort Ord, California* (*HLA, 1993*). Background samples representing the NQTP soil type (i.e., not from the Paso Robles Formation) were used to represent the soil type at Site 39. The background 95% UCL concentrations are presented on Table 2. Because the Site 95% UCL concentration for mercury exceeds the background concentration, mercury in surface soil at the Site is likely within the range of background concentrations.

Antimony and selenium were not detected in the Site background samples. Detection limits for these chemicals ranged from 5.3 to 6.4 mg/kg for antimony and 0.5 to 0.61 mg/kg for selenium. In this analysis, half of the maximum detection limit for each chemical was used as a surrogate concentration for background (Table 2). For antimony, the half-detection limit concentration of 3.2 mg/kg exceeds the range of statewide background concentrations for antimony of 0.15 to 1.95 mg/kg from *Background Concentrations of Trace and Major Elements in California Soils* (*Bradford et al., 1996*). For selenium, the range of statewide background concentrations is 0.015 to 0.43 mg/kg; the half-detection limit concentration of 0.31 mg/kg used in this assessment is within this range.

Aluminum was not analyzed in soil samples at Fort Ord because it is the most commonly occurring metal in soil and is a major component of almost all common inorganic soil particles. However, aluminum is also a major component of ordnance and explosive compounds and, therefore, could be present in Site 39 soils at elevated concentrations. Aluminum is not soluble or bioavailable in soils with a pH range of 5.5 to 8.0 (*Sparling and Lowe, 1996*). Soil pH at Site 39 ranges from 4.7 to 7.7; therefore, it is likely that the majority of aluminum in Site 39 soils is not biologically available. However, background concentrations of aluminum in soil were included in the analysis. A statewide background 95% UCL concentration for aluminum was obtained from Bradford et al. (*1996*) and is presented in Table 2.

RESULTS

Concentrations in plant tissues were modeled from the 95% UCL concentrations in Site and background soils using the methodology described above (Table 2). Parameters for the regression equation were available for arsenic, cadmium, copper, lead, nickel, selenium, and zinc (*Bechtel Jacobs, 1998*). For these compounds, plant tissue concentrations were estimating using the regression analysis. For aluminum, antimony, beryllium, chromium, and silver, regression parameters were not available; thus, plant tissue concentrations were derived by multiplying the 95% UCL concentration by the PUF for each chemical. PUF values were compiled from the National Council on Radiation Protection Measurement (NCRPM; *1989*) for antimony, chromium, and silver and from Baes et al. (*1984*) for aluminum and beryllium. These PUFs are listed in the Toxicity and Chemical-Specific Factors Data Base (*ORNL, 2000*).

The Site and background modeled plant tissue concentrations for each chemical are presented in Table 2. These concentrations represent concentrations of metals in the foliage or stems of plants. The concentrations of compounds in fruits, seeds, or roots of plants are expected to be different because plants typically bioaccumulate inorganic elements to a different extent in these components. However, for purposes of this evaluation, which is related to the assessment of chemical concentrations in smoke from burning of vegetation, plant foliage and stems represent the majority of the burned material. Thus, the concentrations calculated using this method are appropriate for the intended use.

MODEL VALIDATION

In order to assess whether the regression and PUF models were accurate predictors of plant tissue concentrations at the Site, differences between modeled and actual measured background concentrations were assessed. Only the background data were compared because actual plant tissue data are not available for the Site. Table 3 presents modeled background concentrations and measured concentrations of metals in plants collected at reference areas of Fort Ord (*HLA, 1995*). Plant tissue data collected from reference areas for central maritime chapparal, coast live oak woodland, and upland ruderal species were selected because these species are present at the Site and would potentially be subject to burning. As shown in Table 3, all modeled concentrations are within the range of measured concentrations (for each chemical detected in the reference samples). Also, for antimony, beryllium, mercury, selenium, and silver, plant tissue concentrations for background are modeled although the chemicals were not detected in actual reference samples. These results indicate that the plant tissue concentrations modeled in this assessment are likely good or conservative estimators of actual plant tissue concentrations at the Site.

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Table 1. Statistical Data Summary of Metals Detected in Surface Soil
Prescribed Burn Air SAP
Site 39
Fort Ord, California

Metal	Number of Detections	Number of Analyses	Frequency of Detection (%)	Minimum Detected Value (mg/kg)	Maximum Detected Value (mg/kg)	Arithmetic Mean (mg/kg)	Standard Deviation (mg/kg)	95% UCL (mg/kg)
Antimony	48	223	21.5	0.46	100	1.87	7.83	17.2
Arsenic	167	221	75.6	0.46	10.5	1.46	1.13	3.68
Beryllium	59	218	27.1	0.12	66.9	0.47	4.52	9.34
Cadmium	40	218	18.4	0.93	104	3.06	12.2	26.9
Chromium	212	219	96.8	3.7	380	15.1	29.0	71.9
Copper	100	220	45.5	0.49	12900	138	941	1984
Lead	231	233	99.1	1.1	4060	88.4	381	836
Mercury	3	218	1.4	0.05	0.08	0.03	0.01	0.05
Nickel	157	218	72.0	4.9	344	10.7	25.1	59.9
Selenium	6	220	2.7	0.55	1.0	0.42	0.11	0.63
Silver	9	218	4.1	0.38	12.3	0.37	0.99	2.32
Zinc	140	218	64.2	5.2	8910	109	674	1430

% Percent.
mg/kg Milligrams per kilogram.
95% UCL 95 Percent upper confidence limit on the arithmetic mean.

Note: Data from *Basewide Remedial Investigation/Feasibility Study, Fort Ord, California* (*HLA, 1995*).
Only samples collected from 0 to 2 feet below ground surface were used.

Table 2. Modeled Concentrations of Metals in Plant Tissue
Prescribed Burn Air SAP
Site 39
Fort Ord, California

Metal	95% UCL Concentration in Site Surface Soil (C_{soil}) (mg/kg) [a]	95% UCL Concentration in Background Surface Soil ($C_{soilbck}$) (mg/kg) [b]	Regression Equation Parameters [c] B0	Regression Equation Parameters [c] B1	Plant Uptake Factor (PUF) [d]	Site Concentration in Plant Tissue (C_{plant}) (mg/kg) [e]	Background Concentration in Plant Tissue ($C_{plantbck}$) (mg/kg) [e]
Aluminum	--	77,000	--	--	0.004	--	308
Antimony	17.2	3.2	--	--	0.05	0.86	0.16
Arsenic	3.68	1.52	-1.992	0.564	--	0.28	0.17
Beryllium	9.34	0.15	--	--	0.01	0.09	0.001
Cadmium	26.9	0.45	-0.476	0.546	--	3.75	0.40
Chromium	71.9	12.7	--	--	0.04	2.88	0.51
Copper	1984	4.96	0.669	0.394	--	38.9	3.67
Lead	836	12.1	-1.328	0.561	--	11.5	1.07
Mercury	0.05	0.06	-0.996	0.544	--	0.07	0.08
Nickel	59.9	10.7	-2.224	0.748	--	2.31	0.64
Selenium	0.63	0.31	-0.678	1.104	--	0.30	0.14
Silver	2.32	0.19	--	--	1	2.32	0.19
Zinc	1430	19.4	1.575	0.555	--	272	25.0

95% UCL 95 Percent upper confidence limit on the arithmetic mean.
mg/kg Milligrams per kilogram.
ND Not detected.
-- Not available/applicable.

[a] From: Table 1.

[b] From: *Draft Final Basewide Background Soil Investigation, Fort Ord, California* (*HLA, 1993*). Only shallow NQTP (i.e., not derived from the Paso Robles Formation) soil samples applied to this assessment because NQTP is the soil type at Site 39. For antimony and selenium which were not detected, half of the maximum detection limit is presented. For aluminum, statewide background level from *Background Concentrations of Trace and Major Elements in California Soils* (*Bradford et al., 1996*) is presented.

[c] From: *Empirical Models for the Uptake of Inorganic Chemicals from Soil by Plants* (*Bechtel Jacobs, 1998*).

Regression Equation:

$\ln(C_{plant}) = B0 + B1(\ln[C_{soil}])$

where concentrations (mg/kg) are expressed on a dry-weight basis.

[d] From: Toxicity and Chemical-Specific Factors Data Base (*ORNL, 2000*). Soil-to-dry PUFs used in this assessment.

[e] C_{plant} estimated by the regression equation for arsenic, cadmium, copper, lead, nickel, selenium, and zinc. For antimony, beryllium, chromium, and silver, C_{plant} estimated by multiplying C_{soil} by the PUF.

Table 3. Comparison of Modeled and Measured Plant Tissue Concentrations
Prescribed Burn Air SAP
Site 39
Fort Ord, California

Metal	Modeled Concentration in Plant Tissue for Background ($C_{plantbck}$) (mg/kg) [a]	Measured Concentration in Plant Tissue at Reference Areas (mg/kg) [b]
Aluminum	308	--
Antimony	0.16	ND
Arsenic	0.17	0.12 - 0.3
Beryllium	0.001	ND
Cadmium	0.40	ND - 0.52
Chromium	0.51	ND - 0.7
Copper	3.67	1 - 8.1
Lead	1.07	0.18 - 3.5
Mercury	0.08	ND
Nickel	0.64	ND - 2.2
Selenium	0.14	ND
Silver	0.19	ND
Zinc	25.0	13.8 - 68.1

mg/kg	Milligrams per kilogram.
--	Not available.
ND	Not detected.

[a] From: Table 2.

[b] From: *HLA, 1995.* Data for central maritime chapparal, coast live oak woodland, and upland ruderal used.

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Air Emissions from Incidental Ordnance Detonation
During a Prescribed Burn on Ranges 43 through 48
Former Fort Ord, California

November 9, 2001

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