ENVIRONMENTAL EFFECTS OF SELF-PROTECTION CHAFF AND FLARES

FINAL REPORT

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Prepared for:

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EXECUTIVE SUMMARY

This report presents the findings of a study conducted by the U.S. Air Force (USAF), Headquarters Air Combat Command (ACC) on the environmental effects of using self-protection chaff and flares in military aircraft training. Chaff and flares are defensive mechanisms employed from military aircraft to avoid adversary air defense systems. Chaff are fibers that reflect or mask radar signals, and flares are high temperature heat sources that decoy heat seeking missiles. (Illumination and signaling flares are not included in this study.)

The objective of the study was to identify and document environmental, health, and safety effects associated with chaff and flare use. For potential effects that were identified, this report provides guidelines that can be used by ACC units to assess potential impacts and develop procedures that can be implemented to reduce those impacts. The steps followed in performing the study were:

- Review regulatory and policy issues related to chaff and flares use.
- Collect information on how chaff and flares are used in aircraft training.
- Review available data, literature, and studies pertaining to chaff and flares and their impacts on the environment.
- Compile and analyze data on the materials used in the manufacture of chaff and flares and their associated components.
- Identify potential health, safety, and environmental risks, probabilities, and consequences associated with chaff and flare employment.
- Conduct focused research efforts to resolve outstanding issues of concern.
- Identify circumstances that require consideration or analysis of site-specific conditions to fully assess potential impacts from chaff and flare use.

The information contained in this report addresses potential effects from chaff and flares use on human health, safety, air quality, physical resources (soil and water), biological resources, land use and visual resources, and cultural resources. Issues related to fires from flare use are also addressed.

The following paragraphs summarize the findings of this study.

Effects of Chaff Use

The materials in chaff are generally nontoxic except in quantities significantly larger than those any human or animal could reasonably be exposed to from chaff use. Safety risks were found to be extremely low and isolated to specific circumstances that can be avoided or managed. The primary issue is the potential for interference with air traffic control radar, which is managed by requiring units to obtain a frequency clearance from the USAF Frequency Management Center and

Headquarters Federal Aviation Administration (FAA) prior to using chaff that could interfere with air traffic control radar. Air quality issues included questions about the potential for chaff to break down into respirable particle sizes and the possibility that hazardous air pollutants may be generated from pyrotechnic impulse cartridges used with some chaff models. The results of chaff particulate tests and a screening health risk assessment concluded that these are not significant concerns.

The potential for chaff to affect soil and water is remote. Levels of use and accumulation would have to be extremely high to generate any significant adverse effects. Laboratory tests of chaff, using a modified toxic characteristics leaching procedure, indicated little or no potential for adverse effects on soil. Adverse effects to sensitive aquatic organisms, although unlikely, may be possible in certain small, confined water bodies. These should be addressed on a case-by-case basis in areas proposed for chaff use that include highly sensitive aquatic habitats.

No adverse impacts on biological resources have been identified. Since chaff is generally nontoxic, toxicity-related impacts on wildlife are not anticipated. Based on their digestive processes, few animals are expected to suffer physical effects from chaff ingestion. Information was not available concerning the ability of surface or bottom feeding waterfowl and other aquatic species to process ingested chaff. Effects from inhalation are not considered a significant issue, since chaff particles would represent a small percentage of the particulates regularly inhaled by animals. Given the properties of chaff fibers, skin irritation is not expected to be a problem.

Impacts on land use and visual resources are directly related to the visibility and accumulation of chaff debris. A field study of the visibility of chaff and incidental debris in different environmental contexts concluded that significant aesthetic effects are unlikely. A survey of high-use areas did not indicate that chaff or chaff debris accumulates to create visual impacts. Use of chaff over or immediately adjacent to highly sensitive areas such as Wilderness Areas, Wild and Scenic Rivers, National Parks and Monuments, and other pristine natural areas may be incompatible with the land use management objectives for those areas.

Issues regarding potential effects on cultural resources are also primarily related to accumulation and aesthetics, or, in the case of Native American resources, are indirectly associated with effects on physical and biological resources. The findings related to biological resources and visual resources, therefore, indicate that adverse effects are unlikely. While little is known about the potential for chemical effects from chaff on archaeological or architectural resources, they are considered to be remote, since chaff is composed of common, non-destructive materials.

Although the risks of significant problems appear low, based on the data collected to date, there are a few issues that may have a potential for adverse impacts which could be avoided by adopting some restrictions or limitations on chaff use. In some cases it may be appropriate to analyze the potential for impacts to highly sensitive, confined aquatic habitats that support threatened and endangered species in areas underlying airspace where chaff is proposed for use.

The potential for chaff use interfering with air traffic control radar is already being addressed through coordination with FAA prior to initiating chaff use. Also, a new type of training chaff is available which does not interfere with air traffic control radar.

Effects of Flares Use

Toxicity is not a concern with flares, since the primary material in flares, magnesium, is not highly toxic, and it is highly unlikely that humans or animals would ingest flare material. The main issue with flares is their potential to start fires that can spread and have significant adverse impacts on the environment. Fires can cause a wide variety of significant secondary effects on personnel safety, soil, water resources, biological resources, land use, visual resources, and cultural resources. Another issue is the potential for dud flares and falling debris to pose safety risks. Although the probability of injury from falling debris was found to be extremely remote, there may be a risk associated with untrained people finding dud flares dropped over land that is not controlled by the Department of Defense.

The hazard associated with flare-induced fires depends on a number of factors, including the probability of a burning flare or flare material reaching the ground (or a flare igniting after reaching the ground), the probability of the burning flare/material igniting vegetation on the ground, and the probability of a fire spreading and causing significant damage. The frequency of burning flares or associated materials landing on the ground is not information collected in mishap databases, and calculating a probability would involve too many unknown variables to be accurate. However, methodologies exist for predicting the risk that a fire will start and spread. Using a combination of computer modeling and input databases, with information on meteorological conditions and the flammability of various types of vegetation, the relative risk of wildfires can be predicted. This analysis can only be conducted on a site-specific basis because conditions vary so widely from location to location. A flare fire risk assessment methodology is presented in this report.

Impulse cartridges and initiators used with some flares contain chromium and, in some cases, lead, which are hazardous air pollutants under the Clean Air Act. A screening health risk assessment concluded that they do not present a significant health risk.

Laboratory analyses of flare pellets and flare ash indicate that these materials have little potential for affecting soil or water resources, except possibly in small, confined freshwater habitats that support threatened or endangered species. Potential impacts on biological resources are primarily related to fire.

Flare debris is similar to chaff debris, and litter may be a concern in certain pristine areas. However, field studies indicated that debris does not tend to accumulate in noticeable quantities. The principal issues concerning potential effects on cultural resources are related to fire and associated suppression activities. No specific studies were conducted on whether Native Americans perceive that flare use affects traditional resources. As with other resources, traditional resources can be adversely affected by flare-caused fires.

Based on the findings to date, the following actions may be considered within an analysis of flare use:

- Avoiding use of flares over areas sensitive to fire hazards during high-risk periods.
- Establishing a capability to analyze fire risks on a site-specific basis. The methodologies presented in this report provide a mechanism for accomplishing this.
- Replacing impulse cartridges and initiators in future procurements of flares with models that do not contain toxic air pollutants such as chromium and lead.
- Considering a public information program in areas where flares are used over non-DOD land to educate the public about the hazards of dud flares and proper procedures to follow if a dud flare is found.

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ACRONYMS AND ABBREVIATIONS

AAA	anti-aircraft artillery
ACC	Air Combat Command
ACGIH	American Conference of Governmental Industrial Hygienists
AFB	Air Force Base
AFI	Air Force Instruction
AFR	Air Force Regulation
AGL	above ground level
AIRFA	American Indian Religious Freedom Act
Al	aluminum
ALC	Air Logistics Center
ALDS	Automatic Lightning Detection System
AQL	Acceptance Quality Level
AQUIRE	Aquatic Information Retrieval
ASD	Aeronautical Systems Division
ATM	Air Traffic Management
B	boron
Ba	barium
BLM	Bureau of Land Management
C	carbon
Ca	Calcium
CAD	computer aided design
CATEX	Categorical Exclusion
CEQ	Council on Environmental Quality
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
Cl	chlorine
Cr	chromium
Cu	copper
DIALOG	Dialog Information Retrieval Service
DOD	Department of Defense
DOI	Department of the Interior
DROLS	Defense Research On-Line System
DTIC	Defense Technical Information Center
EA	Environmental Assessment
ECM	electronic countermeasures
EIS	Environmental Impact Statement
EOD	Explosive Ordnance Disposal
EPA	Environmental Protection Agency
EDXA	energy dispersive x-ray analysis
F	fluorine
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
Fe	iron

FLPMA	Federal Land Policy and Management Act
FMZ	Fire Management Zone
FONSI	Finding of No Significant Impact
GHz	gigahertz
GIS	Geographic Information System
H	hydrogen
HMDB	Hazardous Materials Data Bank
HRA	Health Risk Assessment
HRI	Hazard Risk Index
HSDB	Hazardous Substances Data Bank
IAMS	Initial Attack Management System
IFSL	Intermountain Fire Sciences Laboratory
IR	instrument route
IRIS	Integrated Risk Information System
K	potassium
kg	kilogram
l	liter
LC	lethal concentration
LD	lethal dose
m^3	cubic meter
MACT	Maximum Achievable Control Technology
Mg	magnesium
*u*g	microgram
mg	milligram
mil	one thousandth of an inch
*u*m	micron
mm	millimeter
Mn	manganese
MOA	Military Operations Area
Mo	molybdenum
MSL	mean sea level
MTR	Military Training Route
N	nitrogen
Na	sodium
NAAQS	National Ambient Air Quality Standards
NEPA	National Environmental Policy Act
NFDRS	National Fire Danger Rating System
NFFL	Northern Forest Fire Laboratory
NIFC	National Interagency Fire Center
nm	nautical mile
NOAA	National Oceanic and Atmospheric Administration
NOTAM	Notice to Airmen
NTIS	National Technical Information Service
O	oxygen
O_3	ozone

OHM/TDS	Oil and Hazardous Materials/Technical Assistance Data System
ONLC	On-Line Computer Library Center
OSHA	Occupational Safety and Health Administration
P.L.	Public Law
Pb	lead
PM_{10}	particulate matter less than 10 microns in diameter
ppm	parts per million
PRA	Probabilistic Risk Assessment
PSD	Prevention of Significant Deterioration
RAWS	Remote Automatic Weather Station
RCRA	Resource Conservation and Recovery Act
RF	radiofrequency
RTEC	Registry of Toxic Effects of Chemical Substances
S	sulfur
SAC	Strategic Air Command
SAM	surface-to-air missile
SAR	Safety Analysis Review
SEA	Science and Engineering Associates, Inc.
SEM	scanning electron microscope
Si	silicon
SIP	State Implementation Plan
TAC	Tactical Air Command
TCLP	toxic characteristic leaching procedure
TFWC	Tactical Fighter Weapons Center
Ti	titanium
TOMES	Toxicological, Occupational Medicine, Environmental Series
TSP	total suspended particulates
TWS	tail warning system
UKHSEMD	United Kingdom Health and Safety Executive for the Ministry of Defense
USAF	United States Air Force
USC	United States Code
USDA	United States Department of Agriculture
USDI	United States Department of the Interior
USFS	United States Forest Service
USGS	United States Geologic Survey
UTTR	Utah Test and Training Range
V	vanadium
V_T	terminal velocity
WAPA	Western Area Power Administration
WSMR	White Sands Missile Range
Zn	zinc
Zr	zirconium

1.0 INTRODUCTION

1.1 SCOPE AND OBJECTIVES OF STUDY

The United States Air Force (USAF), Headquarters (HQ) Air Combat Command (ACC) has conducted a study to develop more comprehensive scientific data on the employment of chaff and flares in training and the associated environmental impacts. These data are needed to perform future environmental analysis prior to releasing chaff and flares in military training ranges, along Military Training Routes (MTRs), in Military Operations Areas (MOAs), and in over-water Warning Areas, and to address public concerns and misconceptions about their impacts. This study resulted in the preparation of a set of Technical Reports that identify the environmental impacts and health and safety risks associated with the dispensing of chaff and flares from aircraft.

Chaff and flares are defensive mechanisms employed from military aircraft to avoid detection and/or attack by adversary air defense systems. Chaff consists of small fibers that reflect radar signals and, when dispensed in large quantities from aircraft, form a cloud that temporarily hides the aircraft from radar detection. Flares are high-temperature heat sources ejected from aircraft that mislead heat-sensitive or heat-seeking targeting systems and decoy them away from the aircraft. The scope of this study is limited to "self-protection" flares employed to keep aircraft from being targeted; illumination flares used to provide light at night are not addressed by this study. Self-protection chaff and flares are used in combat to keep aircraft from being targeted by weapons such as surface-to-air missiles (SAMs), anti-aircraft artillery (AAA), and other aircraft.

The scope of the topics addressed in this study comprises the range of resources typically analyzed in Environmental Assessments (EAs) and Environmental Impact Statements (EISs), including air quality, earth and water resources, biological resources, land use and aesthetics, and cultural resources. In addition, the study includes an analysis of the toxicity of the constituent materials of chaff and flares, as well as the by-products of their use. Safety issues and their risks are also addressed, and for flares, fire hazards are evaluated.

The study was conducted in three phases. The first phase focused on identifying environmental, health, and safety issues associated with chaff and flares use; examining the materials themselves and how they are used in training; reviewing available data, literature, and study results; reviewing regulatory and policy issues; and identifying further data needs and research efforts for resolving outstanding issues. Appendix A provides a listing of all document resources identified in the conduct of this study, and Appendix B lists databases that were accessed. The second phase concentrated on specific follow-up research activities to address data needs identified during the first phase of the study, including a chaff particulate test, a screening health risk assessment of hazardous air pollutants, field studies, laboratory studies, and a flare fire risk assessment. The second phase culminated in a series of topic-specific Technical Reports documenting the results of these research projects. All findings from the study have been integrated into this final report, which can be used in preparing future EAs and EISs for projects involving chaff and flares.

The results of this study generally fall into two categories:

(1) Issues that, based on the studies conducted, are unlikely to result in significant adverse impacts, and findings can be incorporated by reference in future analyses.

(2) Issues that involve potential impacts in certain situations and may require site-specific analysis.

The scope of this study is focused on identifying issues and impacts unique to chaff and flares. It does not include in-depth analysis of common secondary consequences of those impacts. For example, if a flare starts a fire, the secondary environmental consequences could range from increased erosion and sedimentation, to habitat alteration, to property damage and injury. These types of impacts are common consequences of a fire, regardless of its cause, and have been well documented. Therefore, in this example, the study concentrates on identifying the risk of flare use resulting in wildfires that generate significant impacts, rather than characterizing the impacts themselves, except to provide a brief summary of what they might be. As another example, while the study identifies the risk of an aircraft mishap due to chaff or flares malfunction, it does not analyze the potential consequences of a resulting fuel spill on the environment. Limiting the scope of the analysis in this manner allowed the study to concentrate on considerations important to making decisions about chaff and flare use.

1.2 USE OF CHAFF AND FLARES IN TRAINING

The effective employment of chaff and flares in combat requires training and frequent use by aircrews to master the capabilities of these devices and to ensure safe and efficient handling by ground crews. Training is conducted through simulated battle conditions within Department of Defense (DOD) weapons ranges and electronic combat ranges and other airspace areas, such as MOAs, MTRs, that have been assessed and approved for chaff or flare use. Chaff and flares are also used in field exercises such as Red Flag at Nellis Air Force Range.

When ejected from an aircraft, chaff forms the electromagnetic equivalent of a visual smoke screen that temporarily hides the aircraft from radar. Chaff also serves to decoy radar allowing aircraft to maneuver or egress from the area. It consists of small, extremely fine fibers of aluminum or aluminum-coated glass that disperse widely in the air when ejected from the aircraft and effectively reflect radar signals in various bands, in order to create a very large image of reflected signals ("return") on the radar screen. In the air, the initial burst from a chaff bundle forms a sphere that shows up on radar screens as an electronic cloud. The aircraft is obscured by the cloud, which confuses enemy radar. Since chaff can obstruct radar, its use is coordinated with the Federal Aviation Administration (FAA).

Self-protection flares are magnesium pellets that, when ignited, burn for a short period of time (less than 10 seconds) at 2,000 degrees Fahrenheit. The burn temperature is hotter than the exhaust of an aircraft and therefore attracts and decoys heat-seeking weapons targeted on the aircraft.

Locations where chaff and/or flares are used by ACC units are shown on **Figure 1.2-1**. Brief descriptions of the over-land ranges and MOAs are provided in Appendix C.

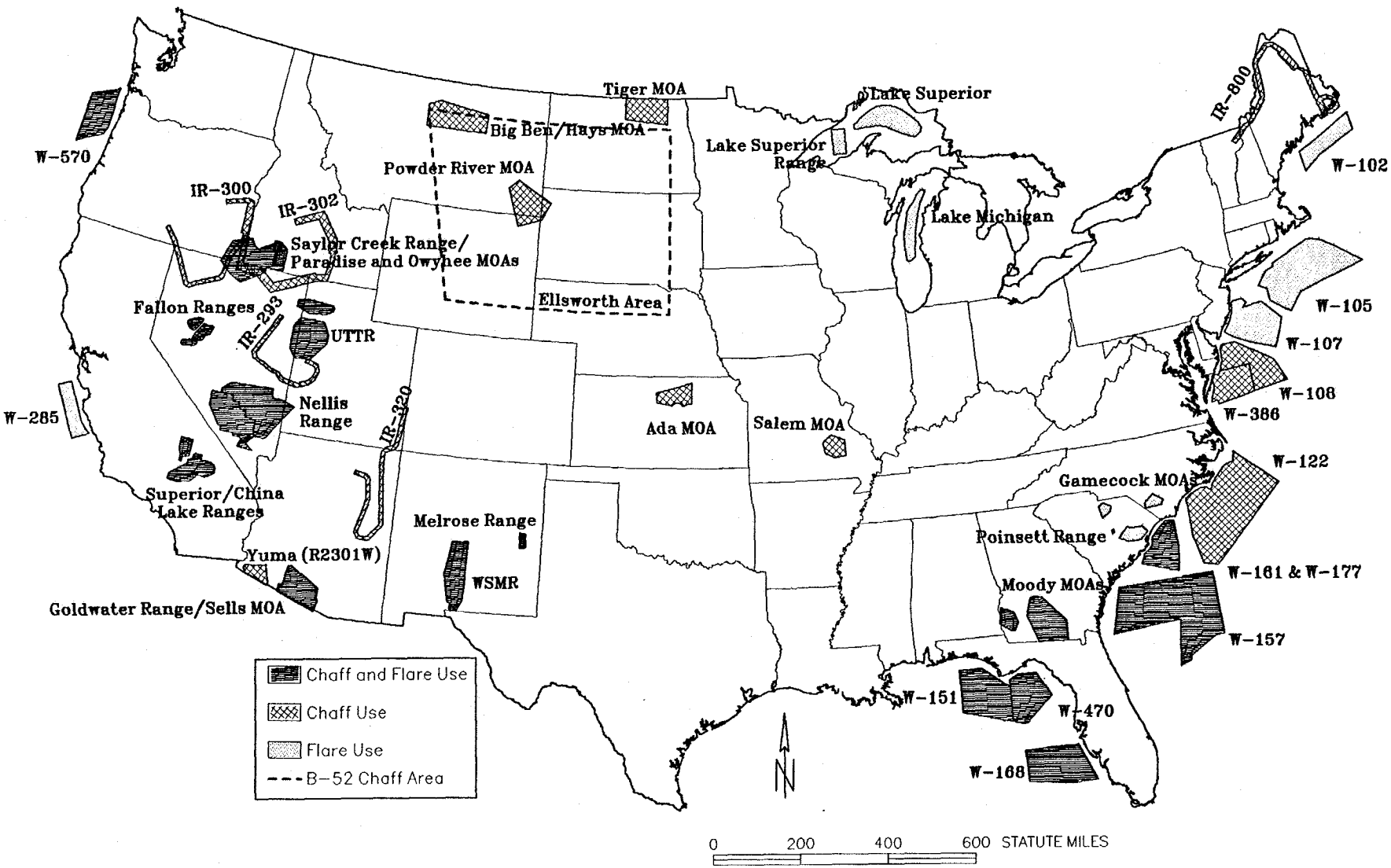


Figure 1.2-1. Location of Chaff and Flare Training Areas Used by ACC Units

Chaff and flares are used by fighter and bomber units over a wide range of altitudes and flight maneuvers or tactics. Deployment of chaff and flares does not interfere with the flight characteristics of the dispensing aircraft. Fighters can drop chaff or flares at any approved altitudes during any flight maneuvers (turns, climbs, descents), airspeed, and G-loading. Although less maneuverable than fighters, bombers can drop chaff or flares at any approved altitudes while in a turn, climb, or descent. Specific descriptions of how chaff or flares are actually employed in training for a combat situation are not releasable.

During peacetime operations, the particular altitude profile typically flown by each fighter or bomber unit is generally dependent on the availability of different range and airspace capabilities. Fighter Intercept Exercises and Red Flag and Warfighter exercises are normally the high-use profiles for chaff and flares. Altitude envelopes for fighter and bomber type aircraft are similar. Typical altitudes and airspeeds provided by Nellis AFB personnel are:

- Low Altitude — surface to 5,000 feet above ground level (AGL), 500 to 600 knots for fighters and 200-400 knots for B-52s and A-10s.
- Medium Altitude — 5,000 feet AGL to 15,000/25,000 feet mean sea level (MSL), transonic airspeeds of 0.8 to 0.9 mach.
- High Altitude — 15,000/25,000 feet MSL to aircraft service ceiling, at or near 0.8 to 2.0 mach.

Fighter aircraft flight profiles are more diverse in vertical movement than bomber profiles, due to their low altitude air-to-ground and higher altitude air-to-air roles. Fighter-type aircraft may ingress to a low level target at 200 to 300 feet AGL and 480 to 600 knots to establish their climb angle, climb to 4,000 to 4,500 feet AGL, release the weapon, execute a hard turn while descending to 200 to 300 feet AGL, with multiple hard turns to exit the target area. Chaff will probably be released as the initial climb is established, just prior to weapon release, post weapon release, and as the hard turns are executed. If target defenses contain infrared capability, flares will be dispensed in place of chaff. High altitude ingress to a target area may require a "combat descent" to the target or to a lower approach altitude. Depending on the defensive capabilities of the target area, chaff and/or flares may be used in the descent. Aircraft dependent, the descent may be accomplished at 30 to 60 degrees or near vertical angle at airspeeds ranging from 500 to 600 knots to supersonic speeds.

During air-to-air combat tactics, the altitude envelope typically increases to the middle and upper altitude structure. Chaff and flares may be used during the employment of Air Combat Tactics or Offensive Counter Air, in which one aircraft opposes one other aircraft, two aircraft oppose two other aircraft, or any number of aircraft oppose some number of others.

Some B-52 aricrews drop chaff on virtually all training missions except local sorties in the traffic pattern. This includes their low- and high-altitude flights on which they drop from 500 AGL to 40,000 feet MSL. Flare drops are accomplished almost exclusively during low level flight (500 to 2,000 feet AGL). Other heavy bomber units use a similar altitude envelope on a variety of ranges, MOAs, and Warning Areas. Bomber aircrews train for low and high ordnance deliveries in which they would use chaff and flares to defeat ground-based radar and airborne radar systems.

ACC units and ranges were interviewed to obtain an estimate of how many chaff bundles and self-protection flares are used annually throughout the command and identify where these countermeasures are employed. Based on those interviews, an estimated 1 million chaff bundles and nearly 400,000 self-protection flares are dispensed annually by ACC units and on ACC ranges. The highest use area for both countermeasures is the Nellis Air Force Range complex, which accounts for approximately 43 percent of the chaff use and 30 percent of the flare use.

About 40 percent of the chaff use occurs on ranges, 25 percent in MOAs, 26 percent in over-water Warning Areas, and 1 percent along MTRs. Total bomber use accounts for about 20 percent of the chaff used by ACC.

Approximately 32 percent of the self-protection flares used by ACC are employed in over-water Warning Areas. The majority of the remaining 68 percent is used in range areas. It is estimated that only about 5 percent is dispensed in MOAs. Bombers account for only about 1 percent of flare use.

1.3 POLICIES AND REGULATIONS ON USE OF CHAFF AND FLARES

Regulations governing chaff and flare use are based primarily on safety and environmental considerations and limitations. General baseline guidance and restrictions have been established at the Air Force or Major Command level, and units have supplemented these procedures as necessary for their particular ranges or other training locations. General procedures are described below; specific procedures for individual training areas are summarized in Appendix C.

Federal Aviation Regulation (FAR) Part 91-6 prohibits pilots of civil aircraft from allowing any object to be dropped from the aircraft in flight that creates a hazard to persons or property, unless reasonable precautions are taken to avoid injury or damage to persons or property. Air Force Instruction (AFI) 11-206, General Flight Rules, July 1994 (formerly Air Force Regulation [AFR] 60-16), is the Air Force counterpart restriction. It prohibits Air Force pilots from allowing any object to be dropped from an aircraft, except in an emergency, without approval. The Air Force approving agency must ensure that any object dropped does not create a hazard to persons, property, or other air traffic.

1.3.1 Chaff

AFI 13-212, Volume I, Weapons Ranges, July 1994, indicates that chaff may be dropped only if specifically authorized for use on the range and when ground impact will occur on government controlled land. This guidance assumes use of current inventory chaff. Any cartridge having significantly different characteristics (such as double squibbed chaff) may be ejected only on test ranges until it is authorized by the Major Command (Bennett, ACC/DORR).

Individual units and ranges may have supplements to AFI 13-212 that identify specific local policies and restrictions on chaff use.

AFI 13-201, U.S. Air Force Airspace Management, July 1994 (formerly AFR 55-34), establishes practices to decrease disturbances from flight operations that might cause adverse public reaction. It

emphasizes the Air Force's responsibility to ensure that the public is protected to the maximum extent practicable from the hazards and effects associated with flight operations.

AFI 11-214 Aircrew and Weapons Director and Terminal Attack Controller Procedures for Air Operations, July 1994 (formerly AFR 55-79), delineates procedures for chaff, flare, and smokey devil employment. It prohibits arming of dispensing systems with intent to dispense, unless in an approved area.

Current USAF policy on use of chaff and flares was established by the Airspace Subgroup of HQ Air Force Flight Standards Agency (AFFSA) in 1993 (Memorandum from John R. Williams, 28 June 1993). It requires units to obtain a frequency clearance from the USAF Frequency Management Center and HQ FAA prior to using chaff, to ensure training with chaff is conducted on a noninterference bases. This requirement ensures electromagnetic compatibility between the FAA, the Federal Communications Commission (FCC), and DOD agencies. USAF does not place any restrictions on use of chaff provided those conditions are met.

1.3.2 Flares

AFI 13-212 states that flares may be dropped only if specifically authorized for use on the range and when ground impact will occur on government controlled land. This guidance assumes use of current inventory flares. Any cartridge having significantly different characteristics, such as pyrophoric flares, may be ejected only on test ranges until its use is authorized by the Major Command. Use of flares will be suspended when warranted by the fire condition code (Bennett, ACC/DORR).

AFI 11-214, in addition to prohibiting arming of flare systems except in approved areas with intent to dispense, sets certain conditions for employment of flares and smokey devils. Flares are authorized over government owned and controlled property and over-water Warning Areas, with no minimum altitude restrictions when there is no fire hazard. If a fire hazard exists, minimum altitudes will be maintained in accordance with the applicable directive or range order.

An ACC Supplement to AFI 11-214, dated 30 May 1997, prescribes a minimum flare employment altitude of 2,000 feet AGL over non-government owned or controlled property. Over government owned and controlled areas, it outlines flare employment restrictions as shown in **Table 1.3-1**.

Current USAF policy on flare use (as reflected in the AFFSA memorandum of 28 June 1993) permits flare drops over military owned/controlled land and in Warning Areas. Flare drops are permitted in MOAs and MTRs only when an environmental analysis has been completed. Minimum altitudes must be adhered to. In addition, flare drops must comply with established written range regulations and procedures.

Table 1.3-1. ACC Flare Restrictions Over Government Land

Aircraft	Minimum Altitude
OA/A-10	400 feet AGL; 700 feet AGL when flying with MJU-7 or equivalent flares
F-4	600 feet AGL
F-15; F-16; EF-111; B-1	700 feet AGL
B-52	1,000 feet AGL

Source: AFI 11-214/ACC Sup 1

1.4 ORGANIZATION AND CONTENT OF THIS REPORT

This report contains seven chapters and five appendices. After this introduction, Section 2.0 describes the approach to conducting the study. The subsequent two sections present data and findings specific to chaff (Section 3.0) and flares (Section 4.0), beginning with a pathway "road map," followed by a detailed description of the materials involved. Data on the toxicity of the constituent materials are also provided. Each section then addresses issues and data related to safety, air quality, physical resources (soil and water), biological resources, land use and visual resources, and cultural resources. Section 4.0 also contains a discussion of fire hazards. Each resource subsection identifies issues addressed; highlights regulatory considerations, if applicable; describes studies conducted, including literature reviewed; summarizes the findings of these studies; and presents conclusions.

Following the detailed analysis, Section 5.0 provides guidelines for conducting environmental assessments for chaff and flare use, concentrating on site-specific studies or analyses that might be appropriate under certain conditions. Section 6.0 lists persons contacted, and Section 7.0 identifies the scientists and specialists who performed the research and analyses for this report.

Some additional background information is included in appendices. Appendix A provides a database of literature sources identified in the course of conducting the study and used as references in the analyses presented in this report. Appendix B identifies other databases accessed. Appendix C provides a short description of ranges and airspace areas identified by ACC units as used for chaff and flare training. Appendix D lists laws, regulations, Executive Orders, cases, and other legal citations that may apply to chaff or flare use in certain areas. Appendix E presents a methodology for conducting fire risk assessments.

2.0 APPROACH TO ANALYSIS

2.1 OVERVIEW

The approach employed in this study centers around a pathway analysis. This analysis identifies the potential events that might occur in the process of using chaff or flares, and defines the pathways by which resulting materials and by-products could enter the environment and affect specific resources. The pathway analysis identifies both primary media — air, land, and water — and secondary means — uptake, inhalation, ingestion, dermal contact — for chaff or flares to enter the environment and have an effect. The physical act of introducing an element into the environment is not itself an impact. There must be an effect on people or on an environmental resource to create a potential concern.

The pathway analysis is based on an understanding of how chaff and flares are designed and how they are employed in training. This is important because it defines what events have a possibility of occurring. It also affects the probability of certain events occurring. For example, information on failure rates of chaff and flares affects the probability of failure-related consequences. If the failure rate is known to be a certain percent, it can be concluded that the probability of any impact stemming from a failure will be that percent or less. To the extent that probabilities can be assigned to potential events, the risks associated with resulting effects farther down the "path" can be estimated, or at least bounded. Risk, along with the consequences themselves, is an important aspect of assessing impact, particularly for unintended and inadvertent events such as material failure and human error.

Once potential pathways of introducing chaff and flares and the by-products of their use into the environment were identified, resulting impacts were addressed on a resource-specific basis. For each environmental resource topic, the analysis of potential impacts was based on a combination of directly applicable data, such as actual studies on chaff and flares, and indirectly applicable data, such as general knowledge about the behavior of environmental elements (wind, water, etc.) and receptors (plants, animals, humans). Thus, conclusions about some potential impacts may be based on physical or behavioral information, even though no studies directly involving chaff and flares have been conducted. In some cases, the available data were inconclusive and additional research was conducted.

Environmental effects can be acute and manifest themselves in the short term, or they can evolve over the long term. Most past studies on chaff and flares have concentrated on acute effects and effects of a single event or a finite number of events. Even discussions of accumulated effects have been limited to one year or less (e.g., the number of chaff bundles or flares used over a year). Prior to this study, almost nothing had been done to assess the long-term effects of continuous chaff and flare use on either the accumulation of residual debris or the chronic effects of this accumulation on such things as soil and water chemistry and wildlife physiology. Although this study did not include any long-term studies, laboratory analysis were designed to simulate long-term chemical effects associated with weathering, and field studies examined areas where chaff has been heavily used over a prolonged period for detectable environmental effects.

2.2 REVIEW OF AVAILABLE DATA

The first phase of this study focused on review of past studies, reports, and available data. The review of existing literature was conducted critically, with the objective of determining whether the data were adequate to support a conclusion, or whether more extensive (or different) research was needed. In many cases, available data and literature were not absolutely conclusive.

A significant component of the first phase of the study was documenting a thorough and accurate description of the materials that comprise chaff and flares, associated containers and debris, and the pyrotechnic and other devices that are used to eject the countermeasures from aircraft. This information was critical to identifying potential impacts and issues and quantifying the extent to which they may be of concern. The materials were reviewed for toxic characteristics, and this information provided input to assessing the toxicity of chaff and flares and their by-products to humans and wildlife, both directly and indirectly. During this phase of the study, information was also collected on historical mishaps related to chaff and flare use, and a safety analysis was conducted using Air Force System Safety Evaluation protocols.

A bibliographic database has been compiled specifically for this study to provide a central listing of citations, reports, and other documents identified and used in the analysis. A printout from this database is provided in Appendix A. This printout also serves as the reference list for text references in this report.

In addition to reviewing existing documents and other literature for this report, a number of computerized databases were accessed to search for relevant information or references. Resource-specific databases are described in the applicable resource subsections of Sections 3.0 and 4.0. A general database, the DIALOG Information Retrieval Service, was used in a number of resource areas. DIALOG is an online information service for technical researchers. The DIALOG menus offer a selection of over 300 databases on science, technology, business, chemistry, engineering, and news. Many of the databases in DIALOG contain information abstracts describing published research and cover trade journals, research publications, and patents. Appendix B provides a list of DIALOG databases accessed for this report.

Another significant database accessed in completing this report is the online Toxicological, Occupational Medicine, Environmental Series (TOMES), which was accessed for information on the toxicity of the materials in chaff and flares. TOMES comprises a number of databases, listed in Appendix B. A computerized bibliography of approximately 30,000 citations dealing with fire issues was also acquired from the International Association of Wildland Fire.

The literature review which summarized available data identified data gaps, and made recommendations for further research in the second phase of the study.

2.3 TECHNICAL STUDIES

Based on the results and recommendations of the first phase, a series of focused analyses were conducted in the second phase of the study. These analyses addressed specific resource issues of concern and were selected because they reflected unresolved issues of credible concern. A number

of unresolved issues that were expected to have little consequence were not pursued because the risk of significant impact was remote. The focused analyses addressed issues of regulatory compliance, particularly with the Clean Air Act, Clean Water Act, and Resource Conservation and Recovery Act (RCRA), and provided an opportunity for limited field verification of impacts. They resulted in the following five additional Technical Reports:

- *Technical Report No. 2, Chaff Particulate Test* (USAF 1994a)
- *Technical Report No. 3, Screening Health Risk Assessment of Chromium and Lead Emissions* (USAF 1994b)
- *Technical Report No. 4, Field Studies* (USAF 1994c)
- *Technical Report No. 5, Laboratory Analysis of Chaff and Flare Materials* (USAF 1994e)
- *Technical Report No. 6, Flare Fire Risk Assessment* (USAF 1995)

The approach to each of these studies is briefly described in the following sections.

2.3.1 Chaff Particulate Test

The purpose of this study was to determine whether aluminum-coated glass fiber chaff dipoles have the potential for breaking up into respirable particulates when they are ejected from aircraft. The study was conducted to determine whether chaff use may result in exceedance of the National Ambient Air Quality Standards with respect to particulate matter less than or equal to 10 microns in diameter (PM_{10}) and, consequently, to assess conformity with the Clean Air Act. The specific objectives of the test were (1) to make a preliminary determination concerning whether the release of chaff generates PM_{10} and (2) if PM_{10} was observed, to develop a quantitative estimate of PM_{10} mass in relation to total mass produced by chaff releases. This information would be used to determine whether chaff use may exceed federal air quality standards in specific locations, based on the volume of proposed chaff use and local ambient air quality.

For the study, samples were collected during a controlled test of chaff conducted at Hill Air Force Base, Utah. A chamber was set up within a test bay at the base, and two static firings of chaff were conducted by Air Force personnel. Two standard high volume (Hi-Vol) air samplers were set up within the chamber to collect chaff particles after each firing. Inlets for both PM_{10} and total suspended particulates (TSP), defined for this analysis as particulate size greater than 10 and less than or equal to 30 microns, were used, providing a two-step size distribution. Each sampler was started one to two minutes after the firing and run for two hours.

The static firings were performed by setting up a canister dispensing system at one end of the chamber. All personnel were evacuated from the chamber before each firing. The tests were observed remotely on a monitor connected to a video camera. Each test was conducted by firing a standard pyrotechnic cartridge used to eject chaff from aircraft. In each firing, the cartridge released the chaff contained in one standard bundle of chaff.

Multiple sampling runs were made, in order to collect sufficient data to conduct statistical tests. They included the following, presented in order of completion:

- Background (pre-test) sampling for TSP (two tests using both samplers).
- Background sampling for PM_{10} (two tests using both samplers).
- Post-release sampling for PM_{10} (four tests using both samplers).
- Post-release sampling for TSP (four tests using both samplers).

The filters in each sampler were weighed before and after each sampling run. In addition to the test filters, two filters were included as "trip blanks" for quality assurance purposes. The post-release weights were then compared to the background weights to measure the increase in PM_{10} and TSP. Approximately half of one TSP filter and two PM_{10} filters were viewed under various magnification levels to obtain an estimate of the chaff fragments that had been collected and to distinguish chaff from other particulates collected on the filters. The findings were then analyzed. The details of the test and its results are described in the chaff air quality analysis in Section 3.5.

2.3.2 Screening Health Risk Assessment of Chromium and Lead Emissions

The purpose of this study was to evaluate the potential health risk impacts resulting from employment of self-protection flares that use initiation cartridges and ignition devices containing chromium and lead compounds. The study used air dispersion modeling and risk modeling to estimate the emission levels that could cause significant short- and long-term health impacts. Both chromium, in its hexavalent form, and lead are listed as hazardous air pollutants under the Clean Air Act Amendments of 1990.

Hexavalent chromium and lead are both known carcinogens. Chromium can also have long-term non-carcinogenic effects on the respiratory system, kidneys, and gastrointestinal/liver system. Lead can have long-term non-carcinogenic effects on the cardiovascular/blood system, central nervous system, reproductive system, kidneys, and immune system, as well as short-term acute effects on the central nervous system. Chromium is not known to have acute health effects.

Modeled concentration of these pollutants resulting from flare use were compared to national standards for Unit Risk Factors accepted by the U.S. Environmental Protection Agency (USEPA), based on dose-response assessments. The cancer risk assessment was based on a 70-year exposure level. The risk assessment model used in the screening analysis was developed by the State of California as part of its air toxics legislation. The calculations were then adjusted to reflect the USEPA-accepted standards.

Three representative release scenarios were developed to estimate the potential concentrations of air toxics under different conditions. One scenario represented a typical target area, assumed to be 10,000 acres, with two representative release altitudes (400 and 900 feet AGL). The second scenario represented a typical range or MOA area of about 490,000 acres, with bounding release altitudes of 400 and 50,000 feet AGL. The third scenario represented a large airspace area, such as the Nellis Air Force Range complex, with an underlying land area of 1.6 million acres. The same bounding release altitudes were used for this scenario as for the range/MOA scenario. To simulate a worst-case 1-hour concentration, a "puff" scenario was also developed, which examined the ground-level concentrations resulting from instantaneous releases at 400 and 30,000 feet AGL.

The SCREEN2 Model, Version 92245, and PUFF screening model were used to calculate downwind ground-level concentrations of lead and chromium. Worst-case meteorological conditions were assumed for all air dispersion runs. For the assessment of long-term cancer and chronic health impacts, the dispersion factor was multiplied by a 0.1 factor to account for annual meteorological variability. Maximum 1-hour (for acute effects) and annual (for cancer and chronic effects) concentrations were calculated for each scenario in each altitude extreme.

These data were then compared to the USEPA-accepted potency values. Using the most restrictive pathway, the number of flares that could be released under each scenario without causing adverse health effects was calculated. This included a 1-hour threshold for acute effects and annual thresholds for long-term effects. In all cases, the long-term thresholds were driven by cancer risk rather than chronic non-cancer health hazards. The evaluation of the results was based on the reasonable likelihood of threshold levels being reached. The findings are discussed in the flare air quality analysis in Section 4.6.

2.3.3 Field Studies

Two field studies were conducted, one at the Nellis Air Force Range complex in Nevada and the other at Townsend Air to Ground Gunnery Range in Georgia, to collect data and observations on the effects of historical chaff (primarily) and flare (incidentally) use on biological resources, soils and sediments, and land use and aesthetics. The two sites were selected to represent different environments, one arid and the other humid/temperate. Within each site, both high-use (e.g., range or target area) and low-use (e.g., MOA) areas were examined so that the influence of utilization levels could be assessed.

Each field study was conducted over a one-week period by a team of two biologists, one environmental analyst with expertise in land use and aesthetics evaluations, and one to two soil sampling specialists. Survey locations within each site were selected based on the following criteria: (1) areas where chaff and/or flare debris are most likely to accumulate, based on consideration of military use, prevailing winds, topography, and drainage patterns; (2) areas representing a range of environmental contexts, considering vegetation, geomorphology, and drainage; (3) areas of resource sensitivity; and (4) accessibility by road. Survey locations were selected in advance using maps, meteorological data, aerial photographs (where available), and information from range personnel. Dispersion modeling was used to estimate the direction and distance that chaff might be expected to be carried before reaching the ground.

The surveys were not designed to be a systematic inventory of chaff and/or flare debris (flares are not employed at Townsend, so surveys there were limited to chaff). However, field team members kept a log of all evidence of chaff and flares that was encountered, and limited amounts of systematic survey were conducted at each site to record the density of chaff and flare debris in different environments. Findings were also recorded photographically.

In addition to surveying for and recording chaff and flare debris, the biologists recorded evidence of wildlife present and of wildlife using debris, excavated rodent burrows, examined bird nests, and looked for evidence of fires (at Nellis, where flares are used). Nest examinations were conducted

without destroying the nests or disturbing the occupants. Survey locations were selected to represent the various habitats at each site, particularly aquatic habitats. The results are discussed in the biological resources analysis in Section 3.7.

Approximately 100 soil and sediment samples were taken at each site. Sampling transects were established in each representative environment, and between four and ten samples were systematically taken along each transect at intervals ranging from 10 to 100 yards. Discretionary samples were also taken in special contexts, such as springs and wetland areas. In aquatic contexts, sediment rather than water samples were taken, based on the assumption that chaff filaments are more likely to accumulate in sediments. Sample dimensions and volumes were standardized, photographed, recorded, and shipped to a laboratory.

At the laboratory, the samples were treated and analyzed for chaff content. Both glass fiber and foil chaff contents were extracted and measured to estimate concentration levels by weight in each sample. Chaff from some samples was also examined using a scanning electron microscope (SEM) to look for evidence of weathering. The pH of each sample was recorded, and weathering patterns were correlated to different pH levels. The field samples were also compared to surrogate environment samples prepared for the laboratory analysis (see Section 2.3.4). The methods and findings are described in more detail in the physical resources analysis in Section 3.6.

The land use and aesthetics field analysis was designed to assess whether chaff and flare debris is visible in the natural environment; determine distances at which the debris is noticeable, distinguishable, and distracting; identify the variables that affect these determinations; compare the frequency that debris was found in high-use versus low-use areas; and compare the effects in arid versus temperate environments. Two methods were used during the field investigations. One involved walking through selected areas to count the number of sightings and observe factors affecting the visibility of the debris found. The second method involved placing chaff and flare debris items in different contexts and evaluating their visibility at various distances. This method was used to control variables in order to obtain a full range of viewing circumstances. Both methods were documented photographically from different viewing distances and environments. The methods and findings are described in more detail in the land use and visual resources analyses in Sections 3.8 and 4.9.

2.3.4 Laboratory Analysis of Chaff and Flare Materials

The purpose of this study was to identify the types and quantities of chemicals that could leach from chaff, flares, and flare ash under various conditions. The tests were conducted by applying a series of surrogate environment treatments to samples of aluminum coated glass fiber chaff, flare pellet material, and a sample of flare ash. Each sample was reacted with four extracting solutions designed to simulate acidic (pH 4), neutral (pH 7), alkaline (pH 10), and marine (synthetic seawater) conditions. A modified toxic characteristic leaching procedure (TCLP) was used for the extractions. Chaff extracts were analyzed for presence of aluminum, magnesium, copper, manganese, titanium, vanadium, zinc, boron, and silicon. Flare pellet and flare ash extracts were analyzed for magnesium, aluminum, boron, barium, and chromium. The flare ash extracts were also examined for ammonia, nitrate, and nitrite. In addition, hydrogen gas formation was measured from

flare pellet samples. The results of the analyses were reviewed and validated according to USEPA Level III standards.

The chaff and flare pellet samples were obtained from controlled sources, but the flare ash was recovered from a U.S. Army facility where flare test burns had previously been conducted. No information was available about the specific composition of the flares used to produce the ash, and there was considerable contamination from other debris.

The analysis results were evaluated for potential effects on soil and freshwater and marine aquatic resources. For the soils analysis, the findings were compared to RCRA reportable quantities and TCLP limits under 40 Code of Federal Regulations (CFR) Part 261.24. In addition, the utilization levels required to increase the concentration of analyses of concern to three times background level in the upper inch of soil were calculated (40 CFR Part 300, App. A, Sec 2.3), based on the worst-case pH conditions (pH 4 surrogate treatment). This was then compared to reasonable worst case accumulation of chaff and flare debris. The analysis of potential effects on freshwater and marine aquatic environments was based on comparisons to studies in the Aquatic Information Retrieval (AQUIRE) data service and freshwater and marine acute and chronic values for chemicals of concern. The methods and results are discussed in more detail in the physical resources analyses in Sections 3.6 and 4.7.

2.3.5 Flare Fire Risk Assessment

The purpose of this report was to examine factors affecting the risk of fires from flare use, present a methodology for assessing fire risk in specific conditions, and demonstrate the use of the BEHAVE fire behavior modeling system in defining site-specific fire hazards. The study included interviews with range personnel and airspace managers in ACC over-land flare training areas to identify fire occurrence history, fire management and environmental protection procedures, operating restrictions used to reduce fire hazard (if any), and fire management capabilities. Data on fire occurrence history were also obtained from the National Interagency Fire Center and other sources as available.

The demonstration applied the BEHAVE computer modeling system to a case study of the Desert Elgin South MOA in Nevada. Fire occurrence data were presented for the area to provide background and context. A number of sample runs were conducted using different vegetation mixes, terrain conditions, and weather conditions, to assess the effect of each variable on predicted fire behavior. The conditions of a real fire that had occurred in the area underlying the MOA were also replicated and applied to a range of vegetation types to show how behavior might vary in differing environments.

Although the study examined fire history data from various locations for correlations between level of flare use, method of flare employment, environmental conditions, and fire occurrence, no correlation could be derived at a statistically valid level. However, the primary focus of the study was to present an approach to identifying and managing fire risk related to flare use. The study is described in more detail in Section 4.5, and the methodology developed from the study is presented in Appendix E.

2.4 FINAL REPORT

The third and final phase of this study involved compiling the results of the individual analyses into a comprehensive report of findings. The primary purpose of this report is to provide information that can be used by ACC units in assessing the potential environmental impacts of chaff and/or flare use at specific locations. In addition to summarizing the results of the research by environmental resource, this report provides guidelines for conducting site-specific analyses and preparing Environmental Assessments to comply with the National Environmental Policy Act (NEPA).

3.0 ENVIRONMENTAL EFFECTS OF CHAFF

3.1 ENVIRONMENTAL ISSUES

Chaff from ACC training activities has the potential for entering every medium of the environment. Chaff fibers are ejected from aircraft into the air and eventually settle to deposit on land or on water, where they may be further transported. Within each medium, chaff has a potential for raising a number of direct and indirect environmental and safety issues. **Figure 3.1-1** presents a graphic depiction of the potential pathways chaff may take in the environment, the various recipients it may affect, and the types of impacts that may result.

Some chaff is ejected through the use of a pyrotechnic initiation cartridge. This device generates air emissions with potential air quality impacts. The chaff itself remains suspended in the air for a period of time, raising issues of air quality impacts, safety impacts from unintended interference with FAA or other radar systems, safety risks to other aircraft engines, and impacts on birds and bats. Not all these pathways may present significant risks, but they all need to be addressed in a comprehensive analysis.

The length of time chaff remains airborne, in combination with local meteorological conditions and the altitude of deployment, affects the distance that chaff is likely to drift and the geographic extent of its potential effects. Eventually, the chaff will settle to the earth's surface, where it may be deposited on water or on land.

If the chaff is deposited on water, the potential issues depend in part on whether the water body is the ocean or an inland water body, and then whether it is an enclosed body (pond or lake) or a running stream or river. The primary areas of concern fall into one of two categories: (1) chemical effects or (2) physical effects. Chemical effects relate to the potential for chaff to cause chemical changes in the water and thereby affect water quality and biota. Physical effects pertain to accumulation of chaff particles and other debris either on the surface or on the bottom. This accumulation raises issues of potential effects on biota, habitat conditions, and aesthetics. If the body of water is a reservoir, issues of impacts on drinking water sources are also raised.

If the chaff is deposited on land, impacts there can also be chemical or physical. Questions about the chemical effects on soil raise issues of potential indirect effects on groundwater, vegetation, and archaeological deposits. Issues concerning chemical effects on wildlife through ingestion, inhalation, or dermal contact are related to the basic toxicity of chaff and its constituent materials. Physical effects to be examined range from impacts on wildlife to impacts on land use and visual resources. If the aesthetics of an area are affected by the accumulation of chaff, this could in turn affect certain types of land use, such as recreation, as well as the context of certain historic resources. Native American values may be indirectly affected by any of the potential direct effects of chaff. Safety issues raised by chaff settling to the ground include potential for interference with electrical distribution if a chaff cloud drifts into a powerline and questions of whether falling debris could pose a hazard to people on the ground.

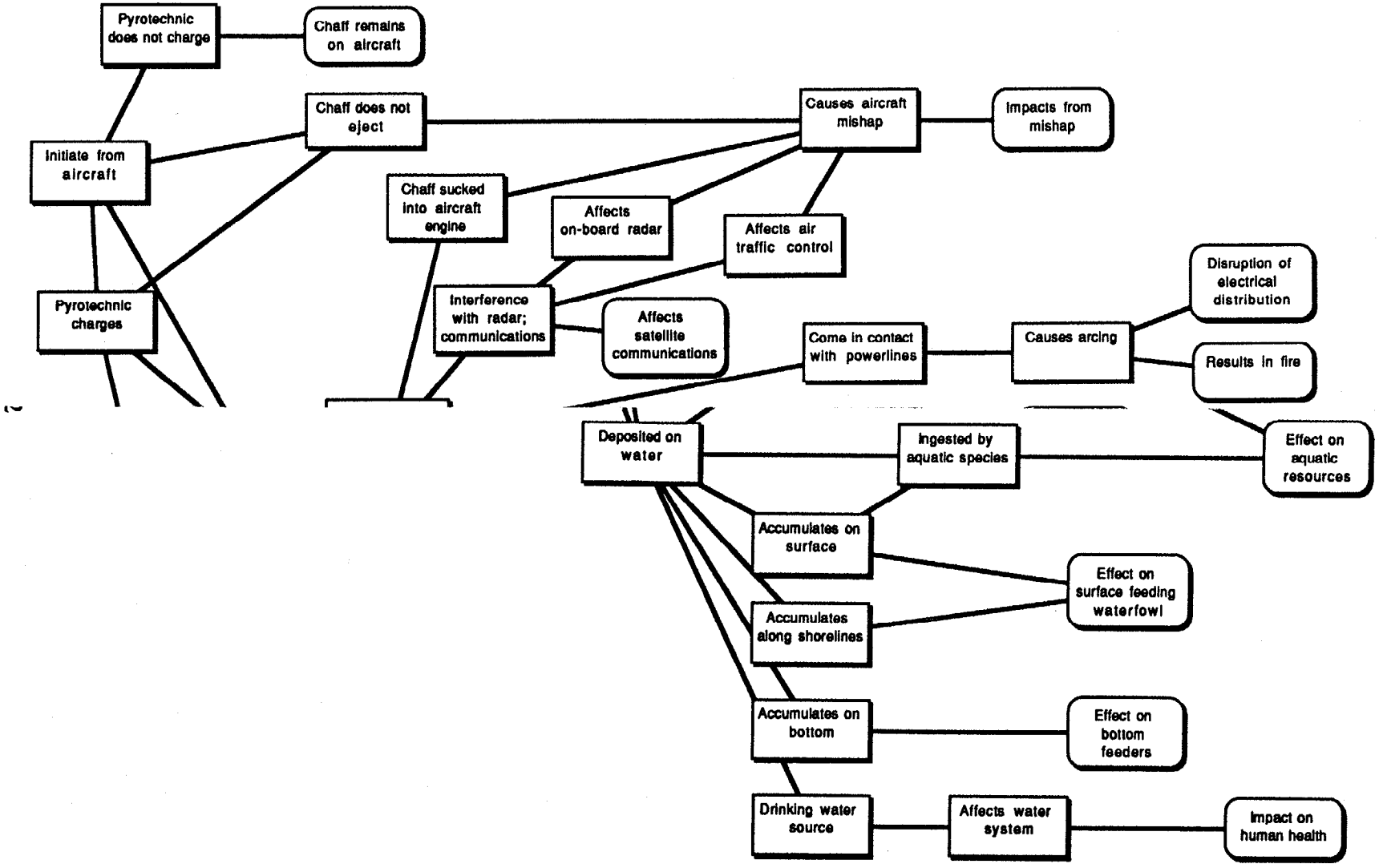


Figure 3.1-1. Chaff Pathways into the Environment

3.2 MATERIAL COMPOSITION AND MANUFACTURE

The principal sources of information on chaff composition are the Air Logistic Centers at Hill AFB, Utah (for pyrotechnic chaff) and Warner Robins AFB, Georgia (for non-pyrotechnic chaff). Data sources used for this study include published specifications and technical orders, supplemented by telephone conversations with Air Force personnel at these Air Logistics Centers and with industry representatives from the Tracor Corporation, and a visit to Hill AFB.

There are two types of chaff, aluminum foil and aluminum-coated glass fibers. The foil type is no longer manufactured, although it remains in the inventory and is used primarily by B-52 bombers. Both types are cut into dipoles ranging in length from 0.3 to over 2.0 inches. They are made as small and light as possible so they will remain in the air long enough to confuse enemy radar. The aluminum foil dipoles are 0.45 mils (0.00045 inches) thick and 6 to 8 mils wide. The glass fiber dipoles are generally 1 mil (25.4 microns) in diameter, including the aluminum coating which is 0.12 ± 0.06 mils thick. A new superfine glass fiber chaff is being manufactured that is 0.7 mil (17.8 microns) in diameter. **Table 3.2-1** lists the components of the glass fibers and aluminum coating of the fiber type chaff.

Both chaff types have a slip coating to prevent end welding of fibers when cut and to minimize clumping when ejected. The coating is a 1 percent solution of Neofat 18 (90 percent stearic acid and 10 percent palmitic acid) with naphtha as the solute. The naphtha is driven off during the curing process. The foil chaff has each cut wrapped in a thin paper sleeve. At one time, the foil chaff contained in cardboard boxes was manufactured with a lead-based stripe coating designed to offset the center of gravity of each dipole to increase flutter. The specification for that chaff is no longer in effect, and Tracor has indicated that lead has not been used for over 10 years (Creel, personal communication, 1993).

Chaff is ejected either mechanically or pyrotechnically. Mechanical ejection uses small foil-laminated cardboard boxes (2.8 by 4.8 by 0.8 inches) that are torn open during ejection. Debris from the cardboard boxes consists of the opened box, two high impact polystyrene plastic support pieces (2.75 by 4.75 by 0.06 inches), and paper wrapping for each dipole cut. Cardboard specifications have been changed from virgin kraft paper to recycled kraft paper because it biodegrades more quickly (Frankel, personal communication, 1993). The sealing adhesive for these boxes is an aqueous type polyvinyl acetate.

Pyrotechnic ejection uses hot gases generated by an explosive impulse cartridge. The gases push a small plastic piston down a chaff-filled tube 8 inches long with a 1 inch square cross-section. This ejects a small plastic end cap, followed by the chaff fibers. The tube remains in the aircraft. Debris that is ejected consists of two 1 inch square pieces of plastic 1/8 inch thick (the piston and the end cap) and a felt spacer. **Table 3.2-2** summarizes the characteristics of two types of impulse cartridges used for pyrotechnic chaff.

Information obtained from ACC indicates they use six varieties of chaff: RR-112, RR-149, RR-170, RR-180, RR-188, and RR-ZZZ (Edger 1993). **Table 3.2-3** summarizes features of these models. RR-141 was historically used by F-111 aircraft, which subsequently converted to

RR-170A/AL prior to being retired from the inventory (Fullmer, personal communication, 1995). RR-129 and RR-144 are Navy models used in ACC airspace. Information on their composition was requested from Navy sources, but it was identified as classified.

Table 3.2-1. Components of Glass Fibers and Aluminum Coating

Element	Chemical Symbol	Percent (by weight)
Glass Fiber		
Silicon dioxide	SiO_2	52-56
Alumina	Al_2O_3	12-16
Calcium Oxide and Magnesium Oxide	CaO & MgO	16-25
Boron Oxide	B_2O_3	8-13
Sodium and Potassium Oxide	Na_2O & K_2O	1-4
Iron Oxide	Fe_2O_3	1 or less
Aluminum Coating*		
Aluminum	Al	99.45 min
Silicon + Iron	Si+Fe	0.55 max
Copper	Cu	0.05 max
Manganese	Mn	0.05 max
Magnesium	Mg	0.05 max
Zinc	Zn	0.05 max
Vanadium	V	0.05 max
Titanium	Ti	0.03 max
Others		0.03 max

*Aluminum is typically Alloy 1145
Sources: Military Specification R-6034b; Aluminum Association, Inc.

RR-112 (**Figure 3.2-1**) is non-pyrotechnic chaff used exclusively by B-52 aircraft. It consists of an aluminum-foil-laminated kraft paper box that contains 11 million aluminum-coated glass fiber dipoles in five cuts ranging from 0.3 to 0.6 inches in length. The older unit that contained foil chaff was designated RR-112/AL. RR-149 is also available for use by B-52 aircraft in both foil and glass fiber. It is the same as RR-112 except in dipole length, which ranges from 0.35 to 2.06 inches in seven cuts. Although the foil versions of these units may still be in the inventory, only glass versions have been purchased for the past 6 to 7 years (Fontaine, personal communication, 1993). B-52 units have indicated that they still use foil chaff.

Table 3.2-2. Impulse Cartridges Used With Chaff Units

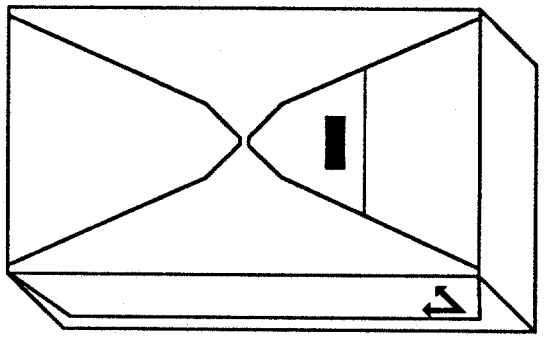
Component	BBU-35/B	BBU-48/B
Overall Size Overall Volume Total Explosive Volume	0.625 inches ′ 0.530 inches 0.163 inches^3 0.034 inches^3	0.975 inches ′ 0.60 inches 0.448 inches^3 0.0031 inches^3
Bridgewire	Tophet A 0.0025 inches ′ 0.15 inches	
Initiation Charge	0.008 inches^3 130 mg 7650 psi boron 20.0% potassium perchlorate 80%**	0.0013 inches^3 50 mg titanium 30% potassium perchlorate 44% boron nitride 25%
Booster Charge	0.008 inches^3 105 mg 7030 psi boron 18.0% potassium nitrate 82.0%	
Main Charge	0.017 inches^3 250 mg loose fill RDX* pellets 38.2% potassium perchlorate 30.5% boron 3.8% potassium nitrate 15.3% super floss 4.6% viton A 7.6%	0.0018 inches^3 50 mg nitrocellulose 88.7% dinitrotoluene 9.5% diphenylamine 0.9% potassium sulphate 0.9% graphite 0.2%

* RDX is cyclotrimethylenetrinitramine (1, 3, 5-trinitro-hexa-hydro-s-triazine)
** Previous manufactures of BBU-35/B contained 15% potassium perchlorate and 64% calcium chromate
mg = milligram
psi = pounds per square inch
Note: some values do not add up to 100% due to rounding
Source: Air Logistics Center, Hill AFB, UT and IMR Powder Company, Plattsburgh, NY

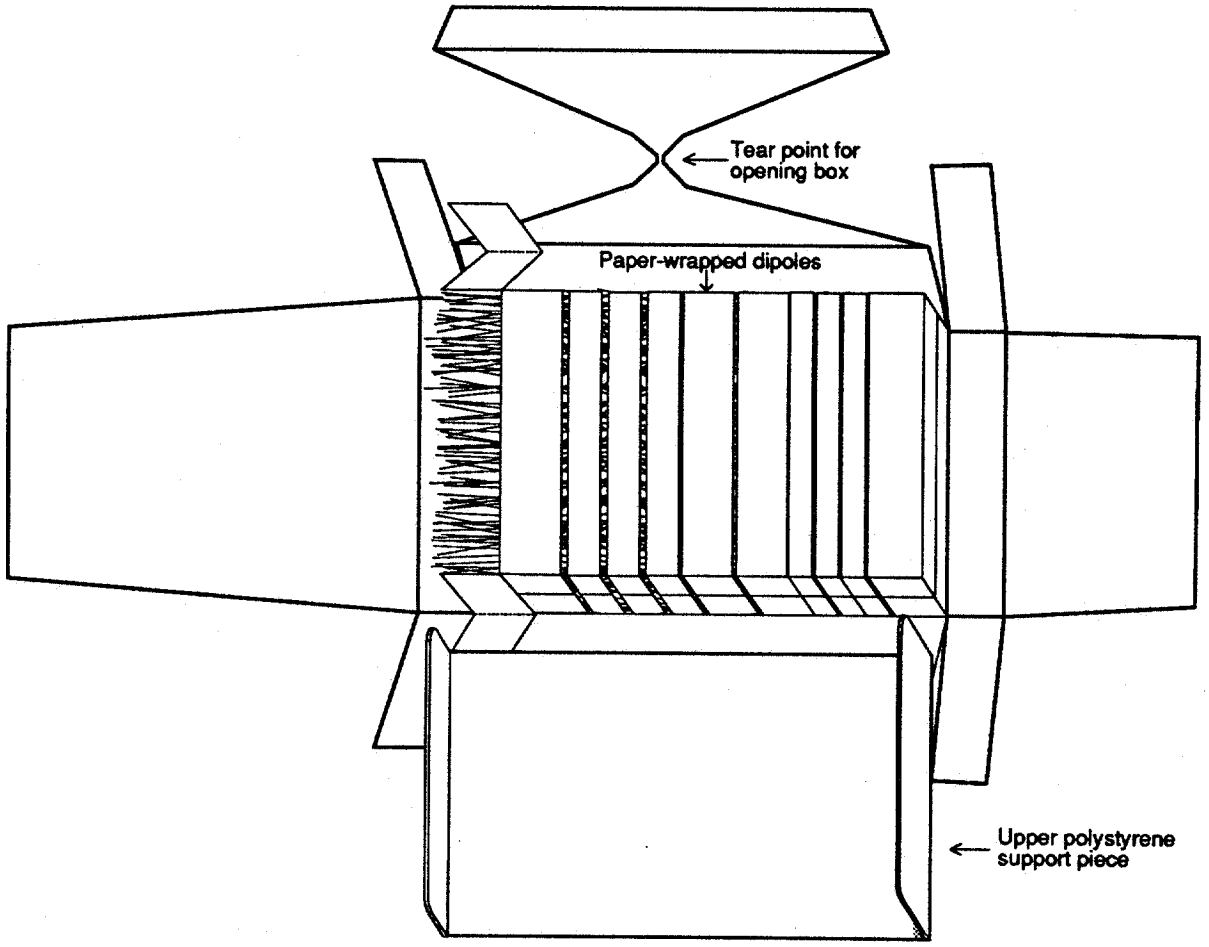
Table 3.2-3. Chaff Used by ACC Units

Attribute	Chaff Types							
	RR-112A/AL	**RR-112/AL**	**RR-149A/AL**	**RR-149/AL**	**RR-170A/AL**	**RR-180/AL**	**RR-188**	**RR-185/AL RR-ZZZ**
Aircraft	B-52	B-52	B-52	B-52, C-130	A-10, B-1, C-5, C-17, C-130, C-141, F-15, F-16	A-10, C-130, F-15, F-16	A-10, F-15, F-16	B-52
Composition	Aluminum coated glass	Foil	Aluminum coated glass	Foil	Aluminum coated glass	Aluminum coated glass	Aluminum coated glass	Aluminum coated glass
Mode	Mechanical	Mechanical	Mechanical	Mechanical	Pyrotechnic	Pyrotechnic	Pyrotechnic	Mechanical
Configuration	Rectangular aluminum foil laminated Kraft paper box with 2 polystyrene supports	Rectangular aluminum foil laminated Kraft paper box with 2 polystyrene supports	Rectangular aluminum foil laminated Kraft paper box with 2 polystyrene supports	Rectangular aluminum foil laminated Kraft paper box with 2 polystyrene supports	Rectangular tube cartridge	Rectangular tube cartridge with dual longitudinal compartments	Rectangular tube cartridge	Rectangular plastic box held together with metal clips
Size	2.8 × 4.8 × 0.8 inches (10.75 cubic inches)	2.8 × 4.8 × 0.8 inches (10.75 cubic inches)	2.8 × 4.8 × 0.8 inches (10.75 cubic inches)	2.8 × 4.8 × 0.8 inches (10.75 cubic inches)	8 x 1 x 1 inches (8 cubic inches)	8 x 1 x 1 inches (8 cubic inches)	8 x 1 x 1 inches (8 cubic inches)	2.8 x 4.8 x 0.8 inches (10.75 cubic inches)
No. of Dipoles	11 million	0.55 million or 1.1 million	Unknown	1.78 million	3.12 million	2.72 million	5.46 million	Classified
Dipole size (x-section)	1 mil (diameter)	0.45 × 8 mils	1 mil (diameter)	0.45 × 6 mils	1 mil (diameter)	0.7 mil (diameter)	1 mil (diameter)	1 mil (diameter)
Impulse Cartridge	None	None	None	None	BBU-35/B	BBU-48/B	BBU-35/B	None
Other Comments	Box ejected	Older type; box ejected	Box ejected	Older type; box ejected	Cartridge stays in aircraft	"Superfine" type; not yet in inventory	Less interference with FAA radar (no D and E bands); will replace RR-170 for training	Special order for Desert Storm

Source: Specifications and Technical Orders for Chaff, Air Logistics Center, Warner Robins AFB; Specifications for Chaff, Aeronautical Systems Division, Wright Patterson AFB and Tracor, Inc.



CLOSED BOX



OPEN BOX

Figure 3.2-1. Non-Pyrotechnic Chaff

The most widely-used pyrotechnic chaff is the tubular type, RR-170A/AL, containing approximately three million dipoles (**Figure 3.2-2**). It uses the BBU-35/B impulse cartridge (**Figure 3.2-3**). Approximately 2 million units per year are used by A-10, B-1, F-15, F-16, C-5, C-17, C-130, and C-141 aircraft; one-half of these are used by ACC (Bodner, personal communication, 1993). The RR-170A/AL is combat chaff. A new type of training chaff, RR-188, has been developed for use by aircraft that employ RR-170. It has the D and E band dipoles removed to avoid interference with FAA radars (Naval Air Systems Command 1991).

A new variety of chaff, RR-180/AL, recently entered the inventory. Its case has the same external dimensions as the RR-170A/AL, but the interior space is divided into two longitudinal compartments that can be fired separately using a BBU-48/B dual impulse cartridge. Each compartment has a piston and an end cap about half the size of those used in the RR-170A/AL. The fibers are slightly smaller in diameter (0.7 mil vs. 1 mil), permitting the unit to hold a total of 1.36 million dipoles per side.

Another experimental unit, RR-185/AL, not yet in production, is being developed to replace the cardboard containers of non-pyrotechnic chaff with a plastic box split along the longitudinal edge. It would be held together with metal clips that would be removed as the unit leaves the aircraft. Plastic is being substituted for paper to avoid problems of moisture absorption when the containers are stored for long periods. When taken to high altitudes or in cold ambient conditions, the moisture in paper containers freezes, and the boxes will not open. The aluminum foil laminated paper boxes and their polystyrene support pieces would be replaced by plastic boxes in the RR-185/AL model. The metal clips would be added to the debris. RR-ZZZ is a version of RR-185 produced specifically for use in Desert Storm, with dipole lengths for radar used in that operation (Bowman, personal communication, 1993).

Chaff cartridges must demonstrate ejection of 98 percent of the chaff in undamaged condition, with a reliability of 95 percent at a 95 percent confidence level. They must be able to withstand any combination of environmental conditions listed in **Table 3.2-4** that might be encountered during storage, shipment, and operation.

3.3 TOXICITY OF CHAFF MATERIALS

Based on reviews of numerous toxicological studies, the principal components of chaff (aluminum, silica glass fibers, and stearic acid) will not pose an adverse impact to human and environmental health. They are unlikely to have significant effects on humans and the environment, based upon the general toxicity of the components, the dispersion patterns, and the unlikelihood of the components to interact with other substances in nature to produce synergistic toxic effects. The primary source of the toxicological information obtained for this study is U.S. EPA's TOMES database, which comprises twelve individual databases (see Appendix B).

The principal ingredient of foil type chaff and of the coating on the fiber chaff is aluminum metal, one of the most abundant metals in the earth's crust, water, and air. Although unlikely, humans and animals may be exposed to aluminum from chaff through ingestion or inhalation. In general, aluminum is regarded as relatively nontoxic. Aluminum compounds are often found as food

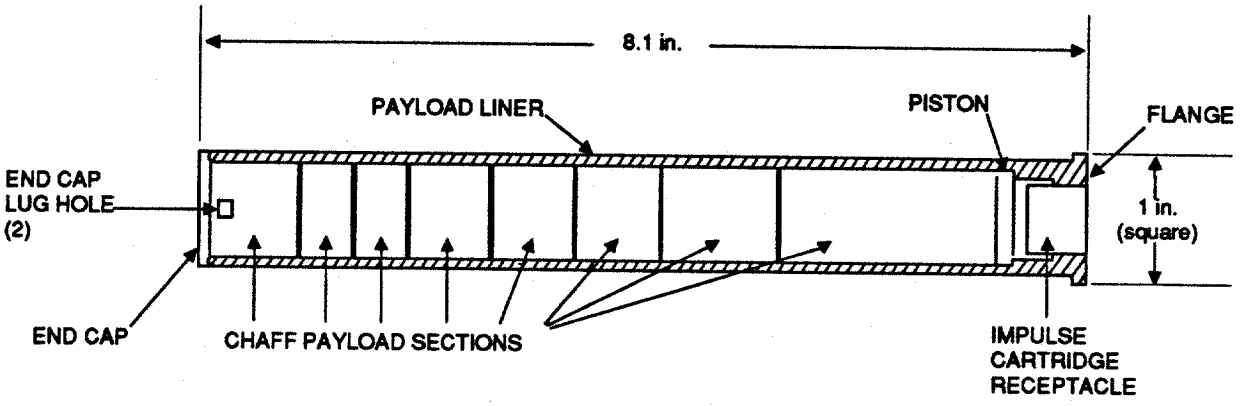


Figure 3.2-2. RR-170A/AL Cartridge Chaff

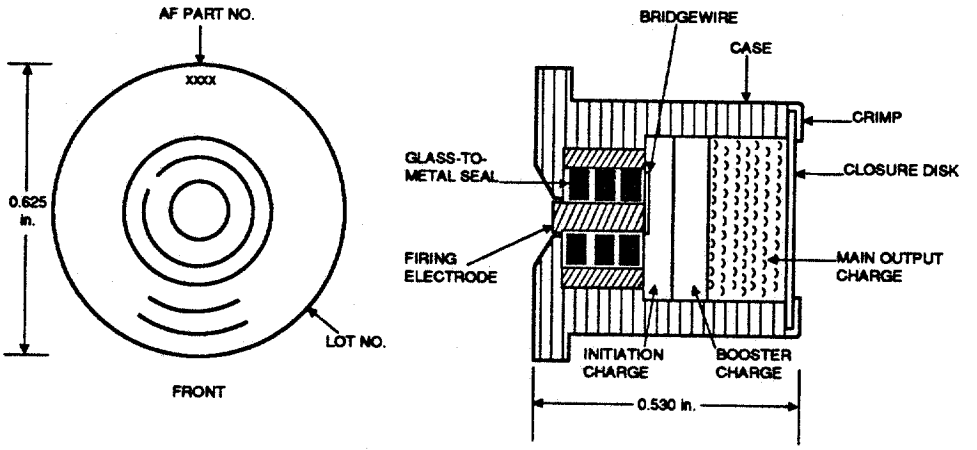


Figure 3.2-3. BBU-35/B Impulse Cartridge

additives and used in the treatment of potable water. Chronic exposure to aluminum as a result of inhalation of bauxite (Al_2O_3-$3H_2O$) fumes has provided evidence of links to development of pulmonary fibrosis (Casarett and Doull 1986). Inhalation of aluminum dust and fumes may also be linked to pneumoconiosis. Particles of aluminum deposited in the eye may cause necrosis of the cornea (Sittig 1985). The amount of potential aluminum exposure from chaff is difficult to predict, but chaff use does not approximate chronic occupational levels or durations for aluminum. Therefore, aluminum in chaff does not pose a health risk.

Table 3.2-4. Environmental Conditions for Chaff Testing

Condition	Performance Requirement	
High Temperature	Up to +165° Fahrenheit	
Low Temperature	Down to -65° Fahrenheit	
Temperature Shock	Shock from -70° to +165° Fahrenheit	
Temperature Altitude	Combined temperature altitude conditions up to 70,000 feet	
Humidity	Up to 95 percent relative humidity	
Fungus	Fungi encountered in the tropics and subtropics	
Salt Fog	Salt fog encountered in coastal regions, sea locations, and during ocean transportation	
Sand and Dust	Sand and dust encountered in desert regions subject to high sand dust conditions and blowing sand and dust particles	
Acceleration/Axis	G-Level	Time (Min.)
Transverse-Left (X)	9.0	1
Transverse-Right (-X)	3.0	1
Transverse (Z)	4.5	1
Transverse (-Z)	13.5	1
Lateral-Aft (-Y)	6.0	1
Lateral-Forward (Y)	6.0	1
Shock (Transmit)	Shock encountered during aircraft flight	
Vibration	Vibration encountered during aircraft flight	
Free Fall Drop	Shock encountered during unpackaged item drop	
Vibration (Repetitive)	Vibration encountered during rough handling of packaged item	
Three Foot Drop	Shock encountered during rough handling of packaged item	

Note: Cartridge must be capable of total ejection of chaff from the cartridge liner under these conditions.
Source: Purchase Description for Chaff Countermeasures, RR-170A/AL, MME-PD-84-6, 11 June 1984.

The aluminum alloy used to coat fiber chaff contains traces of silicon, iron, copper, manganese, magnesium, zinc, vanadium, and titanium (**see Table 3.2-1**). Silicon and iron are abundant in nature. In general, acute exposures to silicon may result in mild eye irritation but otherwise do not contribute significantly to toxicity (Sittig 1985). Silicon is regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The reportable spill quantity is 5,000 pounds (lbs). For comparison, the total amount of silicon contained in all the chaff dispensed at the Nellis Range over the period of one year is estimated to be about 200 lbs.

Iron is a nutritionally essential metal. High concentrations of iron can produce acute effects in a number of species; however, the small amounts of iron present in chaff will not contribute to environmental toxicity.

Of the other trace elements contained in the aluminum alloy -- copper, manganese, zinc, and vanadium -- have OSHA threshold standards. Copper and zinc are also regulated under CERCLA, and the reportable quantities are 5,000 lbs. and 1,000 lbs., respectively. Both are also regulated under the Clean Water Act. However, the quantities of these elements in chaff are extremely small; the total weight associated with annual chaff utilization at the Nellis Range, for example, would be about 20 lbs. for each element. Therefore, no adverse health or environmental impact would result.

The primary component of the glass fibers in chaff is silicon dioxide (SiO_2), also known as silica. This is an abundant compound in nature that is prevalent in soils, rocks, and sand. Silica is practically nontoxic if ingested (Gosselin, et al. 1976). Occupational studies of chronic inhalation exposure to crystalline silica have shown individuals to develop silicosis, a fibrosis of the lung (Casarett and Doull 1986). A study of foundry workers who developed pulmonary silicosis has described a gradual decrease in visual acuity due to corneal opacities in the pupillary area associated with high silicon content in the cornea (Grant 1974). The Department of Health and Human Service's National Toxicology Program has proposed listing respirable size "glass wool" as a potential carcinogen; the listing is currently under review. The potential for chaff fibers to break up into respirable size is addressed in Section 3.5 below.

Additional elements present in the glass fibers include aluminum oxide (Al_2O_3), calcium oxide (CaO), magnesium oxide (MgO), boron oxide (B_2O_3), sodium oxide (Na_2O), potassium oxide (K_2O), and ferric oxide (Fe_2O_3). Each of these chemicals independently exerts toxic effects through various pathways of exposure. For example, both B_2O_3 and CaO exert toxicity primarily through ingestion (CaO is also a skin irritant), whereas toxicity studies on Fe_2O_3 show that exposure occurs mainly by inhalation. Furthermore, as independent chemicals, each may pose acute or chronic health effects depending on the dose and concentration of the chemical, exposure time, and metabolic activity of the recipient. For example, CaO, more commonly known as lye, causes burns on the mucous membrane and skin and can produce acute toxic effects upon ingestion of high doses. Minimal quantities of this compound are also used as supplemental food additives. Several chronic occupational exposure studies have shown ferric oxide to be linked to lung cancer (HSDB 1993), although occupational exposure studies do not accurately reflect the potential effects in the environment because occupational concentrations and exposure durations are much higher and longer than what would be expected in non-occupational settings. A number of laboratory studies on animals have shown that many of the above mentioned chemicals have produced toxicity to

wildlife. However, the chemical additives in the glass fibers are fused together in a stable state, and it is unlikely that they will break down to their independent forms or react chemically with other environmental substances. Even if the fibers are not stable in the environment, the chemicals individually make up a small percentage of the fibers, and it therefore would not contribute significantly to environmental toxicity.

Stearic acid is the main component of the coating agent used to bond the chaff components. Toxicity and environmental fate data on stearic acid reveal that the chemical is essentially nontoxic (HSDB 1993). Stearic acid is naturally found as a glyceride in animal fat and in some vegetable oils. The chemical is virtually insoluble in water but can readily be solubilized by various types of chemical compounds including alcohols. Stearic acid has been shown to easily degrade through bacteriological processes. It lacks the propensity to penetrate skin or mucous membranes. Data on inhalation exposure is limited. Stearic acid is considered an irritant, but due to its lack of solubility capabilities, its ability to biodegrade, and the minimal quantity found in chaff, it can be concluded that this will not pose a hazardous situation. Potential exposure to wildlife may primarily occur through ingestion; however, the quantities required to produce toxic effects are relatively high for most species. Literature review reveals that probable lethal oral dose (LD) for humans would be consumption of more than 2.2 pounds of stearic acid at any one time by an individual weighing 150 pounds (HSDB 1993). A bundle of chaff weighs about 3.4 to 4.4 ounces. A rough estimate of the amount of stearic acid is about 10 grams. Based on that estimate, it would require the consumption of the coating from almost 100 bundles of chaff to achieve a lethal dose of stearic acid.

In summary, the data indicate that the materials comprising the chaff dipoles are generally non-toxic in the quantities present. There is no realistic worst-case scenario under which sufficient quantities would be present in the environmental to pose a health risk.

Older productions of foil chaff reportedly contained lead. Lead is known to be toxic and can result in a number of health problems. However, it is not expected that any chaff containing lead is still in use.

3.4 SAFETY

3.4.1 Issues Addressed

Chaff is used to counter an aircraft's detection by radar by masking the aircraft, or by providing confusing false radar returns to defeat radar-guided anti-aircraft defensive systems. When used, chaff forms a large cloud of fibers that disperses slowly so as to create radar interference for as long as possible. The processes used to eject chaff and the effects chaff produces have the potential to create safety impacts. This study addresses those potential impacts and the issues they raise. These include the following:

- Potential interference with communications/tracking systems, to include satellite communications and tracking.
- Disruption of or interference with FAA or other radar systems, both airborne and ground-based.

- Potential damage to, or disruption of electrical power distribution systems (powerlines).
- Potential damage to aircraft from engine ingestion of chaff.
- Distraction of pilots due to chaff deployment from other aircraft.
- Potential damage to aircraft from chaff system malfunctions.
- Potential injury from falling debris associated with the chaff system.

Any situation that could result in interference with or disruption of a communications or radar system has the potential to create impacts on the environment. Furthermore, any situation that has the potential to damage aircraft or injure or incapacitate aircrews could result in adverse environmental impacts if there is a risk of a catastrophic aircraft mishap or if it could cause serious injury or damage to persons or property on the ground in areas underlying airspace where chaff is employed.

3.4.2 Studies Conducted

Studies conducted to address safety issues associated with chaff use included:

- A review of available literature dealing with safety issues involving chaff use and the operation of chaff dispensing systems.
- A review of accidents and mishaps experienced with chaff use.
- An analysis of chaff safety issues using protocols established for Air Force System Safety evaluations.
- An assessment of safety risks to persons and property on the ground underlying areas where chaff is employed.

The effects of chaff use have been evaluated in numerous studies and reports dating back to 1952. An extensive literature search was conducted as part of this study effort. This included reviewing applicable technical data and examining information available through various databases. While a number of reports and studies exist that address very specific issues associated with chaff use, no formal safety analyses of the chaff system, Safety Analysis Review (SAR), or Probabilistic Risk Assessment (PRA) was located in any of the sources.

Chaff is designed to interfere with specific radar frequencies. It does this by re-radiating electromagnetic signals in the radio frequency (RF) spectrum. In this process, it does not distort the RF radiation. Therefore, direct communications from a transmitter to a receiver through a chaff cloud would not be affected. Thus, chaff has no effect on radio or television communications. While there is no impact on ground-to-ground, air-to-ground, or ground-to-space communications, *per se*, satellite and space object tracking by radars could be interrupted sufficiently that objects being tracked could be "lost" temporarily. If the orbital parameters of the tracked object are known, it can be readily reacquired. Available data do not report any incidents involving interference from chaff with satellite tracking.

There is evidence that chaff use has affected other ground-based radar systems. There are two recorded incidents of interference with FAA radar systems. One occurred in California and involved a Navy fighter aircraft. The other occurred in Arizona and involved two Air Force F-16 aircraft. Detailed information on these occurrences were not available.

While it is possible that chaff clouds could cause airborne radar systems in aircraft to identify "ghost" aircraft and falsely alert pilots to nearby traffic, there is no documentation to indicate that this is either a frequent occurrence or an undue safety hazard. In general, for such a situation to occur, the chaff would have to be clumped in a large mass with a very high concentration of particles, which is counter to the system design.

Although no supporting documentation was found, verbal statements have indicated two occurrences of chaff contacting and crossing high voltage power lines, apparently disrupting electrical service. If these events did occur and chaff actually caused shorting and arcing across high voltage lines, it is reasonable to assume that this would have been caused by a type of chaff (so-called "rope chaff") that is no longer used. The longest dipole of chaff currently used is slightly more that two inches in length and would not be capable of creating the effect described.

An aircraft closely following another aircraft that has dispensed chaff could fly through the cloud and ingest some of the chaff dipoles into its engine. While studies have shown that such an occurrence could result in some loss of engine efficiency, catastrophic engine failure or permanent damage to the engine is not expected. There is no evidence that an aircraft engine ever failed as a result of this event occurring.

Although it is possible that pilots could be distracted by chaff and react by initiating avoidance maneuvers or overcontrolling the aircraft, there are no reported mishaps indicating this has occurred to either a military or civilian pilot.

The most comprehensive data concerning safety mishaps involving chaff and its dispensing systems were received from the Air Force Safety Agency, the Air Force Directorate of Nuclear Surety, and the Explosive Safety Section at Headquarters ACC. These data, as well as data developed from other research, were used to conduct a chaff system safety analysis.

3.4.2.1 Air Force System Safety Evaluation Process

The approach used to conduct the safety analysis is based on mishap categories defined in AFI 91-204, Safety Investigations and Reports, October 1995. The risk and relative incidence of potential mishaps involving chaff use were assessed in accordance with protocols used in Air Force System Safety evaluations.

Air Force mishap categories are:

- Class A Mishap. A mishap resulting in a total cost of $1 million or more in property damage; a fatality or permanent total disability; or destruction of or damage beyond economical repair to an Air Force aircraft.

- Class B Mishap. A mishap resulting in a total cost of $200,000 or more, but less than $1 million in property damage; a permanent disability; or hospitalization of five or more personnel.
- Class C Mishap. A mishap resulting in total damage of $10,000 or more, but less than $200,000; an injury or occupational illness that results in 8 hours or more of lost work; or a mishap that does not meet the criteria for a Class A or B mishap, but which does require reporting under AFI 91-204.
- Class D Mishap. A mishap resulting it total damage of $2,000 or more, but less than $10,000; a loss of worker productivity of more than 1 hour, but less than 8 hours; a nonfatal injury that does not result in a loss of worker productivity; or a mishap that does not meet the criteria for a Class A, B, or C mishap, but does require reporting by the AFI. Class D mishaps are not applicable to aircraft-related mishaps.
- High Accident Potential. An event that could cause injury, occupational illness, or damage to property should it recur. These events may or may not have reportable mishap costs.

Air Force System Safety evaluations are based on hazard severity categories that are evaluated in terms of the probability of occurrence of the event. Hazard severity categories are defined in **Table 3.4-1** and correlated with the mishap categories described above.

Table 3.4-1. Hazard Severity Categories

Category	Severity	Result	Mishap Class
1	Catastrophic	May cause death or system loss.	A
2	Critical	May cause severe injury, severe occupational illness, or major system damage.	B
3	Marginal	May cause minor injury, minor occupational illness, or minor system damage.	C/D
4	Negligible	May result in less than minor injury, occupational illness, or system damage.	HAP

HAP = High Accident Potential
Source: MIL-STD-882B

Next, each potential hazard is categorized by a hazard level. Hazard levels are based on probability and frequency of occurrence. These levels and their associated probability of occurrence are defined in **Table 3.4-2**.

Each potential mishap event is then evaluated and described by its appropriate severity and probability of occurrence category. The result of this categorization is a Hazard Risk Index (HRI) which identifies each event with a unique alpha-numeric designation. The basis for the HRI matrix is shown in **Table 3.4-3**.

Table 3.4-2. Hazard Level Classification

Hazard Level	Frequency of Occurrence	Definition	Assumed Probability of Occurrence (per year)
A	Frequent	Likely to occur frequently.	>1
B	Probable	Will occur several times in life of an item.	1
C	Occasional	Likely to occur sometime in the life of an item.	10^{-2}
D	Remote	Unlikely, but possible to occur in the life of an item.	10^{-4}
E	Improbable	So unlikely to occur that is can be assumed occurrence may not be experience.	10^{-6}

The HRI matrix allows hazards to be identified and ranked by their alpha-numeric value, for comparison of hazards and hazardous conditions. Hazardous conditions identified as being of a serious nature require action to either correct the hazard or reduce its HRI value to an acceptable level. HRI values of 3D or greater normally result in corrective action, with immediate corrective action required by ratings of 3A or higher. HRI values, prioritized by severity, and the actions they trigger are shown in **Table 3.4-4**, Hazard Risk Response.

Table 3.4-3. Hazard Risk Index Matrix

Frequency of Occurrence	Hazard Categories			
	(1) Catastrophic	(2) Critical	(3) Marginal	(4) Negligible
(A) Frequent	1A	2A	3A	4A
(B) Probable	1B	2B	3B	4B
(C) Occasional	1C	2C	3C	4C
(D) Remote	1D	2D	3D	4D
(E) Improbable	1E	2E	3E	4E

Source: MIL-STD-882B

Table 3.4-4. Hazard Risk Response

Hazard Risk Index	Action Required
1A 1B 1C 2A 2B 3A	Unacceptable - Immediate corrective action required
1D 2C 2D 3B 3C 3D	Undesirable - Reduced priority, corrective action required
1E 2E 3E 4A 4B	Acceptable - Low priority for corrective action, may not warrant action
4C 4D 4E	Acceptable - Corrective action not required

3.4.2.2 Historical Mishap Data

Historic mishaps involving chaff systems have been both non-aircraft-related and aircraft-related. From January 1983 through February 1993, there were no Class A, B, or C mishaps during ground operations (non-aircraft-related). There were five class D and 42 High Accident Potential occurrences. Based on 10 years of data, these equate to 0.5 and 4.2 occurrences per year, respectively. During flight operations in the same period, there were no Class A, B, C, or D mishaps. There were 53 High Accident Potential occurrences, an average of 5.3 per year. The frequency of these mishaps by year is shown in **Table 3.4-5**. None of the recorded mishaps caused permanent injury to ground crews or significant damage to aircraft.

Because of its effects on radar, inadvertent release of chaff is a safety concern. This event can occur due to release system electro-mechanical malfunctions, personnel error, or mechanical system

degradation through wear and tear. During a period from 1985 to 1986, a mechanical problem with the AN/ALE-40 chaff/flare dispensing system resulted in a high incidence of inadvertent releases. The system was modified in 1987, correcting the problem.

Table 3.4-5. Chaff Mishaps

Mishap Class	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Non-Aircraft Related (Ground Operations)											
D	0	0	0	0	0	0	0	4	1	0	0
High Accident Potential	3	5	15	10	5	4	0	0	0	0	0
Aircraft Related (Flight Operations)											
High Accident Potential	4	4	15	14	6	3	1	5	1	0	0

3.4.2.3 Radio Frequency Interference

A combination of factors, including FAA chaff use restrictions and limitations, a depletion in the inventory of acceptable types of chaff, and outdated or inconsistent procedural guidance, has made the use of chaff an issue for the Air Force. In recent years, the FAA has placed more stringent restrictions on DOD use of any type of chaff that operates within the bands used by air traffic control radar and navigational systems. In taking the more conservative approach to air traffic control and flight safety, FAA has limited or placed restrictions on the locations, altitudes, and/or time periods within which specific types of chaff can be employed. Incidents have been reported over recent years at Phoenix and some other locations where chaff may have caused interference with FAA radar systems. However, discussions with ACC flying units and staff members and Air Force Representatives at the FAA Regional Headquarters indicate that very few reported occurrences of such interference were attributable to known chaff operations. The Air Force is concerned that possibly unreasonable restrictions are being placed on chaff operations without substantial reason.

The Spectrum Management Office (ASM-500) at FAA Headquarters in Washington, D.C., is the approving agency for DOD chaff use requests. These requests are forwarded through appropriate channels to this office where they are reviewed relative to the types of chaff to be used, requested area and altitudes, dates and times of employment, and other operational data that accompany the military request. After considering the requested action's potential to interfere with any of the air traffic control equipment frequency bands, each request is either approved, denied, or approved with certain restrictions, such as time or altitude limitations. Once the request has been acted upon

and approved to any extent, a copy of the request is provided to Air Traffic Management (ATM-400) for coordination and appropriate action by the affected air traffic control facility. In some cases, Notice to Airmen (NOTAM) may be required to advise the flying public that certain air traffic control equipment or services may be affected during a specified period of time by chaff operations.

While FAA has taken a more restrictive approach to chaff use in recent years, FAA officials feel they try to be reasonably considerate of military training needs. The Spectrum Management Office has been working with requestors to accommodate chaff use. FAA has indicated that they have been able to approve, with added restrictions as necessary, many of the DOD's chaff clearance requests. These restrictions, however, have not always been suitable to the user and have often imposed conditions (altitudes, locations, or times) or constraints (depletion of chaff supplies) that are not compatible with some military training requirements.

As FAA restrictions are imposed on the types of chaff that can potentially interfere with FAA equipment (e.g., RR-170), available inventories of acceptable types are being depleted. There is a newer type of chaff (RR-188) that does not interfere with the affected frequency bands; which is readily available in the supply system.

The ALQ-153 is the tail warning system (TWS) for the B-52 H. This system identifies hostile threats behind the aircraft and automatically dispenses chaff and flares. The Western Area Power Administration (WAPA) has effectively blocked the use of the ALQ-153 within much of the north and central United States, including the Powder River MOAs. B-52 aircrews receive little training in this system. Their training is currently limited primarily to simulators that represent a "perfect" operating system. ALQ-153 operations are restricted to specific geographical areas within the country to prevent frequency interference between the ALQ-153 hardware and WAPA's microwave relay stations. Most of these cleared areas are of no practical training value to B-52 crews because they are not within designated training airspace, such as the Powder River MOAs. Nellis Air Force Range and the Utah Test and Training Range are designated as cleared areas, but they are used primarily for exercises focused on providing combat experience to aircrews, rather than providing airspace to train crews in equipment operation and tactics (Source: 25FTTS/WFF, 2/23/93).

3.4.2.4 Risk of Injury From Chaff Debris

The probability of debris from the chaff system hitting a person on the ground is difficult to quantify. Such an event would be dependent on many variables (e.g., location of use, population density beneath airspace, frequency of use, etc.). Ejected debris consists of the chaff itself, possibly a cardboard box which contains the chaff, flat plastic package stiffeners, a small plastic piston, and a small plastic end cap. Under normal circumstances, all of those elements weigh so little, or create so much drag in comparison to their weight, no injury would be anticipated even if a person were impacted.

No incidences of injuries from falling chaff debris have ever been recorded. When deployed above 500 feet AGL, even though its initial velocity may be greater, all debris would be expected to

decelerate to terminal velocity before hitting the ground because of the many aerodynamic forces acting on it. Terminal velocity (V_T) is calculated by the following equation:

$$V_T = \left[\frac{2}{\rho}\left(\frac{W}{AC_D}\right)\right]^{1/2}$$

Where:

V_T = Terminal velocity
ρ = Air density (2.378×10^{-3} lbs-sec ^{2}/ft^4)
W = Weight
A = Surface area facing the airstream
C_D = Drag coefficient (flat plate drag coefficient - 1.28)

The momentum at terminal velocity is calculated by:

$$\text{Momentum} = m \times V_T$$

Where:
m = Mass
V_T = Terminal velocity

The weight, terminal velocity, and momentum of a complete chaff container and various chaff debris are presented in **Table 3.4-6**. Laboratory experimentation in accident pathology indicates that there is a 90 percent probability that brain concussions would result from an impulse of 0.70 pound-seconds, and less than a 1 percent probability from impulses less than 0.10 pound-seconds (Ommaya and Corrao 1968).

Table 3.4-6. Weight, Terminal Velocity, and Momentum of Chaff System Debris

Debris	Weight (pounds)	Terminal Velocity (feet/second)	Momentum (pound-second)
Unopened Container	0.427	134	1.781
Plastic End-Cap	0.009	30	0.009
Plastic Piston	0.028	52	0.045

As shown, the only component of concern would be a full box of non-pyrotechnic chaff that failed to open during ejection. This would be a very rare occurrence, since the boxes are sliced open as they are ejected. For comparative purposes, the effect of being struck by such an object is equivalent to being struck by an eight-pound sledge hammer dropped from a height of approximately 10 inches.

The probability of an unopened box of non-pyrotechnic chaff hitting a person on the ground is difficult to calculate because it involves a number of variables, including the amount of non-pyrotechnic chaff dispensed, the percentage that do not dispense properly, and the population density in the area underlying airspace where chaff is employed. Based on the testing requirements outlined in Section 3.2, it is surmised that the designed reliability rate is 98.5 percent. It is estimated that approximately 200,000 boxes of non-pyrotechnic chaff are used annually by ACC units; about half are dispensed over water. At a potential failure rate of 1.5 percent, this would result in an estimated 1,500 boxes of chaff per year released over land that may not open properly.

The area covered by aircraft dispensing non-pyrotechnic chaff is immense and not precisely calculable. As a conservative approach, the area of potential impact of any given unopened box can be calculated. Assuming, for example, that a box of chaff is ejected unopened from an aircraft traveling at 600 miles per hour and 500 feet AGL, it is estimated that the box will travel approximately 1,500 to 3,400 feet along the track of the aircraft before it impacts the ground, considering the aerodynamic drag forces acting on the box. Assuming further that the box may impact anywhere along this distance and up to 25 feet on either side of the aircraft, the potential impact zone would encompass an area of approximately 95,000 square feet. To cause injury, it is assumed that the box must impact within a 1.5 square foot area surrounding a person. In this case, the probability of impact within any 1.5 square foot area would be 1.58×10^{-5}, or one chance in 63,000. Even assuming 1,500 unopened boxes are ejected per year, the probability of injury is still one in 42 years. This does not consider the probability that a person will be in the area of impact, which would in reality be less than 100 percent, further reducing the chance of injury.

As another approach, given the random nature of chaff employment, the probability of hitting a person can be presumed to be approximated by the density of persons in areas underlying airspace where chaff is used. Given Air Force regulations prohibiting overflight of population concentrations and the propensity for special use airspace to be located over rural and remote areas, it is reasonable to assume that the density of the exposed population vulnerable to injury is less than 100 per square mile. At this density, again assuming a 1.5 square foot zone of potential injury, the probability of impact is 5.4×10^{-6}, or one in 185,000. Even if there are as many as 1,500 unopened chaff boxes dispensed per year, the probability of injury is less than one every 120 years.

Based on the hazard probability index, the risk of injury from an unopened box of chaff is at most Remote and more likely Improbable. Historically, there has been no report of such an injury in the data collected for the last ten years.

3.4.3 Findings

Postulated safety events were assigned probabilities of occurrence based on historic data records or through reasoned assumptions. For events that have been documented over the 1983 to 1993 period, the number of recorded events was used to estimate probability of occurrence. Although there is no official documentation of chaff interfering with other airborne radars or satellite tracking, these events were conservatively assumed to occur less than once per year. The documentation of interference with FAA radar is not sufficient to derive a statistical probability; however, current procedures requiring units to obtain frequency clearance from FAA are expected

to render it a relatively rare occurrence. Other events that have no record of occurring were conservatively assigned a frequency of once over the 10-year time period for which mishap data were collected. Frequencies of occurrence were computed assuming an estimated average use of 1 million bundles of chaff per year by ACC units. From these data, HRI ratings were assigned to each potential effect, and the need for corrective action was determined.

Table 3.4-7 identifies events, their potential results (effects), probability of occurrence, and the estimated annual number of occurrences. In some cases, more than one effect may be associated with a single event.

Table 3.4-7. Probability of Safety Events

Event	Effect	Probability	Frequency (per year)
Chaff inadvertently release/cloud drifts outside designated airspace	1. Clutters FAA radars	1×10^{-6}	<1
	2. Clutters other airborne radars	1×10^{-6}	<1
	3. Interferes with satellite tracking	1×10^{-6}	<1
Chaff causes shorting/arcing of high voltage power line	Disruption of electrical distribution	2×10^{-7}	0.2
Aircraft engine ingests chaff	Loss of engine efficiency	1×10^{-7}	0.1
Chaff deployed near another aircraft	Pilot distraction/initiation of unnecessary maneuvers	1×10^{-6}	1
Chaff system malfunction (non-aircraft-related)	1. Minor injury/minor damage (Class D Mishap)	5×10^{-7}	0.5
	2. Minimal or no injury or system damage (High Accident Potential)	4.2×10^{-6}	4.2
Chaff system malfunction (aircraft-related)	Minimal or no injury of system damage (High Accident Potential)	5.3×10^{-6}	5.3
Falling debris impacts person on ground	May cause severe injury or death	1×10^{-8}	0.01

Based on the estimated severity of the possible result, and the probability of its occurrence, each postulated effect was assigned an HRI index and response rating. The events, the assigned HRI index, the rating, and the indicated action required are shown in **Table 3.4-8**, based on the hazard level thresholds in **Table 3.4-2**.

As indicated, all postulated effects resulting from safety risks involving chaff and chaff use fall into the acceptable risk level category. Either the potential effects are relatively minor, or the probability of their occurrence is extremely remote so as to render the overall risk inconsequential.

Table 3.4-8. Hazard Risk Index, Rating, and Action Required

Event	HRI	Rating	Action Required
Clutter FAA radar	4E	Acceptable	None Required
Clutter airborne radar	3E	Acceptable	Low Priority
Interfere with satellite tracking	4E	Acceptable	None Required
Arcing of power line	3E	Acceptable	Low Priority
Aircraft ingests chaff	4E	Acceptable	None Required
Pilot distracted	4E	Acceptable	None Required
Class D mishap from system malfunction (non-aircraft)	3E	Acceptable	Low Priority
High Accident Potential from system malfunction (non-aircraft)	4D	Acceptable	None Required
High Accident Potential from system malfunction (aircraft)	4D	Acceptable	None Required
Injury from falling debris	1E/2E	Acceptable	Low Priority

3.4.4 Conclusions

Based on an assessment of available data and analysis of possible events, there is little safety risk to aircrews, aircraft, or the public anticipated from the use of chaff.

Combat chaff in current use does have the potential to interfere with FAA radars. The new RR-188 chaff, which includes no dipoles cut to the RF bands used by FAA radars, is available for use in training by most aircraft. Aircraft that cannot use this model must obtain a frequency clearance prior to use.

Although death or serious injury could result if a person on the ground were hit by an unopened box of chaff, the low probability of such an event occurring indicates that the level of risk is acceptable, and no specific actions appear to be required, other than to avoid dispensing non-pyrotechnic chaff over areas with high population densities.

3.5 AIR QUALITY

3.5.1 Issues Addressed

The Air Force currently employs two types of chaff dispensers: pyrotechnic dispensers, which use hot gasses generated from exploding charges to expel the chaff, and non-pyrotechnic dispensers which use high pressure gas to expel the chaff. Consequently, for the pyrotechnic chaff, air quality and health impacts could occur from both the chaff material and the explosive charges, while for

the non-pyrotechnic chaff, impacts could arise only from the chaff material. Air quality issues pertaining to chaff use that were addressed during this study include the following:

- The potential for noncompliance with the National Ambient Air Quality Standards (NAAQS) due to the release of significant quantities of particulates.
- The potential for release of hazardous air pollutant emissions regulated under Title III of the Clean Air Act.
- Potential for visibility impairment in Prevention of Significant Deterioration (PSD) Class I areas.

To assess compliance with the NAAQS, it is necessary to evaluate whether criteria pollutants are generated or released from chaff usage. Specifically, there is the question of whether the chaff itself breaks down into respirable particulates (PM_{10}, particulate matter with a mean aerodynamic diameter of 10 micrometers or less).

Lead is no longer used in the manufacture of chaff. RR-141 chaff has been phased out, but B-52s still use foil chaff (RR-112 and RR-149 models). It is highly unlikely that any remaining foil chaff containing lead exists since it has not been used in the manufacture of foil chaff since prior to 1983 (Creel, personal communication, 1993).

Recently, increased attention has been given to health risks from exposure to toxic air pollutants. Title III of the Clean Air Act sets a mandate requiring the U.S. EPA to regulate the emissions of 188 listed hazardous air pollutants. Thus, it is necessary to assess whether any components of chaff and/or gases released from explosive charges are considered to be hazardous air pollutants and thus may cause adverse health effects.

The detonation charge used for pyrotechnic chaff is provided by an impulse cartridge. The BBU-35/B impulse cartridges used with RR-170 type chaff used to contain calcium chromate ($CaCrO_4$), which could result in the release of chromium compounds. Chromium is one of the 188 compounds listed by the Clean Air Act as a hazardous air pollutant, and is recognized as a carcinogen; however, an applicable emission standard has not been developed. At this time, the American Conference of Governmental Industrial Hygienists (ACGIH) recommends a threshold limit value for chromium (VI) of 0.5 milligrams per cubic meter (mg/m^3). In addition to the health hazards associated with chromium compounds, special consideration should be given to chromium emissions because of their pending regulatory control. However, the calcium chromate was replaced with potassium perchlorate in the BBU-35/B impulse cartridge. Therefore, the potential for release of hazardous air pollutants is no longer an issue in chaff use. Because some flares still use initiators with calcium chromate, this issue is examined further in Section 4.6.

According to one report, dispersed chaff can produce a spherical cloud approximately 300 to 600 feet in diameter at a density of one dipole per three to seven cubic feet (SEA 1989). Depending on the prevailing wind currents, aircraft speed, and altitude of release, chaff clouds may disperse rapidly or migrate in a single direction. This raises the issue of the potential for short-term visibility impairment in PSD Class I areas.

Some chaff training areas pass over or near PSD Class I areas. **Table 3.5-1** lists Class I areas that could be affected by chaff and flare use. The Ellsworth Area in particular encompasses or is adjacent to four PSD Class I areas: Theodore Roosevelt National Park, Badlands Wilderness, Wind Cave National Park, and U.L. Bend Wilderness.

Some chaff dispenser debris may survive and fall to the ground; however, this debris remains intact and is essentially non-biodegradable. On the ground, this debris will have no impact on air quality.

3.5.2 Studies Conducted

3.5.2.1 Regulatory Considerations

The *Clean Air Act* (42 United States code [USC] 7401 et. seq.; P.L. 90-148; P.L. 101-549) requires the U.S. EPA to set National Ambient Air Quality Standards, descriptions of clean air that must be maintained nationwide. The NAAQS have been set to protect public health and welfare, with a margin of safety. The NAAQS currently include standards for six "criteria" pollutants: ozone (O_3), nitrogen dioxide (NO_2), carbon monoxide (CO), PM_{10}, sulfur dioxide (SO_2), and lead (Pb). These include short-term standards (1 hour, 8 hour, or 24 hour periods) for pollutants with acute health effects, and long-term standards (annual average) for pollutants with chronic health effects.

In addition to the federal standards, various states have adopted ambient air quality standards that are either as stringent or more stringent than the NAAQS. Under the Clean Air Act, each state develops a State Implementation Plan (SIP) setting out the specific measures to be taken in each area of the state that is not in compliance with the NAAQS.

U.S. EPA also establishes standards for new sources of criteria pollutants. Air pollution emitters are divided into stationary and mobile sources (automobiles and some airplanes). While mobile sources are very significant contributors to urban air pollution, states cannot regulate exhaust or other emissions from tailpipes. They are established by U.S. EPA. (California, however, has a statutory waiver allowing it to set different standards than U.S. EPA's.) Military aircraft and engines are not subject to Clean Air Act regulation by either the states or U.S. EPA. 33 USC 7571 provides for establishment of standards for aircraft engines. However, Section 7572 provides for enforcement only through the civil aircraft certification process, which does not apply to military aircraft. As a result, U.S. EPA has never issued any standards specific to military aircraft.

In both nonattainment areas (areas that do not meet the NAAQS) and PSD areas, stationary emitters of more than a specified amount of pollutants (ranging from 25 to 250 tons per year) must have permits, normally from the state but in some cases from U.S. EPA. The permits are intended to be structured so that all of the allowed emissions will result in air cleaner than the NAAQS. Although mobile sources, such as aircraft, are generally exempt from air pollution permitting and emission control requirements, the emissions from the operation of these sources are included in the state's emission inventory.

Table 3.5-1. PSD Class I Areas in the Vicinity of Airspace Used for Chaff and Flares

Airspace	PSD Class I Area	State	Proximity	Chaff	Flares	Chaff and Flares
Superior/China Lake Ranges	Dome Land Wilderness	California	In Vicinity			X
Lake Superior Range	Isle Royal National Park	Michigan	Touches/ In Vicinity		X	
WSMR	Bosque del Apache National Wildlife Reserve	New Mexico	In Vicinity			X
Moody MOA	Okefenokee Wilderness	Georgia	Passes Over			X
Salem MOA	Mingo Wilderness	Missouri	In Vicinity	X		
Big Ben/Hays MOA and Ellsworth Chaff Area	U.L. Bend Wilderness	Montana	Passes Over/ Touches	X		
Ellsworth Chaff Area	Theodore Roosevelt National Park (North Unit, South Unit, and Elkhorn Ranch Site)	North Dakota	Passes Over	X		
Ellsworth Chaff Area	Badlands Wilderness	South Dakota	Passes Over	X		
Ellsworth Chaff Area	Wind Cave National Park	South Dakota	Passes Over	X		
W-107	Brigantine Wilderness	New Jersey	In Vicinity		X	
W-161 W-177	Cape Romain National Wildlife Refuge	South Carolina	In Vicinity			X
W-285	Ventana Wilderness	California	In Vicinity		X	
IR-302	Sawtooth Wilderness	Idaho	Passes Over	X		
IR-302	Craters of the Moon Wilderness	Idaho	Passes Over	X		
IR-302	Jarbidge Wilderness	Nevada	Passes Over	X		
IR-320	Petrified Forest National Park	Arizona	Passes Over	X		
IR-800	Roosevelt Campobello International Park	New Brunswick, Canada	In Vicinity			X

W = Warning Area
IR = Instrument Route

A stationary source under the Clean Air Act is defined as "any source of an air pollutant except those emissions resulting directly from an internal combustion engine for transportation purposes or from a nonroad engine or nonroad vehicle...." Chaff and flares are not internal combustion engines. Aircraft emission standards cover only aircraft engine exhaust, not all substances that might be emitted by or from an airplane. Therefore, chaff and flare emissions should be viewed as stationary source emissions. However, the quantities of pollutants emitted by individual chaff bundles, flares, and their dispensers do not come close to the thresholds for requiring a permit (25 to 250 tons annually). Therefore, no air permit is required.

The 1970 Amendments to the Clean Air Act authorized U.S. EPA to set standards for air toxics (also known as hazardous air pollutants). The Clean Air Act Amendments of 1990 constitute a renewed commitment by the federal government to establish a workable framework to achieve attainment and maintenance of health protective national ambient air quality standards. Title III (42 USC amended Section 112) specifically listed 188 air toxics, identified on the basis of their contribution to health risk, and required U.S. EPA to set standards for them. All major stationary sources will be required to obtain an operating permit under Title V of the Act. The U.S. EPA will set Maximum Achievable Control Technology (MACT) standards for major stationary source categories that emit toxics. The MACT standards are for stationary sources only, not mobile sources.

The Clean Air Act states that it is a national goal to prevent any further impairment of visibility within federally mandated PSD Class I areas from manmade sources of air pollution. Visibility impairment is defined as (1) a reduction in regional visual range and (2) atmospheric discoloration or plume blight. Criteria to determine significant impacts on visibility within Class I areas usually pertain to stationary emission sources. Mobile sources are generally not subject to permit requirements.

Impacts from chaff and flare usage would be considered significant from an air pollution perspective if they result in:

- An adverse change in air quality leading to nonconformance with Clean Air Act.
- An exceedance of any federal, interstate, state, or local ambient air quality standards.
- Significant visibility impairment in federal PSD Class I areas.

3.5.2.2 Literature Review

The primary literature addressing dispersion of chaff and air quality effects is comprised of environmental studies conducted by Science and Engineering Associates, Inc. (SEA) for Strategic Air Command and the National Guard Bureau (SEA 1989 and 1990). These efforts concentrated on evaluating air dispersion and settling effects of chaff. Review of these previous studies revealed some inconsistencies with current information in a number of areas, including dipole diameter size, the continued use and manufacture of aluminum foil type chaff, composition of the foil chaff, and the typical lengths of chaff dipoles.

In addition to reviewing past studies on chaff, several databases were accessed through the DIALOG Information Retrieval Service. To narrow the scope of the literature search, chaff was paired with other key words such as air pollution, combustion, countermeasure, components, materials, and emission. The key words were used to search nine DIALOG databases (Aerospace, Chemical Exposure, Current Technology, Metadex, Inspec2, Pollution Abstracts, NTIS, and PTS). The DIALOG literature search did not uncover any new data, research, or other documentation addressing emissions or air pollution associated with chaff usage or the effect of chaff release on air quality.

Section 3.2 lists aluminum coated glass fiber dipole diameters ranging from 0.001 inches (25 microns [*um*]) for typical chaff to 0.0007 inches (18 *um*) for superfine chaff. The chaff dipole diameter is significant in the air quality impact analysis due to the possibility of dust formation resulting in respirable particulates, a regulated criteria pollutant under the Clean Air Act. Chaff particulate mass is also dependent on chaff diameters when predicting dispersion of chaff to calculate ground level concentrations. Chaff lengths range from 0.30 inches to 2.06 inches.

The SEA documents reference a technique developed by the Applied Technology Division of Tracor, Inc., to evaluate the dispersion of chaff based upon chaff diameter and atmospheric conditions (Aeronautical Systems Division [ASD] 1990). The use of Tracor dispersion modeling charts has limited application since they relate to a single event. Given the random nature of training flights in special use airspace, it is probably not feasible to predict the long-term accumulation of chaff at ground level using dispersion modeling. The Tracor charts correlate dispersion to chaff diameter, coating thickness, release altitude, and wind speed. However, they do not account for the aircraft airspeed, which is also a factor that will affect chaff dispersion. The Tracor article also bases all of the curves on 1 mil and 0.5 mil diameter dipoles (0.001 and 0.0005 inch diameter, respectively). No consideration is given to the variation in chaff length. The report indicates that the descent rate of chaff is primarily a function of coating thickness. However, chaff cloud formation and dispersion will be based on chaff mass, which is a function of coated chaff diameter and length, rather than just the coating thickness and chaff diameter. From a dispersion modeling standpoint, the curves presented in the Tracor article have very limited application.

It is believed that both the glass fiber type and the foil type chaff completely settle to the ground. However, differences in reported chaff settling rates were identified during data review. The SEA 1990 document mentions typical chaff fall rate of 23 to 50 feet per minute. Another source indicated that chaff fall rates vary from 50 to 100 feet per minute (Taylor 1983). Variances in chaff settling times were also identified. For example, the 1989 SEA document reports that chaff remains aloft for 1 to 1.5 hours, which disagrees with a 10 to 12 hour estimate from the Armament Development and Test Center (Armament Development and Test Center 1973).

As part of this study, ground-level dispersion was calculated for two locations, based on actual climatic conditions: Nellis Air Force Range complex, Nevada, and Townsend Air to Ground Gunnery Range, Georgia (USAF 1994c). Depending on altitude of release, the chaff was estimated to disperse a minimum of 0.10 to 0.24 mile (at 100 feet AGL) to a maximum of up to 140 miles (at 25,000 feet AGL).

Existing literature from previous studies did not address the possible formation of inhalable particulates from chaff and issues related to compliance with the Clean Air Act.

3.5.2.3 Particulate Test

The nominal size of typical chaff dipoles (25 *um* in diameter and at least 10,000 *um* in length) is significantly larger than the 10 *um* definition of respirable particles. To determine whether small particles can be formed due to dipole breakage during chaff releases, a field sampling program was conducted at Hill AFB near Ogden, Utah with the following objectives:

- To make a preliminary determination whether the release of chaff generates PM_{10} (particles with equivalent aerodynamic diameters of 10 *um* or less).
- If PM_{10} contributions are observed, to develop a qualitative estimate of PM_{10} mass in relation to total mass produced by a chaff release. This information could potentially be used in determining whether chaff use may lead to exceedance of federal ambient particulate standards.
- Assess where the release of chaff generated suspended particulates which have a nominal particle size selection (cut-point) of 30 *um*. Some states maintain air quality standards for TSP.

The sampling procedure used standard high volume (Hi-Vol) air samplers with size-selective PM_{10} inlets and glass fiber filters to collect respirable particles after chaff releases in a controlled environment. Hi-Vol samples were also collected using standard TSP inlets. These measurements could therefore provide a two-step size distribution. The following is a summarization of the findings. A detailed description of the methodology and results is presented in *Technical Reports on Chaff and Flares, Technical Report No. 2, Chaff Particulate Test* (USAF 1994a).

Chaff testing was conducted in an enclosed sampling area (the test facility) which was constructed inside a test bay at Hill AFB. The test facility was 24 feet by 28 feet by 8 feet and was covered in heavy black plastic sheeting secured to a wooden frame. A door permitted entry into the test facility. Because the plastic sheeting fully enclosed the test facility, air exchange between the test facility and the surrounding test bay was minimal. The only sources of air exchange were small slits cut in the plastic sheeting in order to provide access for a video camera, power cords to the Hi-Vol samplers, Hi-Vol exhaust tubing, and the test facility door, which was only opened between tests. A chaff canister dispensing system was set up 2 feet from one end of the test facility, with the Hi-Vols deployed near the other end.

All personnel were evacuated from the test facility and the test bay before each chaff test. Tests were observed remotely on a monitor connected to a video camera located inside the test bay. Each test was conducted by electrically firing a standard BBU-35/B impulse cartridge, which released the chaff contained in one chaff cartridge (RR-170A/AL chaff cartridges were used in these tests).

The operation of the Hi-Vols followed standard operating procedures for this equipment, including Hi-Vol maintenance and calibration, and filter handling and weighing. The Hi-Vols were started

remotely, without entering the test facility, 1 to 2 minutes after each chaff release. The purpose of the delay was to allow the large chaff dipoles to settle out of the air.

Observation of each individual chaff release on the monitor indicated that most of the chaff was dispersed in relatively large, loose clumps, which settled almost immediately. A small fraction of individual particles appeared to stay suspended for a few seconds, but virtually all of the material visible on the monitor appeared to have settled out within one minute.

Multiple sampling runs were conducted for each of the scenarios described below, in order to collect sufficient data to conduct statistical tests. The scenarios were evaluated in the following order:

- Background sampling, TSP (two tests using two Hi-Vol samplers with TSP inlets)
- Background sampling, PM_{10} (two tests using two Hi-Vol samplers with PM_{10} inlets)
- Chaff Testing, PM_{10} (four tests using two Hi-Vol samplers with PM_{10} inlets)
- Chaff Testing, TSP (four tests using two Hi-Vol samplers with TSP inlets)

To ensure that representative background levels were measured, no chaff testing was conducted in the test facility prior to conducting the background sampling. Each sampling run was conducted for a two-hour period. This time period was based on preliminary screening tests which indicated that a sufficient sample would be collected within that time interval on the background filters. A system was installed to eliminate the potential for contamination of the Hi-Vol filters during tests that may be caused by recirculation of the Hi-Vol motor exhaust within the test facility (although the motor is electric, small carbon particles can be liberated from the motor's carbon brushes). Flexible tubing was attached to the Hi-Vol exhaust port and used to duct the flow outside of the test facility. Although this system worked satisfactorily, it was not installed until after the first background samples were collected (the four TSP background samples).

The TSP and PM_{10} concentrations were based on a gravimetric analysis, by weighing the filters before and after each sampling run using an analytical balance capable of measuring to 0.1 milligram. The filters were weighed after being conditioned in the laboratory environment for 48 hours, so that there would be no effects of humidity or temperature on the filter weight. Two additional filters were included as "trip blanks" for quality assurance purposes. The results of three of the samples were flagged as invalid due to equipment problems.

3.5.3 Findings

3.5.3.1 Particulate Test Sample Results

The total mass gain on the PM_{10} filters during the background sampling averaged 7.6 mg. Based on the air flow through the Hi-Vols during the two-hour sampling period, the average background concentration was 54.5 micrograms per cubic meter (ug/m^3), with a standard deviation of 5.7 ug/m^3.

Total mass gain on the PM_{10} filters during the chaff tests averaged 44.2 mg. The average PM_{10} concentration during the two-hour tests was 331.3 ug/m^3, with a standard deviation of 47.8 ug/m^3. A statistical t-test determined that the average of the PM_{10} concentrations measured in the chaff tests were significantly different from the average of the PM_{10} concentrations measured during the background tests at the 99 percent confidence level.

Trip blanks were also included as part of this sampling program, to determine if there were any systematic errors introduced during shipping and handling of the filters in the field. Two filters were taken out to the field and returned to the laboratory without being exposed in the Hi-Vols. The results showed that there were no systematic errors in the determination of particulate mass collected in this study.

The total mass gain on the TSP filters during the background sampling averaged 12.4 mg. Based on the air flow through the Hi-Vols during the two-hour sample periods, the background concentration was 88.1 ug/m^3, with a standard deviation of 4.5 ug/m^3.

Total mass collected during the chaff tests averaged 40.0 mg. The average TSP concentration during the two-hour tests was 285.7 ug/m^3, with a standard deviation of 20.5 ug/m^3. A statistical t-test determined that the average of the TSP concentrations measured in the chaff tests were significantly different from the average of the TSP concentrations measured during the background tests at the 99 percent confidence level. The results for the trip blanks showed that there were no systematic errors in the determination of particulate mass collected in this study.

The average background measurement of PM_{10} (54.5 ug/m^3) measured in the test facility was 62 percent of the average background measurement of TSP (88.1 ug/m^3). As expected, these levels reflect the larger size fraction of particles collected by the TSP monitors (and therefore greater particulate mass). PM_{10} particulate matter, with a size range of 0 to 10 um, is actually a subset of TSP particulate matter, which has a nominal size range of 0 to 30 um.

3.5.3.2 Analysis of Results

The large increase in particulate concentrations measured during the chaff tests, compared to the background tests (significant at the 99 percentile level for both PM_{10} and TSP) was unexpected. It was also unexpected that the average PM_{10} concentration measured in the test facility during the chaff tests was 16 percent higher than the average TSP concentration. The wider size range of particles defined as TSP particulate matter generally results in higher measured atmospheric concentrations. This difference was significant at the 95 percentile level. A detailed visual analysis of the filters was conducted in an attempt to determine the source of the increase in particulates during the chaff tests.

The increase in particulates collected during the chaff testing in comparison to the background tests can only result from three possible sources of particulates:

- Air containing additional quantities of particulates, which was drawn into the test facility from the test bay through openings in the plastic sheeting or through leaky seams.

- The chaff dipoles, because of potential dipole breakage.
- The BBU-35/B impulse cartridge, because of combustion products resulting from the activation of its explosive charge.

Each of these is discussed below.

There is no question that air from the surrounding test bay was drawn into the test facility during each sampling run. The filtered air exhausted at the bottom of each Hi-Vol was carried outside the test facility by flexible tubing and released into the test bay. As a result, a vacuum would soon exist during a test if no additional air were drawn back into the test facility. Each Hi-Vol theoretically sampled 89 percent of the air in the test facility during each two-hour test. Thus, to prevent a complete vacuum from forming inside the test facility, a return flow needed to occur through the slits and leaks in the walls formed by the plastic sheeting, potentially bringing in additional particles. In fact, the walls were observed to be bowed in during the tests, indicating that there was a slight vacuum inside the test facility. However, these conditions existed during both the background tests and the chaff tests, so that any effect on particulate mass would be expected to be the same during both the background and chaff tests.

One of the TSP filters and two of the PM_{10} filters exposed during the chaff tests were viewed under a binocular dissecting microscope (variable 7X to 40X power). Chaff material recovered from one of the tests was also viewed under the microscope, to ensure that it could be identified from the glass fiber filter substrate or other material collected on the filters. The chaff dipoles were readily distinguishable under the microscope because they appeared to be perfectly straight and uniform rods, had a metallic luster, and (under higher magnification) had a characteristic rough surface appearance.

Approximately 50 percent of each of these three filters was viewed under various magnification levels to obtain an estimate of the dipoles or small fragments of dipoles that had been collected on the filters. In general, there were very few dipoles collected on the filters: two dipoles were identified on the TSP filter, three dipoles were identified on one of the PM_{10} filters, and no dipoles were identified on the second PM_{10} filter. Although the actual chaff dipoles should be too large to be drawn into the Hi-Vol samplers intact, both the TSP (0 to 30 *u*m) and PM_{10} (0 to 10 *u*m) inlet cutpoints are known to be nominal design values, and it is not unusual for a few larger particles to reach the sampling filter. No broken pieces or fragments of dipoles were found on the filter.

These results suggest that one-half of each filter collected an average of two chaff dipoles, so it was estimated that approximately four dipoles would be found on the average exposed filter. With an estimated average weight of approximately 0.1 mg/dipole, four dipoles on a filter would cause a 0.4 mg increase in weight. The average weight gain of the PM_{10} filters during the chaff tests and the background tests were 38.0 and 12.4 mg, respectively. Consequently, of the 25.6 mg increase in an average filter over background, only approximately 0.4 mg or 1.6 percent could be attributed to the weight of the chaff dipoles collected on the filter.

The BBU-35/B impulse cartridge, used to eject the chaff, contains approximately 485 mg of explosive charge material. The average PM_{10} filter exposed during the chaff testing gained 25.4 mg

more than the average PM_{10} filter exposed during the background tests. Consequently, if only 5 percent of the explosive mass in the impulse cartridge was converted into PM_{10} particles and collected on the Hi-Vol filters, this would account for the increase in particulates measured on the PM_{10} filters.

Discussions with a staff member involved in the Air Force chaff and flare testing program (Amey, personal communication, 1994) indicated that charge ignition produces a considerable amount of combustion products, including carbonized particles. Some of the carbonized particles are expelled out of the cartridge into the air, while some remain behind (and are readily visible) in the spent chaff cartridge. The carbonized particles will be produced in a wide range of particle sizes, some of which will be below 10 *um*. It is this material that was probably captured on the PM_{10} and TSP filters and resulted in increased levels of particulates during the chaff tests.

This phenomenon appears to account for the increase in filter weight measured during the chaff tests. There was also empirical evidence that combustion products were contributing to the increased weight of the filters exposed during the chaff tests; the small black particles visible on the filters under the microscope had a similar appearance to the combustion residue remaining in the spent chaff cartridges. It should be noted the air impacts measured during this field testing program were accentuated because the testing was conducted in a relatively small, confined area.

The average PM_{10} concentration measured during the chaff tests was shown to be slightly higher (16 percent) than the average TSP concentration, and statistically significant at the 95 percentile level. This difference was probably a result of some of the variables in the individual impulse cartridges, such as the mass of the explosive charge, the characteristics of the explosion within each impulse cartridge, and the particle quantity and size range generated by each impulse cartridge. These variables could easily account for the observed difference between the average TSP and PM_{10} concentrations.

As a further check on the analysis, the amount of chaff material released was compared with the amount of chaff material collected. The difference in these quantities was then compared to the material collected on the filters. However, there was a relatively large uncertainty in the amount of chaff released and in the amount of chaff collected, so that the difference in these quantities could not be accurately determined and compared to the mass increase on each filter. The greatest uncertainty came in the measurement of the chaff material collected. This process consisted of carefully sweeping up the chaff deposited in the test facility after the tests were completed. However, not all of the chaff dipoles could be collected, and some additional dirt or other material on the floor of the test facility was probably included in the collected sample. Therefore, this check was not sufficiently sensitive and had too many potential interferences to yield conclusive results.

3.5.4 Conclusions

In a test conducted of chaff particulate matter, a statistically significant increase in the levels of both PM_{10} and TSP particulates was measured in the test facility during chaff releases, when compared to background levels of particulates in the test facility. However, microscopic observations of filters exposed during the chaff tests revealed that there were very few chaff dipoles and no dipole

fragments collected on those filters. Consequently, the chaff material was not a source of the increased levels of PM_{10} particulates measured during the chaff releases.

The production of carbonized particles during the ignition of the explosive charge material in the impulse cartridge was shown to be the most likely source of increased particulate levels measured during the chaff tests. Although the actual mass of the explosive charge in each impulse cartridge is low (approximately 0.5 gram), the testing was conducted over relatively short time periods in a relatively small, confined test facility, so that the resulting increase in the measured particulate levels appears to be large. Air quality impacts from chaff releases under actual flight conditions would be low because of the small quantity of explosive material contained in each impulse cartridge, which would be dispersed over a large area.

Based on this chaff testing, it is believed that most chaff fibers maintain their integrity after ejection. Although some fibers are likely to fracture during ejection, it appears that this does not result in the release of PM_{10}. Although not significant, the tests indicated that the explosive charge in the impulse cartridge results in minimal releases of PM_{10}. Therefore, it appears that chaff deployment would not result in an exceedances of the NAAQS.

Potential short-term visibility impairment from chaff use near PSD Class I areas were not specifically addressed in this study. However, considering that the dipoles settled quickly during the particulate test, it would appear that visibility impairment is not an issue. Location of PSD Class I areas coincident or in the vicinity of training areas where large quantities of chaff are used may warrant further consideration. The conclusions of this study are predicated on the assumption that lead-containing chaff is no longer used.

3.6 PHYSICAL RESOURCES

3.6.1 Issues Addressed

This section addresses potential effects of chaff on earth resources, primarily soils, and water resources. The principal issues include:

- Effects of chaff deposition on soil chemistry.
- Potential for chaff to accumulate in water bodies and sediments.
- Potential for chaff deposited on water bodies to leach toxic chemicals or change the chemical composition of the water.
- Effects of chaff on drinking water sources and systems.

Factors that influence the potential for chaff to change soil and water chemistry include the chemical composition of the chaff, the concentration of chaff deposited in a given area, the rate of chaff decomposition in the environment, the propensity of chaff to leach toxic chemicals under various soil and water conditions, and the background soil and water chemistry and conditions. Alteration of the natural soil chemistry of an area has the potential to affect vegetation and vegetative cover and, consequently, the stability of soil conditions, as well as the type and quality of

habitat. Changes in soil composition can also affect groundwater and surface water bodies through chemical leaching and runoff. If chemicals leach from the chaff, deposition in water bodies, such as rivers and wetlands, may have the potential to alter the chemical composition of the water and/or sediments and, consequently, the habitat value.

3.6.2 Studies Conducted

There are a number of laws and regulations to protect water quality that restrict what can be deposited directly into water bodies and onto land where groundwater or surface water quality may be indirectly affected through leaching or runoff. Studies conducted to investigate the potential for chaff to affect soil and water composition and quality included a review of available literature, laboratory analysis of chaff decomposition in a range of surrogate environments, and microscopic laboratory examination of soil and sediment samples taken during field studies of areas where chaff is employed in training.

3.6.2.1 Regulatory Considerations

Legislation and regulations that relate to the potential impacts of chaff use on soil and water composition and quality include laws designed to protect water resources and laws that regulate the disposal of solid and hazardous wastes.

RCRA (42 USC 6901 et seq.) regulates the disposal of solid and hazardous waste. Disposal is defined as "the discharge, deposit...dumping, spilling, leaking, or placing of any solid waste or hazardous waste into or on any land or water so that such solid waste or hazardous waste...may enter the environment or be emitted into the air or discharged into any waters, including ground waters." Solid waste is defined as "refuse...discarded material containing solid, liquid, semisolid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations" (42 USC 6903(27)). Chaff and chaff debris could be considered refuse or discarded materials, except they are technically not from industrial, commercial, or agricultural operations. However, this technicality has not exempted other DOD waste from being defined as solid waste under RCRA. Thus, chaff and chaff debris appear to qualify as solid waste and chaff employment to qualify as disposal.

RCRA defines hazardous waste as "solid waste...which because of its quantity, concentration, or physical, chemical, or infectious characteristics may...cause mortality or an increase in serious...illness; or...pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, or disposed of, or otherwise managed." U.S. EPA has established standards of hazardous waste based on characteristics of reactivity, ignitability, corrosivity, and toxicity and has also listed specific compounds that are considered hazardous. None of the constituents of chaff or chaff debris are specifically listed as hazardous waste, but some of the elements may qualify as characteristic toxic wastes if released in sufficient quantities. Silica, aluminum, and stearic acid are neither toxic nor hazardous, but some of the trace metals in the aluminum alloy coating can be toxic in large quantities. Of the five transition metals that are potentially found in the coating (copper, manganese, titanium, vanadium, and zinc), only

copper, vanadium, and zinc have RCRA reportable spill quantities, and these range from 454 to 2273 kilograms. Therefore, chaff does not appear to qualify as a hazardous waste.

The *Clean Water Act* (33 USC 1261 et seq.) prohibits the discharge of any pollutant from any point source into the waters of the United States without a permit. Pollutant is defined as dredged spoil, *solid waste*, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal, and agricultural waste (33 USC 1362 (6)) [italics added]. A point source is a "discernible, confined, or discrete conveyance" which may include an aircraft. Waters of the United States include any surface water that is tidal, navigable, or connected to such waters or their tributaries. Water with some relationship to interstate commerce are also included, such as those used by migratory birds. As a result, virtually any surface water is subject to the Clean Water Act.

The *Marine Protection, Research, and Sanctuaries Act* (33 USC 1401-1445) requires a permit for "a disposition of material" (dumping) in the ocean. Material includes solid waste and munitions. There are few exceptions to the requirement for a permit, one being operation of a vessel, and there is no threshold of quantity. EPA regulations (30 CFR 227-228) are not particularly restrictive in granting ocean dumping permits, as long as the environmental impact and the effects on recreation, economic values, and other uses of the ocean are not unacceptable. Persistent inert materials that may float or remain in suspension in such as manner that they may interfere materially with fishing, navigation, or other legitimate uses of the ocean may not be dumped unless they have been treated so they will sink to the bottom and remain in place. Otherwise, insoluble wastes are generally approved for dumping if they are of a particle size and density that they would be rapidly deposited or dispersed without damage to the biota. Chaff and chaff debris may float for extended periods of time, but the small concentrations that are deposited on the ocean disperse rapidly and are unlikely to interfere with fishing or any other activity. Permits granted under the Marine Protection, Research, and Sanctuaries Act specify a disposal site, which is not practical for chaff use. There are provisions for general permits, which are authorized for dumping small quantities of harmless substances when there is minimal environmental impact (40 CFR 220.3(c)).

The Air Force does not currently hold any permits for chaff use.

3.6.2.2 Literature Review

Soil Chemistry

There are no existing reports that provide substantive data regarding the effects of chaff on soil chemistry. A number of studies have inferred conclusions on potential for impacts based on the known chemical constituents of chaff, but there has been no systematic analysis of chemical changes in soils exposed to various concentrations of chaff. A study that included collection and analysis of soil samples in England (United Kingdom Health and Safety Executive for the Ministry of Defense [UKHSEMD] 1988) identified chaff fibers in the soil, but did not provide a systematic analysis of potential effects on soil chemistry.

The major components of chaff, silica, aluminum, and stearic acid, are generally prevalent in the environment. Silica (silicon dioxide) belongs to the most common mineral group, silicate minerals. Silica is inert in the environment and does not present an environmental concern with respect to soil chemistry. Aluminum is the third most abundant element in the earth's crust, forming some of the most common minerals, such as feldspars, micas, and clays. Natural soil concentrations of aluminum ranging from 10,000 to 300,000 ppm have been documented (Lindsay 1979). These levels vary depending on numerous environmental factors, including climate, parent rock materials from which the soils were formed, vegetation, and soil moisture alkalinity/acidity. The solubility of aluminum is greater in acidic and highly alkaline soils than in neutral pH conditions. Aluminum eventually oxidizes to Al_2O_3 over time, depending on its size and form and the environmental conditions. Stearic acid is an animal fat that degrades when exposed to light and air.

Water Resources

Literature on the effects of chaff on water quality and aquatic habitats is limited. Reports compiled for Strategic Air Command and the Air National Guard (SEA 1989 and 1990) concluded that chaff, including its coating materials, is insoluble in water and, if it settled on a water body, it would either sink to the bottom or be driven across the surface by wind and deposited along the shoreline. These reports also concluded that chaff introduced into public drinking water sources would be readily filtered out by standard screens and settling tanks.

The principal past study addressing potential chemical effects of chaff on water was a 13-day experiment in which salt water from the Chesapeake Bay was spiked with chaff (Block and Schiff 1977). No appreciable increases in aluminum, cadmium, copper, iron, or zinc levels were detected. Any detectable increases were in the parts per trillion range.

3.6.2.3 Laboratory Analyses

Surrogate Environment Tests

Laboratory tests were conducted to identify the types and quantities of chemicals that could leach from the chaff materials under various conditions. The tests were conducted by applying a series of surrogate environment treatments to samples of aluminum coated glass fiber chaff. The samples were reacted with four extracting solutions designed to simulate acidic (pH 4), neutral (pH 7), alkaline (pH 10), and marine (pH 7.8 synthetic seawater) conditions. A modified TCLP was used for the extractions. The chaff samples were analyzed for the presence and quantity of aluminum, magnesium, copper, manganese, titanium, vanadium, zinc, boron, and silicon. Details of the study methodology and findings are presented in *Technical Reports on Chaff and Flares, Technical Report No. 5, Laboratory Analysis of Chaff and Flare Materials* (USAF 1994e).

The samples were prepared and extracted according to TCLP guidelines in a sodium acetate buffer solution. The acidic and alkaline solutions were more extreme than normally encountered in nature. They were selected to rigorously subject the chaff to harsh conditions while maintaining a relatively stable pH. The amount of aqueous solution used to act upon the sample was substantially less, and the resulting ratio of chaff to solution much higher, than would occur in the environment. The

TCLP extraction procedure and the extreme pH levels allowed the material to be subjected to simulated long-term weathering in a relatively short period (18 hours). The buffered solution was used to maintain as constant a pH as possible, simulating the mitigating effects of soils and salts that perform this buffering process in nature.

Standard TCLP techniques were slightly modified to simulate a range of conditions. In order to obtain precision and accuracy data for these modified procedures, additional quality control samples were analyzed along with the primary samples. These included analysis of all samples in duplicate, a matrix spike, a blank, a blank spike, and a laboratory quality control spike for each extraction medium. All laboratory data were reviewed and validated to U.S. EPA Level III standards according to the *Laboratory Data Validation Functional Guidelines for Evaluating Inorganic Analysis* (EPA 1988a).

Considerable variation was found in the duplicate samples, and several of the findings were consequently qualified as estimated. Matrix spike recoveries of boron and aluminum were also generally low. Boron and magnesium contamination was found to varying degrees in most of laboratory blanks. In accordance with standard protocol, concentrations of elements occurring in samples associated with contaminated blanks were qualified as non-detects if the sample concentrations were less than five times the blank concentration. Because of the differences encountered, the findings with respect to aluminum and boron are considered approximate.

Field Study Soil and Sediment Sample Analysis

Two field studies were conducted to analyze the effects of chaff use in varying environments. One study was conducted at the Nellis Air Force Range complex in Nevada to represent an arid environment; the other, representing a temperate environment, was conducted at Townsend Air to Ground Gunnery Range, Georgia. Details of the field survey methods and results are presented in *Technical Reports on Chaff and Flares, Technical Report No. 4, Field Studies* (USAF 1994c).

At the Nellis complex, 103 soil and sediment samples were collected in locations chosen to represent the primary geomorphologic contexts in an arid environment: ridgeline, bajada, basin floor, and drainage bottom. Sample sites included locations on the range itself, where chaff use is relatively heavy, and in the Desert MOA, where chaff use is less concentrated. At Townsend, 96 soil and sediment samples were collected in locations chosen to represent a variety of contexts, including wetlands, pine forest, mixed hardwood/pine forest, and open flowing surface water.

Sample dimensions and volume were standardized to 10 centimeters square by 2 centimeters deep. For each sample, a data form was completed to record the sample number, type, depth, date collected, location, associated vegetation, soil texture, depositional environment, and sampler's name, along with a photographic reference. Chain-of-custody forms were completed and shipped with the samples to the laboratory.

No standard methodology exists for the detection and quantification of chaff in soils. Therefore, preliminary studies were performed prior to the field collections using spiked soil samples. These studies indicated that glass fiber chaff could be recovered from soil samples containing minimum

chaff concentrations of 0.35 milligrams per kilogram. The spiked samples were subjected to wetting, drying, and shaking before analysis. The field samples were weighed with their containers upon receipt at the laboratory to determine the initial mass of the sample. The samples were force-air dried at room temperature, to remove free standing water, and then dried in an oven at 105 degrees Celsius in preparation for analysis.

The soil samples were analyzed using a combination of methods, including visual inspection, low power magnification (10X hand lens), and sieving through a 10 mesh sieve (2.0 mm opening). Due to static, the glass fiber chaff was attracted to the sides of the polypropylene sample container, which aided in detection and recovery. For most samples, the chaff was extracted from the whole sample using tweezers, and the length of each fiber was measured. Empirically derived mass-to-length ratios were used to convert the measured chaff length (both fiber and foil types) to mass.

In addition to measuring the weight of chaff content, the water content, gravel content, and pH of each sample were recorded. The antecedent water content of the sample was determined gravimetrically after drying the sample at 105 degrees Celsius for 16 hours. The soil pH was determined with a glass electrode on a saturated soil paste (McClean 1982) The electrical conductivity of the saturated paste extract was determined using a conductivity meter after vacuum extraction of the soil solution (U.S. Salinity Laboratory Staff 1954).

Ten of the samples were examined using a SEM with energy dispersive x-ray analysis (EDXA) capabilities. The SEM was used to examine the physical condition and composition of the fibers for evidence of weathering. Control samples of raw (unused) chaff fibers were compared to the fibers recovered in the field from the two locations. The EDXA function was used to assess the chemical composition of areas of interest. This enabled the surfaces to be identified as aluminum coating or exposed silica core.

3.6.3 Findings

3.6.3.1 Surrogate Environment Tests

Table 3.6-1 presents the average concentrations of elements found in the chaff tests for various solutions. Four of the nine elements analyzed, aluminum, magnesium, zinc, and boron, were detected. Aluminum was the dominant element at pH 4 and 10. The highest concentration was at pH 4, with an average of 170 mg per liter (l). In contrast, the average at pH 10 was 3 mg/l, and the findings in the pH 7 and synthetic seawater solutions average 0.3 mg/l. In both of the neutral solutions, boron was the dominant element found. The high quantities of magnesium detected in the synthetic seawater treatment are attributable to the composition of the extracting solution.

3.6.3.2 Field Study Soil and Sediment Sample Analysis

The findings of the field soil and sediment samples are presented in **Table 3.6-2**. Glass fiber chaff was recovered from 57 and aluminum foil chaff from 30 of the 103 samples collected at the Nellis complex. Glass fiber chaff was collected from all the samples that contained aluminum foil chaff. Concentrations of glass fiber chaff ranged from 0.02 to 251 mg/kg, with most of the samples containing less than 0.5 mg/kg. Concentrations of foil chaff ranged from 1.25 to 578 mg/kg, with

most containing less than 10 mg/kg. It should be noted that the foil chaff weighs about 42 times as much as equivalent length of glass fiber chaff, so the higher weights of the foil chaff samples to not represent larger concentrations. The overwhelming majority of detections were in samples taken in range areas. Only three of the 28 samples taken in MOA areas contained chaff, all glass fiber type; two at concentrations of 0.08 mg/kg and one at 0.24 mg/kg.

Table 3.6-1. Average Element Concentrations from Chaff Subjected to Surrogate Environment Solutions

Treatment	Concentration (mg/l)								
	Mg	Al	Cu	Mn	Si	Ti	V	Zn	B
pH 4	0.24	170	<0.02	<0.02	<.0	<0.05	<0.02	0.40	1.5
pH 7	0.17	0.3	<0.02	<0.02	<1.0	<0.05	<0.02	0.06	1.4
pH 10	0.18	3.0	<0.02	<0.02	<1.0	<0.05	<0.02	0.03	0.9
SSW	871	0.3	<0.02	<0.02	<1.0	<0.05	<0.02	0.04	0.8

SSW = synthetic seawater
Less than (<) values indicate the element was not present or occurred below the method detection limit.

Only six of the 96 samples collected at Townsend contained glass fiber chaff, and none contained foil chaff. Concentrations ranged from 0.03 to 0.9 mg/kg, with one sample of 29,661 mg/kg that contained a clump of chaff.

The pH of the soil solution was found to significantly affect the stability of the aluminum coating. Aluminum solubility is highest in solutions with pH less than 5.0 or more than 8.5. The glass core, on the other hand, was found to be more stable in acidic than alkaline environments. The Nellis samples were generally neutral to alkaline, and the Townsend samples were acidic. However, the Nellis environment is also arid and, although the pH may be high enough in places to solubilize the aluminum and silica, there is generally not sufficient water for the reaction to occur.

The microscopic observations found the most evidence of weathering in soil samples collected from Townsend. Four of the five samples examined showed evidence of weathering in the aluminum coating, ranging from minor effects to extensive surface pitting and dissolution. The pH of the samples ranged from 3.8 to 4.7. Though exposed in some areas, no apparent weathering of the silica core was observed in any of the samples.

Fibers from three of the five Nellis samples examined exhibited surface alteration. The surfaces differed from the smooth appearance of the control samples and were dominated by small "fuzzy" irregularities. The SEM scans and EDXA data revealed that the silica core was rarely exposed. The irregular surface morphology of the fibers is speculated to result from the formation of aluminum

oxyhydroxides, sulfates, and carbonates on the aluminum coating. Like the hydroxide anion, carbonate and sulfate have strong affinity for Al_3+ and are likely to be present in arid region soils (Hsu 1989).

Table 3.6-2. Detection of Chaff in Field Soil Samples

Location	No. of Soil Samples	Laboratory Detection (percent)	Location	No. of Soil Samples	Laboratory Detection (percent)
Nellis Complex			**Townsend Range**		
Range Areas			Range Area		
Ridgeline	8	75	Upland pine forest	10	20
Bajada	21	100	Open uplands	15	13
Basin	16	63	Wetlands	24	4
Drainage	18	77	Canal	7	0
Playa	8	37			
Spring	4	25			
Total	75	73	Total	56	9
MOA Areas			MOA Area		
Ridgeline	2	0	Upland pine forest	10	0
Bajada	11	0	Open uplands	0	N/A
Basin	5	20	Wetlands	30	0
Drainage	10	10	Canal	0	N/A
Playa	0	N/A			
Spring	0	N/A			
Total	28	7	Total	40	0

N/A = Not applicable

Microscopic evaluations were also conducted of surrogate solution samples to compare with the field samples. These observations were generally consistent with the field sample results. Fiber subjected to the pH 10 treatment showed a portion of the aluminum coating dissolved and formation of crystals on the coating. The crystals were presumed to be synthetic gibbsite or bayerite ($Al(OH)_3$ polymorphs). This speculation is supported by documented formation of gibbsite in solution with OH:Al ratios greater than 3:1 (Hsu 1989). Incipient solution pits were seen, which agreed with the expected response of both aluminum and silica in high pH solutions. The pH 4 surrogate environment solution resulted in extensive pitting of the aluminum coating, consistent with the Townsend samples.

3.6.4 Conclusions

The potential for chaff to have adverse effects on the physical environment depends on the quantity of material deposited in a particular area, the stability of the materials, the specific chemical

conditions of the receiving soil and water, and the sensitivity of the environment to contaminants of concern. However, in any condition, the likelihood that a sufficient quantity of chaff would fall into a particular pond, stream, or estuary to measurably affect its chemical makeup is remote. The stability of the materials is important because it determines the rate of release of chemical constituents. The main factors influencing stability include the size of the particle (exposed surface area), the chemical environment, and the availability of water. The aluminum coating on glass fiber chaff is the least stable under acidic and extremely alkaline conditions; the glass core is more stable in acidic than alkaline environments. Dissolution will be greatest where water content is high. Thus, weathering will be more rapid in wet, acidic environments than in dry, neutral and alkaline environments.

3.6.4.1 Soil Chemistry

Elements of concern for chaff include aluminum, magnesium, copper, manganese, titanium, vanadium, zinc, boron, and silicon. Of these, only aluminum, magnesium, zinc, and boron were detected in the laboratory analysis. The absence of copper, manganese, titanium, and vanadium in the laboratory extracts may indicate that the chaff samples used did not contain these elements, but they may still occur and are therefore included in the analysis.

Aluminum, magnesium, and silicon occur naturally in relatively high concentrations in soils, and the probability of significant toxic effects are slight. The national average for natural aluminum concentration in soils is 72,000 mg/kg. Aluminum restricts root growth in some plants at soil solution concentrations as low as 1 mg/l. However, soil solution aluminum concentrations are reduced by ion exchange reactions, solid phase precipitation, and ligand exchange processes. Consequently, soil solution concentrations of aluminum in the toxic range are only likely to occur in extremely acid and very sandy soils. Potential plant toxicity would likely be limited to sensitive crops, since native vegetation will have adapted to local conditions, and liming, a common practice on acid agricultural soils, would reduce the potential for aluminum toxicity (Munk 1994a).

There are no reportable spill quantities for aluminum under RCRA or CERCLA. One test used in evaluating action levels for hazardous materials is the occurrence of analytes of concern at a concentration equivalent to three times the background level (40 CFR Part 300, App. A, Sec. 2.3). Based on the results of the pH 4 surrogate environment laboratory treatment, which produced the highest concentration of aluminum, an estimated 325,000 kilograms of chaff would have to be deposited on an acre of land to triple the aluminum concentration in the upper inch of soil, assuming a mean soil content of 72,000 mg/kg (Munk 1994a). This is equivalent to over 3 million chaff bundles and exceeds the total annual use by ACC units nationwide.

Magnesium also occurs naturally in large concentrations in soil (mean content of 9,000 mg/kg). Magnesium deficiencies may occur in humid acidic soils, and toxicity occurs rarely in alkaline soils formed from ultra-mafic rocks. Correcting deficiencies or inducing plant toxicity would require the addition of readily available magnesium at the rate of several tons per acre (Munk 1994a).

Silicon is not known to be toxic to plants, and elevated uptake by plants has not been documented. The surrogate environmental laboratory tests did not detect dissolution of silicon in even the most acidic solution (pH 4).

Small quantities of copper, manganese, titanium, vanadium, and zinc may occur in the aluminum coating of chaff. Only zinc was detected in the laboratory tests. It is likely that the other trace metals were not present in the particular lot of chaff analyzed (Munk 1994). Except for titanium, these trace elements are considered essential nutrients for either plant or animal growth. Toxic effects may occur at elevated concentrations in soil or plant tissue. Copper, manganese, titanium, and zinc have strong affinities to precipitate as hydroxy oxides with oxygen and hydroxyl ligands under oxidized neutral and alkaline conditions. Under anaerobic conditions, they tend to precipitate as sulfides and carbonates, depending on pH. In addition, a number of other mechanisms may reduce the activity of these elements in solution, including ion exchange coprecipitation and chelation with natural organic compounds. In general, the mobility and availability of these metals increase with increasing acidity, which also tends to coincide with soil conditions likely to be deficient in these elements. In contrast, vanadium occurs as anions, and its mobility and availability may decrease with increasing acidity in some soils (Munk 1994a).

Of the five transition metals that may occur in chaff, only copper, vanadium, and zinc have RCRA reportable quantities, and none have critical TCLP limits under 40 CFR Part 261.24. The RCRA reportable quantities are 2,273 kg for copper and 454 kg for vanadium or zinc. This would represent nearly 1 million kg of chaff, or about 4 million bundles, for the more restrictive metals.

Boron is both an essential and toxic element for plants. Boron deficiencies are most likely to occur in humid, acid soils, and toxicity occurs in alkaline environments. Sensitive plants are affected by concentrations as low as 0.3 mg/l. In general, the availability of boron to plants decreases with increasing soil pH and under arid conditions. Increased availability corresponds with conditions most likely to be deficient in boron. Boron detection in the surrogate environment laboratory tests of chaff corresponded with pH. There is no RCRA reportable quantity or critical TCLP limit for boron. However, natural soil content is low (mean of 33 mg/kg), and the amount of chaff deposition required to raise soil concentration to triple background level is less than for any other element (estimated 571 kg/acre) (Munk 1994a). Nevertheless, this represents about 2,500 bundles of chaff.

In summary, the exposure of organisms to elements in chaff depends on the rate of release of these materials in the environment. The availability and mobility of metals in the soil will be reduced by a number of attenuation factors, including solid phase precipitation, ion exchange, coprecipitation, and complexation with iron and aluminum oxyhydroxides and organic matter. Retention of elements in soil will reduce their availability to organisms and the potential for ground water contamination. The results of the laboratory tests indicate that chaff is more susceptible to dissolution in wet, acid environments than under arid, alkaline or neutral conditions. Based on available data, broad-scale, significant accumulations of metals in soil would require extremely large releases of chaff (Munk 1994a), equivalent to dispensing approximately the full amount of chaff used at the Nellis Range complex on a 160 acre area. It would take roughly 2,000 years to accumulate that density at current utilization levels.

3.6.4.2 Water Resources

Freshwater aquatic environments are potentially more sensitive to chemicals released from chaff and flares than terrestrial environments for the following reasons: (1) dissolution of materials will be faster in water than on land, (2) chemicals are more mobile and more available to organisms, and (3) the thresholds of toxicity tend to be lower for sensitive aquatic species. The extreme pH levels used in the laboratory analysis are not directly applicable to aquatic environments because pH 4 is too acidic and pH 10 too basic for most aquatic organisms. These data, along with the more normal pH 7 test results, can, however, be used in a qualified fashion to indicate trends in solubility and toxicity.

Among the elements examined in chaff, only aluminum and copper have the potential for sufficiently high concentrations to be of concern in aquatic environments. Magnesium, boron, manganese, titanium, vanadium, and silicon concentrations are less than values known to cause toxicity to aquatic organisms.

Aluminum solubility and toxicity are highly pH dependent. The highest concentrations in the laboratory tests occurred at pH 4 (170 ppm) and the lowest at pH 7 (0.3 ppm). The freshwater acute value for aluminum is 1.496 ppm, and the chronic value is reported as 0.742 ppm for a pH range of 6.9 to 8.2. There are no data available on acute or chronic levels at the extreme pH levels of 4 and 10 used in the laboratory analysis. The extracts from the pH 7 samples, which lie within the 6.9-8.2 range, were approximately one-sixth the freshwater acute value for aluminum. These extract values represent a very high chaff-to-water ratio (1:20) which could not occur in the environment. Therefore, aluminum toxicity due to chaff is not a concern in aquatic environments.

The freshwater acute value for copper is 0.018 ppm. Although no copper was detected in the laboratory tests, which had a detection limit of 0.02 mg/1, it is possible that trace quantities of copper could occur in some lots and, if deposited on freshwater bodies, could leach out. The quantity of chaff that would have to be released over a given water body would have to be very large, however, to reach acute values. A worst-case calculation was used to assess the likelihood of causing concern.

Chaff disperses widely when employed from military aircraft. Depending on the altitude of release and wind speed and direction, the chaff from a single bundle can be spread over distances ranging from less than a quarter mile to over 100 miles (USAF 1994c). The most confined distribution would be from a low-altitude release in calm conditions. The chaff from one bundle could be expected to distribute over about a quarter mile area (160 acres). The average distribution for a bundle of RR-112A chaff (the largest model) would be about 69,000 chaff dipoles per acre. Each dipole could contain a maximum of 1.8×10^{-9} gram of copper (at 0.05 percent of the aluminum coating). An entire bundle of 11 million dipoles could contain approximately 0.02 gram of copper (the quantity would be proportionally less for the smaller bundles, such as RR-170A which contains approximately 3 million dipoles). Thus, the worst case condition would be an entire clump of undispersed RR-112A chaff falling in a small, confined body of water. Even in this worst case situation, the amount of copper introduced would be equivalent to the copper in one penny. (Pennies manufactured since 1982 have a total weight of 2.5 grams and are 0.8 percent copper.)

A significant amount of training with chaff and flares occurs over the open ocean. Although the vastness of the receiving waters and the resulting dilution of any materials or chemicals deposited make the potential for impact extremely remote, laboratory extraction tests were conducted using synthetic seawater to identify chemicals that could be released into the ocean. The results could be of interest in a more confined estuarine environment.

The concentrations detected for all elements of concern were low in the synthetic seawater solution. The high levels of magnesium detected are attributable to the magnesium in the extracting solution. As with freshwater aquatic environments, the only chemical of potential concern is copper. The marine chronic value for copper is 0.003 ppm, which is well below the laboratory detection limit of 0.02 mg/L. However, the quantity of copper involved, if any, is minute.

Neither chemical nor physical effects are expected to occur to drinking water sources exposed to chaff. The quantities of chemicals released are too small to be of concern, and filtering systems would remove any fibers.

3.7 BIOLOGICAL RESOURCES

3.7.1 Issues Addressed

The primary pathways for potential effects of chaff on biological resources include inhalation, ingestion, and direct body contact. Chemical alteration of soil and/or water resulting from chemical decomposition of chaff could also affect vegetation and aquatic life. Considering the physical and chemical characteristics of chaff, methods of employment, and the habitat requirements and sensitivities of biological resources, the following issues were identified and addressed regarding the potential effects of chaff on biological resources:

- Startle effects on birds and other wildlife (behavioral response).
- Ingestion effects on wildlife (physiological response).
- Inhalation effects on wildlife (physiological response).
- Physical effects from external contact (physiological response).
- Interference with wildlife activities (behavioral/physiological response).
- Chemical effects on plants through soil (physiological response).
- Chemical effects on aquatic life (behavioral/physiological response).

Startle Effects. Military overflights often elicit startle responses from a wide variety of animals (Gladwin et al. 1987; Manci et al. 1988). Release of chaff from these aircraft could contribute minimally to that response. However, any sudden release of chaff would be accompanied by noise and visual effects of the aircraft dispensing the chaff, which would be more likely to elicit a response than the chaff itself. Therefore, this issue was not addressed further.

Ingestion Effects. Selective ingestion of chaff does not appear likely, but inadvertent consumption of chaff fibers could occur during normal feeding activities by grazing animals, waterfowl, or

aquatic organisms in areas beneath or downwind of locations where chaff is released during military aircraft operations. The primary issues include potential for toxic effects, disruption of digestive processes (e.g., blockage of the gastrointestinal system), and irritation of digestive membranes.

Chaff on dry land would tend to be blown about by wind, trapped by rocks and vegetation, and generally subject to disintegration due to abrasion from surface features. In contrast, chaff fibers that land on standing water could float and potentially accumulate on the leeward side of the water body, with little fragmentation due to abrasion. Because floating material (e.g., algal mats, wood, etc.) tends to accumulate on the leeward side of standing water bodies, surface-feeding animals also generally feed in those areas. Clumps of chaff within other debris could be ingested by surface-feeding ducks.

Inhalation Effects. Inhalation of chaff fibers could occur during chaff releases as the fibers drift to the ground or whenever wind or other activities resuspend them in the air. Chronic inhalation of chaff could cause an inflammatory response in the respiratory system, potentially resulting in silicosis. The diameter and length of the fibers is important in determining how far into the respiratory system they could penetrate and how easily they could be cleared out.

Physical Effects. Chaff is similar in form to fine human hair. Due to its flexible nature and softness, external contact with chaff would not be expected to adversely affect most wildlife. The hair or feathers covering wildlife bodies and their hooves or tough foot pads would minimize the potential for direct skin contact with chaff fibers. Consequently, it is very unlikely that chaff could become embedded in the skin and/or feet of most animals. It is possible, however, that chaff fibers on the ground or on plants could be picked up and used by birds and burrowing rodents in their nests. Since the young of these species have bare skin when they are born, the chaff fibers could cause skin irritation.

Interference with Wildlife Activities. Fairly dense clouds of falling chaff or clumps of chaff that did not deploy correctly could temporarily affect flying bats by creating clutter that could confuse them when using echolocation to avoid obstacles and to hunt for insects. Accumulation of chaff on the ground or on surface waters could cause wildlife to avoid these areas for foraging.

Chemical Effects on Plants. Chemical decomposition of chaff could have localized effects on soil chemistry from aluminum, silicon dioxide, stearic acid, or trace constituents in the chaff.

Chemical Effects on Aquatic Life. Chemical changes in surface waters as a result of chaff deposition are expected to be negligible (see Section 3.6). Natural concentrations of aluminum in fresh water bodies have been reported as high as 10 mg/liter. Only in acidic waters would dissolution of the aluminum in chaff be expected.

3.7.2 Studies Conducted

Two types of studies were conducted to address issues related to chaff effects on biological resources. First, a literature review was conducted to determine what kinds of studies had been undertaken previously and the results of those studies. Published and unpublished information was

reviewed. From this, data gaps necessary to address the issues were identified. The second type of study was a field survey conducted at two military installations where chaff is frequently used.

3.7.2.1 Regulatory Considerations

Legislation and regulations that relate to the potential impacts of chaff use or biological resources include laws designed to protect plants and animals, and particularly, endangered species and critical habitats.

Endangered Species Act of 1973, 16 USC section 1531 et seq., as amended, protects proposed and listed threatened or endangered species. Consultation with the U.S. Fish and Wildlife Service is required under Section 7 of the Act for federal actions where such actions could directly or indirectly affect any proposed or listed species.

Marine Mammal Protection Act of 1972, 16 USC section 1361 et seq., prohibits taking or harassment of any marine mammals except incidental take during commercial fishing, capture under scientific research and public display permits, harvest by Native Americans for subsistence purposes, and any other take authorized on a case-by-case basis as set forth in the Act. The Department of the Interior, Fish and Wildlife Service, is responsible for the polar bear, sea otter, marine otter, walrus, manatees, and dulong, while the Department of Commerce, National Marine Fisheries Service, is responsible for all other marine mammals.

Migratory Bird Treaty Act of 1972, 16 USC sections 703-711, protects migratory waterfowl and all seabirds by limiting the transportation, importation, killing, or possession of these birds.

Executive Order 11990, Protection of Wetlands, requires that governmental agencies, in carrying out their responsibilities, provide leadership and take action to minimize the destruction, loss, or degradation of wetlands, and to preserve and enhance the natural and beneficial values of wetlands. Each agency is to consider factors relevant to a proposed project's effect on the survival and quality of the wetlands by maintenance of natural systems, including conservation and long-term productivity of existing flora and fauna, species and habitat diversity and stability, hydrologic utility, fish, and wildlife. Agencies are required to provide for early public review of any plans or proposals for new construction in wetlands.

If chaff fibers or debris were to accumulate and affect air, soil, or water composition resulting in changes of food supply, or cause irritation to plants or animals from contact, ingestion or inhalation, particularly to protected species, this could result in an impact to biological resources under any of the laws referred to above.

3.7.2.2 Literature Review

The literature review found that several experiments had been conducted regarding ingestion of chaff by livestock but that essentially no field data have been collected to describe exposure of wildlife to chaff. No information was found in the literature describing startle effects of chaff on wildlife, physical effects of external contact between animals and chaff fibers, or potential effects on bat echolocation.

Previous studies have been conducted to address ingestion effects of chaff on animals. Cattle and goats apparently avoided eating clumps of chaff placed in their feed. Calves fed chaff in dry meal would consume the chaff only when it was coated with molasses and thoroughly mixed into the meal (Barrett and MacKay 1972). A similar study using cattle and goats found that the animals avoided consuming intact chaff (Taylor 1983). No information was found documenting ingestion of chaff by terrestrial wildlife, waterfowl, or aquatic organisms in the wild.

Toxicity of the various chemical components of chaff (primarily aluminum, silicon dioxide, and stearic acid) have been addressed above in Section 3.3. The data indicate that some components could be toxic to biological resources under certain conditions. Oral toxicity of aluminum is very low in animals (Browning 1969; Venugopal and Luckey 1978), and silicon dioxide is inert. Stearic acid is a natural compound that can be metabolized by animals. High concentrations may be toxic, but the small amount present on chaff fibers would not cause toxic effects.

No evidence of digestive disturbance or other clinical symptoms were observed in calves fed chaff (Barrett and MacKay 1971). The experimental and control groups gained weight at the same rate, and blood samples showed no deviation from normal. Postmortem examinations of the digestive system and major organs showed no lesions of pathological significance that could be attributed to chaff.

Exposure of six marine organisms from Chesapeake Bay to chaff resulted in no significant increases in mortality for any of the species (Block and Schiff 1977). The animals used were a benthic polychaete worm (*Nereis succine*), various life stages of the American oyster (*Crassostrea virginica*), the blue mussel (*Mytilus edulis*), the blue crab (*Callinectes sapidus*), the filter-feeding menhaden (*Brevoortia tyrannus*), and the killifish (*Fundulus heteroclitus*). In the same study, Chesapeake Bay water spiked with chaff found no appreciable increase in the levels of aluminum, cadmium, copper, iron, or zinc after 13 days.

No reports were found documenting ingestion of chaff by waterfowl or aquatic organisms in nature. Nor were any studies found that addressed effects of chaff ingestion by waterfowl under laboratory conditions. No reports were found addressing effects of chaff on water quality in freshwaters, particularly acidic waters in bogs or lakes affected by acid rain.

Inhalation of chaff fibers is not expected to have any adverse effects on terrestrial wildlife due to the size of the fibers. A study on the potential for inhalation by livestock and humans showed that the chaff fibers are too large to penetrate the larynx and would be expelled through the nose or swallowed (UKHSEMD 1988).

No evidence of chaff affecting vegetation through changes in soil chemistry were found during the literature review. Plant tissues normally contain approximately 29 to 1,400 ppm of aluminum, depending on the species and location. Any uptake of aluminum attributed to the presence of chaff in the soil would be negligible.

3.7.2.3 Field Studies

Installations in arid and wet, temperate climates were selected to obtain information over a range of environmental conditions. The surveys involved walking transects in a variety of habitat types to assess accumulation of chaff debris (fibers, end caps, and casings) on the ground or in aquatic habitats. Bird nests and rodent burrows were inspected for signs of chaff debris. Areas surveyed included ranges where low altitude release of chaff is often concentrated near targets and under MOAs where higher altitude release of chaff is dispersed over a large area.

3.7.3 Findings

3.7.3.1 Field Study at Nellis Air Force Range Complex

A variety of chaff debris was evident at all locations surveyed on the range. Observed debris included plastic caps, plastic cartridges, and assorted foil and paper. Chaff fibers, which pose the greatest concerns regarding effects on wildlife, were observed only four times during all of the biological surveys. The chaff fibers observed were in clumps, apparently from chaff bundles that did not disperse normally. Under the MOAs, the only chaff debris found was several plastic caps.

Vegetative cover was generally low in the areas surveyed. Shrub communities on the bajadas and in the basins consisted of widely spaced shrubs with varying amounts of grass and herbaceous species in the intervening spaces. The pinon-juniper woodlands on the mountains varied from sparse to relatively dense tree cover. Bare ground was always present in each plant community.

Animal abundance was low in the areas surveyed on the range, due to habitat type and aridity. Rodent activity was very low in areas with hard or rocky soils. Areas with sandy soils and areas of recent disturbances, such as roadside berms, had greater rodent activity. Five burrows were excavated within the compacted soils of the valley floor north of Gold Mountain. Another 30 burrows were excavated along a dirt road across a bajada where chaff debris was observed. Burrows were located both in the soft soils of the road berm and in the less disturbed habitat off the road. No evidence of chaff debris was found within the burrows, although vegetation and bedding material were found. Seven woodrat nests were investigated, and no chaff debris was found in any of them.

A variety of breeding birds was observed in the pinon-juniper woodland on the west side of the Kawich Range, but no nests were found. Twelve bird nests were found in cholla cacti within the Joshua tree woodland on the west side of the Delamar Mountains under a MOA. They included house finch, cactus wren, and Bewick's wren nests. No chaff debris was observed in any of the nest material, although no samples were taken for microscopic examination.

One small spring with water was surveyed on the range. No visible chaff fibers were observed on the water surface, but fibers were found in one of the four sediment samples taken from the spring. The spring was too small to support waterfowl, but it did contain a large population of cladocera (small invertebrate crustaceans).

3.7.3.2 Field Study at Townsend Air to Ground Gunnery Range

Little evidence of chaff debris was found during the surveys. Three separate clumps of chaff fibers were observed floating on the surface of a small pool of water at one of the targets. The chaff had been released during training activities in the morning. The clumps were still floating on the pool the next day, even though a substantial rainfall occurred during the night. Several other clumps of chaff were seen in this area. Other chaff debris found during the surveys on the range and under the MOAs included two plastic end caps.

The habitat within the Townsend range area consisted of open, maintained areas; natural, second-growth forests; and planted stands of loblolly, slash, or long-leafed pine in varying stages of growth, from recently planted saplings to mature stands. These pine forests were interspersed with marshy, cleared areas, forested wetlands, or occasional mixed deciduous forest. The understory composition and density ranged from nearly barren to dense vines and shrubs that included myrtle, saw-palmetto, blackberry, and blueberry. The target area is kept clear of trees. Herbaceous and shrubby vegetation was present in areas not used for targets. A number of canals support emergent wetland vegetation where the water is shallow. Within the vicinity of the Altamaha River, the forest is composed of bald cypress, cedar, maple, oak, and sweet gum trees. Recorded animal signs included those of raccoon, coyote, wild pig, white-tailed deer, armadillo, snapping turtle, rat snake, green snake, rattlesnake, and numerous bird species. Although many birds were observed during the field surveys, no nests were found.

Very few burrows were located in the areas surveyed. No chaff debris was found in them.

3.7.4 Conclusions

The literature review revealed that few conclusive studies concerning the effects of chaff on wildlife have been conducted. The two studies on the effects of chaff ingestion on cows concluded that chaff presented no health hazards to farm animals, while a study on the effects of chaff on the Chesapeake Bay ecosystem concluded that there were no environmental impacts from chaff on that system. There were no data describing the decomposition process for chaff under a variety of environmental conditions (e.g., arid, alkaline, wet, acidic, and anaerobic) or within the digestive systems of various animals.

Although the field surveys performed were of a limited duration and scope, areas selected for survey were chosen specifically to include locations with a high use of chaff. The areas were chosen to increase the probability that any potential wildlife use of chaff debris would be found. The field observations and results of laboratory analyses of soil samples allow a number of conclusions to be drawn regarding the effects of chaff use on wildlife.

Decomposition of chaff in aquatic environments is expected to have no adverse impacts on water chemistry and aquatic life. In alkaline to neutral waters, decomposition would be very slow. Under acidic conditions, decomposition would be faster, but the small amount of chaff expected to accumulate in the water would produce an incremental increase in aluminum relative to natural sources in these waters. No data are available to assess the decomposition rate under anaerobic

conditions found at the bottom of some water bodies. However, the amount of chaff expected to accumulate in these areas is low, and the released chemicals would mix with those released from other sources in these waters. Aquatic life, other than anaerobic bacteria, would not be exposed to the released chemicals until the anaerobic waters mixed with aerobic waters. Such mixing would dilute the chemicals (from chaff along with all other sources), and no toxic effects would be expected from the chaff chemicals.

Based on the field survey results, chaff on land would generally be subject to disintegration due to abrasion from surface features in arid areas and chemical processes in wet, acidic environments. In wet temperate areas, chaff debris would also be covered by vegetative growth and leaf litter. Both aluminum and silica are major constituents of the earth's crust and occur commonly in soils. Silicon dioxide is inert and would have no effect on soils. Metallic aluminum oxidizes and combines chemically to form oxides, sulfides, and metallic salts. Aluminum and most of its common compounds are insoluble except in acidic conditions. Stearic acid is a natural compound that is biodegradable and is used as a carbon source for microorganisms in many laboratory experiments (Taylor 1983).

In arid areas, the slow chemical decomposition of chaff is expected to have no adverse effects on soil chemistry and plant growth. In wet, acidic environments, chemical decomposition is more rapid, but no adverse effects are predicted for several reasons. The small quantity of chaff accumulating on the ground would release minute amounts of chemicals (primarily aluminum and silicon dioxide) that are abundant in soils. The trace amounts of other chemicals in the fibers would be released in such small quantities that no effects would occur.

The dispersal and decomposition of chaff fibers on land would limit the exposure of grazing animals to chaff, making it unlikely that ingestion of quantities large enough to have adverse physiological effects would occur. Plastic caps and cartridges are not likely to be eaten by wildlife and would have no effect on them.

Animals are unlikely to inhale chaff particles during chaff releases as the filaments drift to the ground, due the size of the fibers and to the dispersal of the fibers in the air. Once on the ground, chaff fibers would tend to break up when agitated by wind or water or when crushed by the movements of humans, animals, or machinery. Any activity that would stir up dust could potentially resuspend the shorter chaff particles, rendering them available for inhalation by animals. Due to the diameter and length of the filaments, chaff would not penetrate far into the respiratory system and would be easily cleared out. Relative to the background concentrations of dust in the air, the amount of additional particles contributed by chaff fibers would be negligible, and no adverse effects on wildlife would be expected from inhalation of the fibers.

The low visible accumulation of chaff fibers on the ground, even in arid environments, makes it unlikely that wildlife would have enough direct contact to cause any skin irritation. Low visibility and low concentrations would also limit the likelihood of selective collection of chaff fibers for nesting material. Thus, exposure of young with no hair or feather covering to chaff fibers would be minimal.

The potential for chaff accumulation on the surface of standing water bodies would depend on site-specific conditions. For small standing water bodies not subject to wind chop, surface tension would tend to make chaff float longer than on larger water bodies such as lakes and rivers. Chaff fibers that land on standing water and float could potentially accumulate on the leeward side of the water body. It is likely that wildlife would avoid ingesting chaff, if possible, due to its unnatural appearance, but if a large quantity of chaff were mixed with plant material, it could be consumed by an animal while ingesting the vegetative matter. Thus, a surface-feeding or bottom-feeding animal might ingest chaff.

While some birds have developed gizzards that use ingested sand as a digestion aid, the gizzards of surface-feeding ducks are not effective in dealing with such foreign materials. In addition, while some bird species routinely regurgitate hair, feathers, and other foreign material commonly ingested during feeding, surface-feeders do not have this ability. Ingested chaff would likely pass through the duck's digestive system as does fibrous plant material and not be harmful to the duck. However, if compaction of the chaff occurred in the gizzard, blockage of the digestive system could occur. Although individual animals could be affected, the number of incidents would be too low to impact species population. Impacts would be insignificant unless a protected species were affected.

This is a site-specific issue that could be of concern in areas where large quantities of chaff are dispensed over aquatic habitats heavily used by waterfowl. Impacts on aquatic species is a concern for waterfowl, particularly migratory species that are facing population declines as a result of habitat degradation or loss. It is also a concern where state or federally listed threatened or endangered species use the water bodies.

Chaff interference with wildlife activities is expected to be negligible based on information about chaff use, characteristics of chaff, and field observations of chaff accumulation. Any effects on bats would be short term because chaff dissipates in the air (i.e., is dispersed by winds and settles to the ground) and because the bats would recover quickly from the confusion. Bats would not likely misinterpret the chaff particles as insects and so would not be likely to consume them. Since there is no evidence of heavy accumulation of chaff on the ground or water, even in heavy use areas such as the Nellis complex, avoidance of foraging areas by wildlife due to chaff is unlikely.

3.8 LAND USE AND VISUAL RESOURCES

3.8.1 Issues Addressed

The two primary issues concerning impacts on land use and visual resources from chaff use in military training are:

- Effects of the accumulation of chaff fibers and debris on the use of an area for existing, designated, or planned land use.
- Effects of the accumulation of chaff fibers and debris on the visual quality of an area.

Land use impacts result when an existing, designated, or planned land use is altered or displaced, due to changes to attributes that make it suitable for such a use. Land can be owned or controlled by

federal entities (such as the Department of Agriculture, National Park Service, Bureau of Land Management, Department of Defense), states or local jurisdictions, or by individuals. These entities have the obligation and authority to determine suitable land use and management objectives. The goals and benefits can be economic, ecological, or social (public). Therefore, the primary factors to consider in evaluating land use effects are the physical changes that could affect the use and/or the management objectives of the owner/custodian of the land. Specifically in this case, the measure of impact on land use is the degree to which chaff and associated debris accumulate and alter the attributes of the land or interfere with its management or use.

Visual resources are affected by changes in the environment that impact personal visual perceptions of a place. Particular visual attributes of the environment may be valued for the feelings they tend to evoke in the majority of people. Places that are highly valued for their aesthetic quality are considered important visual resources. When visual attributes are altered sufficiently to elicit altered feelings about a space and its aesthetic quality, a visual impact results. The primary factors to be considered in evaluating visual effects are the visual quality of the area and the visibility of accumulated chaff and related debris. Only the foreground visual environment is expected to be affected, due to the small size of chaff debris.

Table 3.8-1 identifies the potential sensitivity of land uses and specially designated areas to various types of effects. It includes the sensitivity of specific related resources, as well as of the land use itself. Based on the analysis of physical resources in Section 3.6 and biological resources in Section 3.7, the sensitivity of wildlife, livestock, and crops is generally considered low. The only exception might be sensitive (e.g., threatened or endangered) species in wildlife protection areas, particularly areas with aquatic habitats frequented by waterfowl. Water resources are not generally expected to be affected by chaff, unless it accumulates along shorelines. Because of their high level of dependence on water resources, the sensitivity of Wild and Scenic Rivers, coastal zones, well-head protection areas and sole-source aquifers, and wildlife preserves/refuges is considered higher than other land uses.

Chaff training is generally conducted in remote areas. It may be employed over land used for timber or agriculture but would have no effect on forest growth or crop production (see Sections 3.3, 3.5, 3.6, 3.7). Residential, commercial, and industrial uses also would not be affected by chaff material, which is widely dispersed, although chaff debris may be a slight nuisance if found. However, low use areas are not likely to experience significant accumulation of chaff debris and the overall sensitivity of these uses to chaff effects is therefore considered low.

Effects on aesthetics and land management objectives related principally to aesthetics, such as for visual resource areas and national parks and monuments, depend on local conditions and the potential visibility of chaff debris to visitors to the area.

3.8.2 Studies Conducted

Studies to examine the effects of chaff use on land use and visual resources included reviewing applicable laws for the protection of land use areas and resources, literature and database review, and field study to determine the visibility of chaff debris in various settings.

Table 3.8-1. Sensitivity of Land Uses to Chaff Impacts

Land Use or Specially Designated Area	Potential Resource Effect					
	Wildlife	Livestock	Crops	Water Resources	Management Objectives	Aesthetics
Wilderness	L	L	N/A	L	M/H	M/H
Wild and Scenic River	L	N/A	N/A	M	M/H	M/H
Coastal Zone	L	L	L	M	M	M/H
Wildlife Protection Area/Refuge	M	N/A	N/A	M	M	L
Wellhead Protection Area/Sole Source Aquifers	L	N/A	N/A	M	L	L
Area of Critical Environmental Concern	M	N/A	N/A	M	M	L
Visual Resource Area	L	L	L	L	M/H	M/H
National Park/Monument	L	N/A	N/A	L	M/H	M/H
Military	L	L	L	L	L	L
Forest	L	L	L	L	L	L
Agricultural	L	L	L	L	L	L
Recreation	L	L	N/A	L	M	M
Industrial	L	N/A	N/A	L	L	L
Residential	L	N/A	L	L	M	M
Commercial	L	N/A	L	L	L	L

H = High M = Medium L = Low N/A = Not Applicable

3.8.2.1 Regulatory Considerations

Federal laws protecting land use and visual resources are primarily aimed at preserving the attributes of specially designated areas and providing the legal basis for management actions by federal land managers or custodians. Review of legislation focused on federal laws concerning preservation and management of land for specific uses. Several states have enacted laws which apply specific land use restrictions or protection to land resources, but these can vary widely among local jurisdictions and have not been included in this review.

Federal Land Policy and Management Act of 1976 (FLPMA) (43 USC 1701 et seq.) was enacted to reverse historic federal land disposal policies and treat the public domain as a public trust to be retained forever and managed wisely, including lands that have been withdrawn for military use. The act defines the mission of the Bureau of Land Management (BLM) and requires the BLM to inventory and manage all resources within the lands it administers. FLPMA does not give BLM control of the sky above the public domain, nor does it forbid the landing of aircraft. Use of chaff in airspace over public land that has not been withdrawn for military may be of concern to the BLM if land attributes are degraded and if the ability to meet land management objectives is reduced. Visual resources are protected to the extent that managers of public lands have inventoried and evaluated visual resources and designated areas of outstanding visual quality which are managed to limit visible modifications according to the degree of sensitivity of the area.

Wilderness Act of 1964 requires a wilderness review of roadless federal land areas managed by the BLM or the U.S. Forest Service (USFS), to determine suitability for designation by Congress as a Wilderness Area. Wilderness Areas encompass at least 5,000 acres "of underdeveloped Federal land retaining its primeval character and influence, without permanent improvements or human habitation, which is protected and managed so as to preserve its natural conditions and which (1) generally appears to have been affected primarily by the forces of nature, with the imprint of man's work substantially unnoticeable..." (16 USC 1131(c)). Wilderness Study Areas, apparently suitable for wilderness designation but not yet confirmed by Act of Congress, are managed "so as not to impair the suitability of such areas for preservation as wilderness" (FLPMA, Section 603[c]). Temporary uses or uses that would not be detrimental to wilderness quality as defined above may be permitted.

Overflights over Wilderness Areas do not involve physical use or occupancy of the land, and Congress made provisions for certain kinds of established aircraft activity. On surface uses, the Wilderness Act specifies that "wilderness areas shall be devoted to the public purposes of recreational, scenic, scientific, educational, conservation, and historical use" (16 USC 1131[c]). Dropping chaff debris in Wilderness Areas is not one of the listed uses. Even if the quantities of debris from chaff and flare use are modest, if the debris is noticeable, a wilderness hiker could be annoyed at finding the "imprint of man's work." However, many hikers may not notice any debris and be unaware that chaff is being used in the area.

Wild and Scenic Rivers Act of 1968 defines wild, scenic, and recreational rivers, designates a river classification, and establishes limits to development on shoreline areas. Similar to highly valued Wilderness Areas, selected rivers and their immediate environments which "possess outstandingly

scenic, recreational, geologic, fish and wildlife, historic, cultural, or other similar values, shall be preserved in free-flowing condition, and they and their immediate environments shall be protected for the benefit and enjoyment of present and future generations." Accumulations of chaff fibers or chaff debris which affect any of these attributes along designated rivers could result in land use impacts to sensitive resources.

Coastal Zone Management Act of 1972 (CZMA) (P.L. 92-583; 16 USC 1451-1454) provides for state Coastal Zone Management Plans that control development and land use in a state-defined coastal zone. The state management plan is a land use plan with additional environmental elements. Federal land was excluded from the coastal zone, but each federal agency was required to determine whether its actions on federal property would be consistent with state plans for the coastal zone. The 1990 amendments to the CZMA provide that "Each federal agency activity within or outside the coastal zone that affects any land or water use or natural resource of the coastal zone shall be carried out in a manner which is consistent to the maximum extent practicable with the enforceable policies of approved State management programs" (16 USC 1456 [c][1][A]). Although nothing in the definition of the coastal zone includes airspace above the surface, states have argued that overflights of the coastal zone are federal agency activities outside the coastal zone that affect the coastal zone. If chaff fibers and other debris can accumulate in coastal zones (including shorelines) and affect the suitability of the land for designated uses (such as sensitive wildlife habitat or scenic recreation areas), then chaff use may not be consistent with the enforceable policies of approved state management programs, resulting in land use impacts.

Federal Aviation Act (Air Commerce Act of 1926) (44 Stat. 568) declared that the sky above the minimum safe altitude of flight established by the Civil Aeronautics Authority was public highway, and any citizen could fly over the property of another in accordance with Civil Aeronautics Authority (now Federal Aviation Administration) rules. Minimum altitudes are specified in FAA Air Traffic Regulations (14 CFR 91,119). In sparsely populated areas, overflight is not permitted within 500 feet of any person, vessel, vehicle, or structure. Federal Aviation Regulations provide for special use airspace where users may conduct low-altitude or highly dangerous activities away from conflicting traffic (14 CFR 73).

3.8.2.2 Literature Review

No studies have been identified on the effects of chaff on land use or visual resources. A search was conducted of the DIALOG database, including the NTIS and Sociological abstracts, using combinations of key words, such as chaff, litter, visual resources, visual resource management, agriculture, recreational use, landscape, aesthetics, parks, forest, and land management. No citations relating to or analogous to this topic were retrieved. A search of the LIBROS database at the University of New Mexico using similar key words yielded some articles, mostly from the 1970s. The BLM library in Denver indicated that BLM documents are listed in the On-Line Computer Library Center (ONLC). This database is included within the LIBROS database. The U.S. Department of Agriculture Forest Service Information Center Service is only available for internal Forest Service use. Direct contact with agencies was limited to the Forest Service, Intermountain Research Station offices in Ogden, Utah and Missoula, Montana. Some information on litter in forest areas was available from these sources.

The literature review concentrated on topics related to scenic value and recreation uses, and perception of manmade objects in natural settings. The BLM and USFS have methodologies for rating scenic quality of landscapes (BLM 1986b; USFS 1974; Benson et al. 1985). The primary purpose for these ratings is to set objectives for preserving and managing areas relative to their scenic value. These methodologies are principally concerned with mid-to-distant landscape features.

Many research papers have presented study results and methods for evaluating public preferences and attitudes concerning landscape and recreation choices and reactions to visible management actions (e.g., controlled burns) (Watson et al. 1991; Schuler and Meadow 1975; Kaplan et al. 1972; Dunn 1976; Daniel et al. 1989). Much of the literature reviewed focused on evaluating methodologies used to measure viewer/user attitudes and choices and examining the reliability of the results. At issue were assumptions used in certain studies, the wide range of variables affecting choices, and the inability to control variables which influence the choices of the study participants (Dunn 1975; Brown et al. 1988; Forster 1989; Fischer 1975; Vaux et al. 1984).

Research papers by the USFS have examined the perceptibility of manmade objects and management actions (such as managed clear cuts, controlled burns, planned roadways) in natural settings (Magill 1990) and viewer attitudes towards the landscape settings and alterations (Magill 1990; Magill 1992). No studies were found on the perceptibility of litter in the landscape or small objects in foreground settings.

3.8.2.3 Field Studies

Field studies were conducted at two locations: Nellis Air Force Range Complex, Nevada (representative arid environment) and Townsend Air to Ground Gunnery Range, Georgia (representative temperate environment). The purpose of the studies was to determine if chaff and flare material is noticeable in the natural context, determine the distances at which chaff and flare material is visible, identify and examine variables affecting its visibility, compare the frequency of visible chaff and flare debris in high-use compared to low-use area, and compare the frequency of visible chaff in arid versus temperate environments. The methodology and results of these studies are documented in *Technical Reports on Chaff and Flares, Technical Report No. 4, Field Studies* (USAF 1994c). Field investigations were conducted in both high-use and low-use areas.

Two methods were used during field investigations: an *in situ* method and a "placed" method. The *in situ* method consisted of walking through selected areas to count the number of sightings of chaff debris and filaments, and to observe factors affecting their visibility in the natural environment. Observations were recorded about the natural context and contrast of the material. A log was kept of the number of person-hours spent looking, and the number and type of chaff debris items found.

The second method consisted of placing chaff debris items in different natural contexts, and evaluating at what distances items were visible and whether visibility was affected by context. Items were placed in both "optimal" viewing contexts (such as the center of a pathway in full sunlight) and "average" viewing contexts (such as to the side of a pathway, in shadow, or close to a rock or shrub). A log was kept of the context, type, and distance at which each placed item was

noticed. The "placed" method was intended to control variables in order to determine distance that specific debris items can generally be seen.

3.8.3 Findings

The literature review indicated that scenic quality affects recreational choices (Daniel et al. 1989). However, factors such as previous experience, location, and amenities would also affect choices. Studies indicate a broad range of landscape preferences (Magill 1990; Magill 1992; Vaux et al. 1984) and opinions about the desirability of manmade features (such as roads, mines, structures) or management actions (such as clear cuts, fire breaks, controlled burning) (Magill 1990). In addition, people perceive similar views differently, and some viewers may not detect manmade objects in natural settings, or may erroneously perceive manmade features in unaltered landscapes. When objects were detected, opinions varied about the desirability or effect of these objects on landscape quality (Magill 1990; Magill 1992). Reactions to both natural and altered landscapes range from highly positive to highly negative, depending on the individual (Magill 1990; Vaux et al. 1984). Viewers who were informed of the purpose of planned alterations, such as controlled burns, planned access roads, managed clear cuts, tended to respond more positively (McCool and Stankey 1986, Magill 1990).

The results of the field studies indicated that most debris and chaff fiber clumps found *in situ* were noticeable at distances of 5 to 25 feet, depending on the type, color, and size of the debris and the complexity of the background. Background complexity was found to reduce visibility of debris. This is consistent with literature findings that "heterogeneity" of landscapes reduces the visibility of "visual misfits" in landscapes (Magill 1990). In the absence of intervening objects (such as rocks or shrubs), visibility was mostly reduced by the complexity of ground texture in arid environments and by varied surface coloration (from leaves, grasses, soils, and twigs) in temperate environments. In areas with high levels of chaff use, sightings occurred once per hour on average in both temperate and arid environments. In low-use arid environments, sightings occurred about once every 8.5 hours (once per day). In temperate conditions, several chaff fiber clumps were observed from recent (previous day) training activity, but there was no evidence of accumulated chaff fibers over time. It is assumed that fibers are washed down by rain and quickly covered by soil or vegetation.

In the "placed" study, distances were recorded at which debris became noticeable, distinguishable, and distracting. Debris was determined to be "noticeable" when its color, reflectivity, or general form first could be identified from a distance although it could not be distinguished as a separate object with certainty. (For example, a glimpse of yellow is the first "noticeable" characteristic of one type of plastic casing). Debris became "distinguishable" when its form was determined to be separate from surrounding objects such that it was clearly perceived to be a distinct object. Debris became "distracting" when the geometry of its form cued the viewer that the object may be intrusive, and not an element of the surrounding natural environment, particularly if it was not a familiar, identifiable object. Analogous terms were used by Magill (1990) to describe detection and identification thresholds for distances at which objects were initially perceived and subsequently identified in natural landscapes. **Table 3.8-2** summarizes the results of the chaff visibility studies in arid and temperate environments.

Table 3.8-2. Summary of Visibility of Chaff Items Placed in Arid and Temperate Environments

Item	Area Description	Viewing Context	Noticeable (feet)	Distinguish-able (feet)	Distracting (feet)
Arid Environment					
Endcap (cream)	Basin and bajada, low sage	Optimal	12	7	4
		Average	5	5	3
Endcap (red)	Joshua tree, low sage	Optimal	20	15	7
		Average	15	12	7
Chaff casing	Joshua tree, low sage	Optimal	75	70	10
		Average	20	10	10
Chaff casing	Piñon-juniper slopes	Optimal	40	20	20
		Average	10	5	5
Endcap (cream)	Piñon-juniper slopes	Optimal	6	3	2
		Average	3	2	1
Temperate Environment					
Endcap (cream)	Upland forest, along old logging road, shady, dark soil, varied colors on surface from leaf debris	Optimal	12	12	5
		Average	6	6	6
Endcap (red)	Upland forest, along old logging road, shady, dark soil, varied colors on surface from leaf debris	Optimal	15	7	7
		Average	6	16	6
Chaff casing	Upland forest, along old logging road, shady, dark soil, varied colors on surface from leaf debris	Optimal	60	30	30
		Average	15	15	15

In both arid and temperate environments, chaff debris was often indistinguishable from natural and human made "look-alikes" found in the same context. Broken chaff filaments incorporated into soils resembled the reflectivity of mica or quartz sand grains. Weathered yellow chaff casings appeared indistinguishable from yellow-green native vegetation. Small endcaps blended with the gravels and pebbles of the desert pavement.

In temperate areas, chaff filament clumps appeared to be tufts of animal hair on vegetation, or feathery plumes of milkweed seeds. Dew on spiderwebs appeared like chaff filaments on the ground. Small endcaps were similar in size, color, and visibility to small mushrooms and had the same visibility as bottle caps, one of the most common litter items. In most areas with public access where chaff is used, common litter items included empty cans and bottles, bullet casings, paper and foil wrappers, and bottle caps, all of which have similar visibility as chaff debris.

No chaff debris was visible from within a moving vehicle due to viewing distance and reduced ability to focus on specific objects in the foreground.

The field observations conducted for this study were made by personnel familiar with chaff and chaff debris and who were specifically looking for evidence of chaff debris. It is not known if chaff debris would be detected by unknowledgeable observers as frequently as it was by the field study investigators. It is probable that the investigators' familiarity with the appearance of chaff debris contributed to a higher rate of observation and detection at farther distances than by unfamiliar observers.

3.8.4 Conclusions

Based on the field studies, frequency of sighting chaff fibers and other chaff debris is related to the intensity of its use. This conclusion is also supported by a previous field survey of the Desert Elgin South MOA at the Nellis complex, which found that chaff and flare debris would be encountered infrequently by recreational users (USAF 1994d). Typically, chaff and flare use in MOAs is less intense than in range areas.

Overall, chaff debris has low visibility and little effect on the aesthetic quality of the environment. Chaff debris does not accumulate in quantities that make it objectionable, or even noticeable to most persons in low-use areas. Chaff debris is only visible in the foreground and would not affect the attributes that contribute to outstanding visual quality using the BLM or USFS methodologies. In addition, chaff debris is only visible in fairly open contexts where vegetation is sparse, along a road or pathway, or in cleared and maintained areas. These types of areas provide access for pedestrians and unobstructed line-of-sight to the ground. Chaff fibers and debris may be noticed occasionally by outdoor recreationists but would not attract attention, due to their small size or to their similarity to other familiar natural or manmade objects. However, in areas specifically protected to preserve naturalness and pristine qualities, such as Wilderness Areas or Wild and Scenic Rivers, users (both the public and land managers) are more likely to perceive chaff debris as undesirable and unattractive since it conflicts with expectations of primeval character and management objectives to preserve naturalness.

It is unlikely that chaff debris could accumulate in quantities that would be noticeable by private owners, or, if it did, that it would reduce the land's value for a specific use (residential, commercial, agricultural, or industrial), although it may be perceived as annoying or intrusive.

Chaff use is not expected to affect agricultural, industrial, or commercial land uses. Based on studies of chaff effects on livestock (see Section 3.7), incidental ingestion of chaff does not affect health, weight gain, or reproductive capability. Furthermore, chemicals leaching from chaff would not adversely affect livestock food sources. Chaff that becomes deposited on crop lands would be easily washed off and is not expected to affect the quality or safety of agricultural products. Should chaff fibers become imbedded in the fur of livestock (e.g., wool), these would be removed during standard cleaning operations. No adverse effects are anticipated.

3.9 CULTURAL RESOURCES

3.9.1 Issues Addressed

The effects of chaff on cultural resources discussed in this section relate to:

- The potential for accumulation of chaff debris to alter the aesthetic setting and context of significant cultural resources.
- The potential for chaff to physically or chemically impact cultural resources by deposition, accumulation, clumping, decomposition, leaching, and drifting.

Cultural resources are defined as any prehistoric or historic district, site, building, structure, or object considered important to a culture, subculture, or community for scientific, traditional, religious or any other reason. They include archaeological resources, architectural resources, and traditional resources. Prehistoric and historic archaeological resources are locations where human activity has measurably altered the earth or left deposits of physical remains. Architectural resources include standing buildings, dams, canals, bridges and other structures of historic or aesthetic significance. Traditional resources, or traditional cultural properties, can include archaeological resources, buildings, neighborhoods, prominent topographic features, habitats, plants, animals, and minerals that Native Americans or other groups consider essential for the persistence of their traditional culture.

3.9.2 Studies Conducted

Existing literature about chaff was reviewed to determine whether there was any available information pertaining to its potential effects on cultural resources. No field observations or experimental studies were conducted as part of this analysis. Field studies were conducted to assess visual effects of chaff debris in various contexts (see Section 3.8). The findings from those studies were used to evaluate potential aesthetic effects on cultural resources.

3.9.2.1 Regulatory Considerations

Numerous federal laws and regulations require federal agencies to consider the effects of actions on cultural resources. These laws and regulations stipulate a process for compliance, define the responsibilities of the agency proposing the action, and prescribe the relationship among other involved agencies such as state historic commissions. The most pertinent laws and regulations concerning the protection and treatment of cultural resources are described below.

National Historic Preservation Act of 1966 (16 USC Section 470-470(m)) provides a broad base for the implementation of preservation goals by establishing the National Register of Historic Places and the Advisory Council on Historic Preservation. Section 160 of this Act requires that federal agencies take into account the effect of an action or undertaking on cultural resources included in or eligible for inclusion in the National Register. 36 CFR 800 establishes an explicit set of procedures for federal agencies to meet their obligations under the National Historic Preservation Act. The regulations operationalize the requirements of the Section 106 process, establishing procedures for determining the eligibility of a resource and for defining possible adverse effects.

To be considered significant, archaeological and architectural resources must meet one or more of the criteria for inclusion on the National Register of Historic Places (as defined in 36 CFR 60.4). Impacts to cultural resources could result if the integrity or research potential that make a site eligible for inclusion on the National Register of Historic Places are damaged or altered, or if the surrounding environment that contribute to the resource's significance are altered. Regulations also indicate a resource must not be neglected to the extent that it deteriorates or is destroyed.

Executive Order 11593 (1971) directs all federal land-holding agencies to identify cultural resources, nominate qualifying resources to the National Register, and avoid damaging resources that might be eligible for the National Register.

Archaeological Resources Protection Act of 1979 (16 USC Section 470) ensures the protection of archaeological resources on federal lands. This act defines civil and criminal penalties for illegally obtaining or affecting archaeological resources on federal or Native American lands.

American Indian Religious Freedom Act of 1978 (42 USC Section 1996) states that it is the policy of the United States to protect and preserve for American Indians their inherent right of freedom to believe, express, and exercise traditional religions. These rights include, but are not limited to, access to traditional sites, use and possession of sacred objects, and the freedom to worship through ceremonial and traditional rites.

Native American Graves Protection and Repatriation Act of 1990 provides protection to gravesites of Native Americans. There are no legally established criteria for assessing the significance of traditional Native American resources. These criteria must be established primarily through consultation with Native Americans according to the requirements of the American Indian Religious Freedom Act and the Native American Graves Protection and Repatriation Act.

3.9.2.2 Literature Review

The literature review revealed no studies on the effects of chaff on cultural resources. However, a few studies pertaining to other resources can be used to infer the effects of chaff on certain classes of cultural resources. For example, various studies have been conducted on the physical and chemical effects of chaff on natural resources, and these can be used to infer potential effects on some traditional Native American resources, such as wildlife, plants, and water. Reviews of available data on these issues are included in Sections 3.3, 3.6, 3.7, and 3.8. In all cases, potential effects would be related to how chaff can become dispersed on the ground and, consequently, on archaeological, architectural, and traditional resources. Factors affecting chaff dispersal include release altitude, wind direction and velocity, humidity, and release quantities.

3.9.3 Findings

3.9.3.1 Aesthetics Effects

The potential for chaff deposition, accumulation, clumping, and drifting to adversely affect the aesthetic setting and context of cultural resources depends on how noticeable it is and whether it diminishes the quality of the setting. Such an effect would be adverse only on cultural resources where setting is a contributing characteristic of site significance, as evaluated under National Register criteria (36 CFR 60.4).

Few studies have examined the effects of chaff on architecture in general, and none have evaluated effects on historic buildings, because this type of resource is not often located near training areas where chaff is used. One report (HQ TAC/DOO 1984) referenced urban areas and concluded that chaff has no adverse impact to rooftops. Nonetheless, because airborne chaff can travel a significant distance from its point of dispersal, possibly drifting onto buildings, the potential for impact on the aesthetics of important architectural resources was examined.

Field studies conducted in conjunction with the land use and aesthetics analysis (see Section 3.8) concluded that chaff and chaff debris are rarely encountered in low-use areas, such as MOAs, and that they are not generally distracting. In most cases, chaff debris was indistinguishable from other litter or from natural analogs. Thus, the only circumstance in which chaff debris has the potential to significantly affect the setting of a cultural property is if large quantities of chaff debris accumulated in a confined area, such as an architectural site or district or an archaeological site that attracts visitors. This is highly unlikely because these types of resources are not generally located beneath airspace where heavy chaff use is concentrated.

No research has been conducted on Native American concerns related to the aesthetics of chaff deposits on the landscape. For example, chaff is relatively insoluble in water and, depending upon individual particle weight, could collect along a shoreline. The aesthetic effects of such accumulation may be viewed by Native American fisherman as adverse should the chaff accumulate within a traditional use area.

3.9.3.2 Physical and Chemical Effects

It is not know whether chaff can have physical or chemical effects on archaeological or architectural resources; however, it is unlikely. The constituents of chaff and chaff debris are either inert or already prevalent in the environment (see Section 3.6).

Airborne chaff can travel significant distances, possibly drifting onto Native American communities, traditional food gathering areas, and religious use areas. This could lead to increased deposition and accumulation of chaff on traditional cultural resources. For example, chaff may be ingested by wildlife considered to be a traditional resource by Native Americans. There are few data available on the impact of chaff on aquatic animals and wildlife; however, various studies (SEA 1990; USAF Aeromedical Laboratory 1952; UKHSEMD 1988) suggest that chaff is not toxic to animals. Increased uptake of aluminum by plants used by Native Americans is not considered to be a concern.

3.9.4 Conclusions

Based on the findings presented in other sections of this report, there appears to be little potential for chaff to have direct physical or chemical effects on cultural resources or their environment, or indirect effects on traditional resources such as plants and wildlife. The primary possibility for impact on cultural resources is the potential for accumulated chaff debris to affect the aesthetic setting and context of such resources. Although this is highly unlikely, it should be examined on a site-specific basis if there are resources that are particularly sensitive to aesthetic impacts underlying airspace used for chaff.

4.0 ENVIRONMENTAL EFFECTS OF FLARES

4.1 ENVIRONMENTAL ISSUES

Like chaff, self-protection flares are ejected from aircraft into the air. Unlike chaff, flares that perform properly are designed to be consumed (burn out) before reaching the ground. Therefore, the only materials that would be deposited on the earth's surface are the incidental debris from flare canisters and occasional duds or burning flares. Flares have the potential for raising a number of direct and indirect environmental and safety issues. **Figure 4.1-1** presents a graphic depiction of the potential pathways self-protection flares and the by-products of their combustion may take in the environment, the various recipients they may affect, and the types of impacts to be investigated. This chapter addresses the potential effects of self-protection flares only; it does not address illumination or signaling flares.

Use of self-protection flares raises a number of environmental issues. Flares may present potential safety risks to aircrews from improper or incomplete ejection. Safety risks to persons on the ground may result from faulty ignition, leading to duds that could be immediately hazardous if they hit someone on descent, or that could remain a potential hazard if picked up later and handled improperly. Burning flares generate air emissions with potential air quality impacts. If a flare is still burning when it hits the ground, it may cause a fire and result in a variety of secondary impacts on soil, water, biological resources, cultural resources, land use, and human safety.

Dud flares and flares that have not been fully consumed are potentially explosive when mixed with water. This raises questions of potential hazards and chemical effects from flares falling into water bodies, as well as resulting impacts on biota. If a dud flare lands on the ground, it may react with latent moisture or it may remain intact, raising issues of chemical effects on soil and potential indirect impacts on groundwater and vegetation. Wildlife issues include whether light from flares might affect the vision of nocturnal animals. Dud flares and flare debris may accumulate in areas underlying training airspace and result in land use and visual impacts.

4.2 MATERIAL COMPOSITION AND MANUFACTURE

Information on self-protection flares used by the Air Force was obtained from the Air Logistics Centers at Hill and Warner Robins AFBs. Published specifications and technical orders were reviewed, and interviews were conducted with Air Force and Tracor personnel.

Self-protection flares are primarily mixtures of magnesium and Teflon (polytetrafluroethylene), molded into rectangular shapes. Longitudinal grooves in this material provide spaces for more sensitive materials that aid in ignition. They include:

- First fire material (potassium perchlorate, boron powder, magnesium powder, barium chromate, Viton A or Fluorel binder) which is applied to grooves on the top of the flare next to the ignitor;

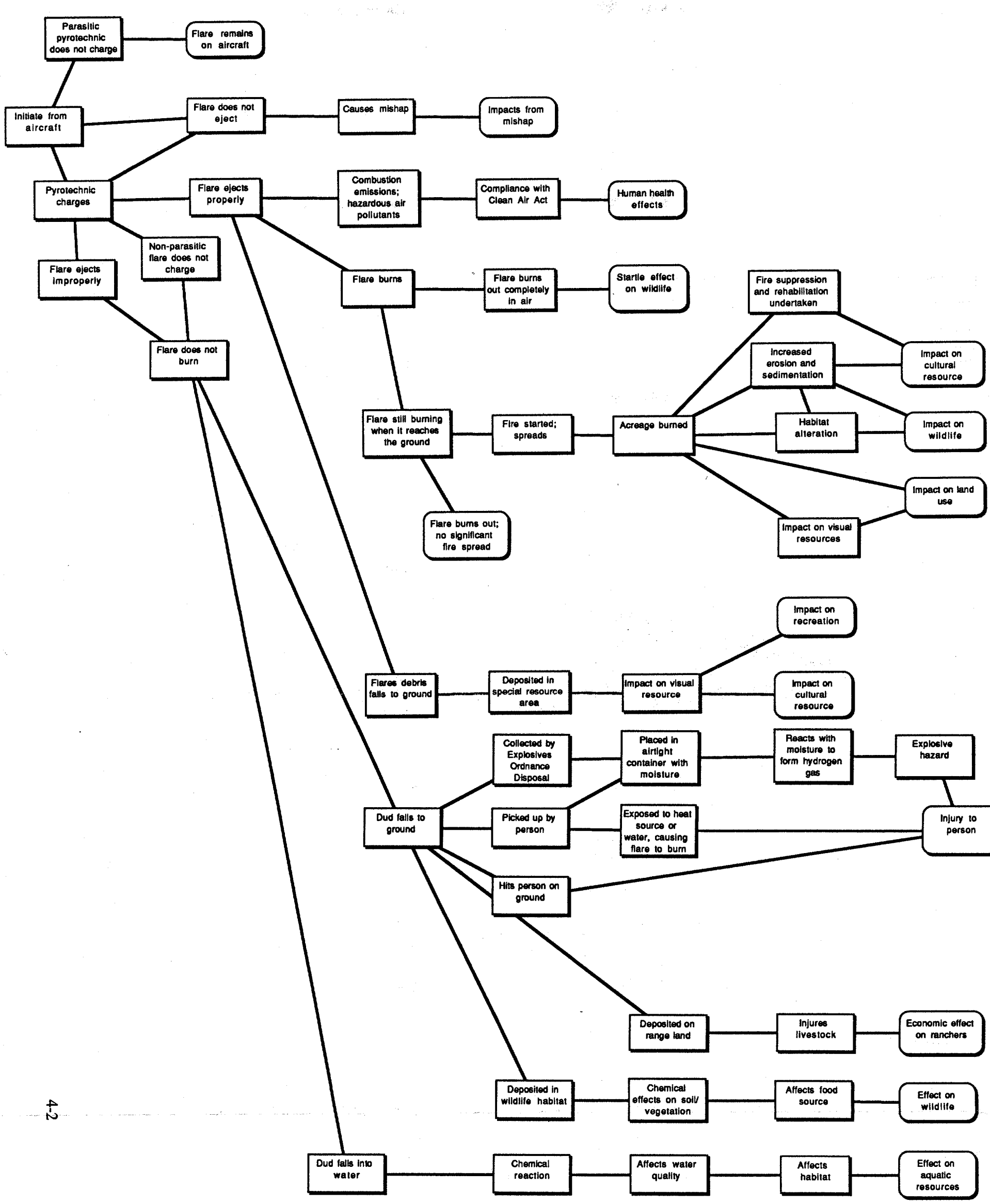


Figure 4.1-1. Flares Pathways into the Environment

- Intermediate fire material (magnesium powder, Teflon, Viton A or Fluorel) which is applied to side grooves; and
- Dip coat (magnesium powder, Teflon, Viton A or Fluorel) which is applied to the outer surface of the flare pellet.

The purpose of these materials is to provide an ignition path to the main body of the flare.

Typically, flares are wrapped with an aluminum-filament-reinforced tape and inserted into an aluminum (0.03 inches thick) case that is closed with a felt spacer and a small plastic end cap. The top of the case has a pyrotechnic impulse cartridge that is activated electrically to produce hot gases that push a piston, the flare material, and the end cap out of the aircraft into the airstream. Typical flare composition and debris are summarized in **Table 4.2-1** for most flares used on ACC aircraft. Different types of flares differ primarily in their size and the method used for ignition. **Table 4.2-2** identifies the types of self-protection flares used by ACC units. In addition, Navy MJU-2, MJU-8, and Mark 46 flares are used in ACC controlled airspace.

When ignited, flares burn for less than 10 seconds at approximately 2,000 degrees Fahrenheit. The combustion products from a MJU-10 flare were analyzed in a report by the Tracor Company to the Aeronautical Systems Division (12 July 1978) as follows:

- Magnesium oxide (MgO) -- 551 grams
- Magnesium chloride (MgCl) -- 91 grams
- Carbon (C) -- 41 grams
- Magnesium fluoride (MgF) -- 319 grams

Small quantities of carbon dioxide (CO_2), carbon monoxide (CO), and difluorine oxide (F_2O) were also found. Cartridge residue was analyzed to contain:

- Nitrogen (N) -- 0.1 gram
- CO_2 -- 0.3 gram
- CO -- 0.2 gram
- Water vapor -- 0.1 gram
- Hydrogen (H_2) -- 0.05 gram

Less than 0.05 grams of boron oxide (B_2O_3), potassium oxide (K_2O), and chromium oxide (Cr_2O_3) were also identified. No comparable data were available for other flares.

The ALA-17A/B flares consist of two independently fired aluminum cylinders, each 4.75 inches long and 2.25 inches in diameter, crimped together end-to-end. When the top cylinder is fired, the flare pellet is ejected from the aircraft, along with the entire bottom cylinder. Impulse cartridges are

Table 4.2-1. Typical Composition and Debris of Self-Protection Flares

Part	Components
Combustible	
Flare Pellet	Polytetrafluoroethylene (Teflon) (-[C_2F_4]$_n$- n=20,000 units) Magnesium (Mg) Fluoroelastomer (Viton, Fluorel, Hytemp)
First Fire Mixture[1]	Boron (B) Magnesium (Mg) Potassium perchlorate ($KClO_4$) Barium chromate ($BaCrO_4$) Fluoroelastomer
Immediate Fire/Dip Coat	Polytetrafluoroethylene (Teflon) (-[C_2F_4]$_n$- n=20,000 units) Magnesium (Mg) Fluoroelastomer
Primer Assembly (in Safety and Initiation Device)[2]	Initiation Charge (15 mg) Lead styphnate Lead azide (N_6Pb) Barium nitrate (N_2O_6Ba) Antimony trisulfide (Sb_2S_3) Tetracene ($C_{18}H_{12}$) Output Charge (40 mg) Zirconium (Zr) Molybdenum trioxide (MoO_3) Potassium perchlorate ($KClO_4$)
Assemblage (Debris)	
Aluminum Wrap	Mylar or filament tape bonded to aluminum tape
End Cap	Plastic (nylon) or aluminum[3]
Felt Spacers	Felt pads (0.25 inches by cross section of flare)
Piston	Plastic (nylon, tefzel, zytel) or aluminum[6]
Slider Assembly[4]	2 plastic pieces, 0.5 ′ 0.825 ′ 2 inches, (delrin) 2 springs, 0.625 ′ 0.125 inches, (steel) 1 roll pin (steel)
Safety and Initiation Device[5]	G-weight (steel) Locking bar and fork (steel) Push button and spring (steel) Firing pin (steel) Primer assembly

Generally applies to M-206, MJU-7/B, MJU-7A/B, and MJU-10/B flares, except as noted below.

Notes:

1) MJU-10/B does not have first fire mix; all other types do.
2) Within safety and initiation device used by MJU-7/B (non parasitic) and MJU-23/B only.
3) Aluminum used in MJU-10 and MJU-23/B only. MJU-23/B end cap has 0.5 inches of black rubber potting compound for shock absorption.
4) MJU-7/B and MJU-10/B only.
5) Used in non-parasitic MJU-7/B and MJU-23/B only.
6) Aluminum used in MJU-23/B only.

Source: Ogden Air Logistics Center, Hill AFB, Utah

Table 4.2-2. Self-Protection Flares Used by ACC Units

Attribute	ALA-17	MJU-7/B MBT Lot	MJU-7/B	MJU-7A/B	M-206	MJU-10/B	MJU-23/B
Aircraft	B-52	F-4, F-16, C-130	F-4, F-16, C-130	F-4, F-15, F-16, C-130	A-10, AC-130, C-17, F-16	F-15	B-1
Mode	Parasitic	Parasitic	Non-parasitic	Semi-parasitic	Parasitic	Semi-parasitic	Non-parasitic
Configuration	2 cylindrical cartridges in series	Rectangular	Rectangular	Rectangular	Rectangular	Rectangular	Cylindrical
Size	Each cylinder 4.75 x 2.25 in (diameter)	1 x 2 x 8 in (16 cubic inches)	1 x 2 x 8 in (16 cubic inches)	1 x 2 x 8 in (16 cubic inches)	1 x 1 x 8 in (8 cubic inches)	2.66 x 2 x 8 in; (42.6 cubic inches)	10.5 x 2.75 in (diameter); (19.8 cubic inches)
Impulse cartridge	None; electrically activated M-2 squib	BBU-36/B	BBU-36/B	BBU-36/B; MJU-7(T-1)/B simulator uses M-796	M-796	BBU-36/B; MJU-10(T-1)/B simulator uses M-796	BBU-46/B
Safety and Initiation Device	None	None	Mechanical mechanism with ignition charge	Slider assembly	None	Slider assembly	Mechanical mechanism with ignition charge
Weight (nominal)	Pellet: 18 oz Canister: 10 oz	13 oz	13 oz	13 oz (T-1 type: 4.8 oz)	6.9 oz	40 oz (T-1 type: 7.2 oz)	43 oz
Other Comments	Canister ejected with first unit	No longer being produced	No longer being produced	Simulator version (T-1) uses potassium chlorate, powdered sugar, and yellow dye smoke charge	Simulator version (T-1) uses potassium chlorate, powdered sugar, and yellow dye smoke charge	Simulator version (T-1) uses potassium chlorate, powdered sugar, and yellow dye smoke charge	

in = inch oz = ounce

Source: USAF Technical Orders 11A16-40-7, 11A16-41-7, 11A16-46-7

not used; the flares are fired directly with an electrically activated squib set in potting compound. The M-2 squib weighs 64.8 milligrams and is composed of 40 percent potassium chlorate, 32 percent lead thiocyanate, 18 percent charcoal, and 10 percent Egyptian lacquer. The debris includes the entire bottom cylinder assembly, as well as the end cap and felt spacers from the top flare. ACC units are estimated to use less than 4,000 of these flares annually.

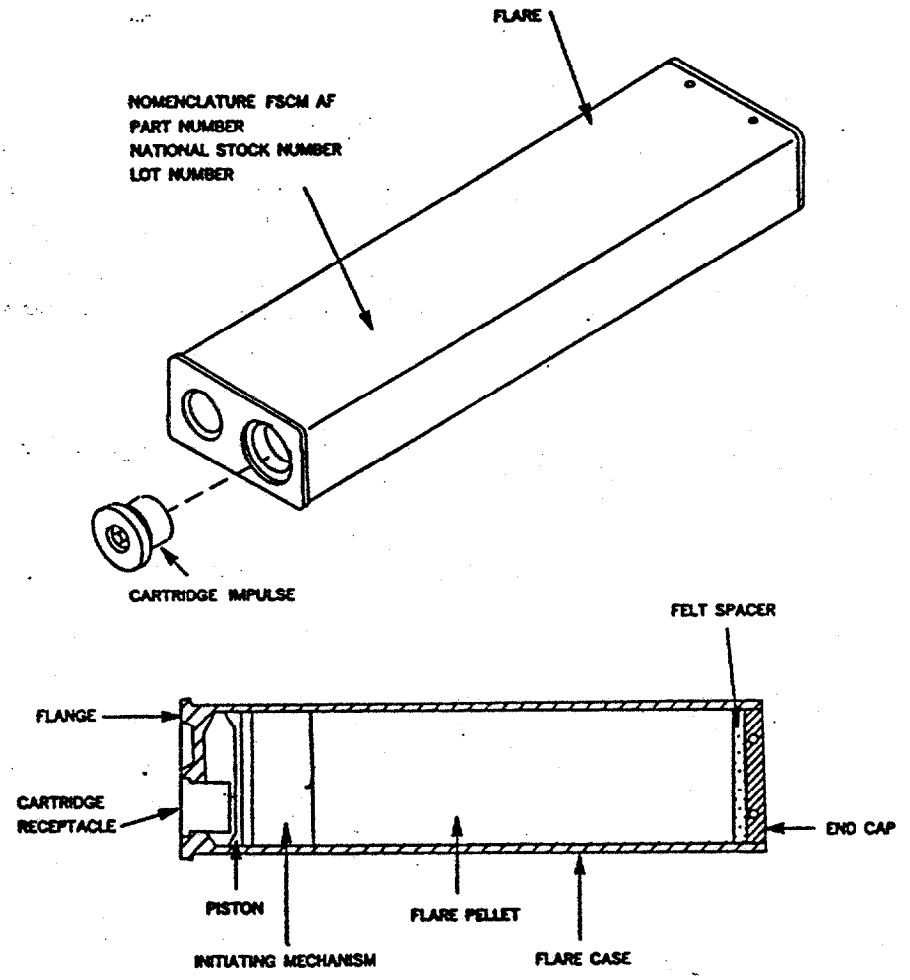
The MJU-7/B and A/B flare configuration is shown in **Figure 4.2-1**. All versions of this flare measure 1 by 2 by 8 inches and have a nominal weight of 13 ounces. They use a BBU-36/B impulse cartridge. The components of the cartridge are described in **Table 4.2-3**. These are the most heavily used flares by ACC units, which employ an estimated 215,000 per year.

There are two versions of the MJU-7/B: a "parasitic" and a "non-parasitic" type. The parasitic type is ignited in the aluminum case before it leaves the aircraft by holes in the piston that permit ignitor gases to contact the first fire mixture on top of the flare pellet. The non-parasitic type flare incorporates a mechanical mechanism (a safety and initiation device) to prevent ignition of the pellet in the case. This mechanism includes a G-weight, a locking bar and fork, a push button and spring, a firing pin, and primer assembly. When ignited by the firing pin, the primer assembly fires the ignition charge (15 mg of basic lead styphnate, lead azide, barium nitrate, antimony trisulfide, and tetracene) which fires the output charge (40 mg of zirconium, molybdenum trioxide, and potassium perchlorate), which ignites the flare pellet.

The MJU-7A/B, shown in **Figure 4.2-2**, was designed to reduce the complexity of the non-parasitic type flare, improve its reliability, and reduce debris. In this flare, the mechanical mechanism is replaced with a slider assembly that incorporates an initiation pellet (640 mg of magnesium, Teflon, and Viton A or Fluorel binder). This pellet is ignited by the impulse cartridge, but its hot gases do not reach the flare until the slider exits the case, exposing a fire passage from the initiation pellet to the first fire mixture on top of the flare pellet.

The parasitic type flare is less likely to produce duds, and the only debris is the plastic end cap and the remains of the piston. However, there is an increased risk of fire damage to the aircraft, compared with the non-parasitic flare. The non-parasitic flare can be expected to produce the largest number of duds and the most debris, due to the complexity of the ignition process. The MJU-7A/B provides a middle ground by igniting a small pellet inside the case, rather than the flare itself, thereby reducing both the safety risk and the quantity of debris. Since the complexity of the flare ignition process of the MJU-7A/B falls between the parasitic and non-parasitic versions of the MJU-7/B, the dud rate can also be expected to fall between them. The MJU-7/B is being phased out of the inventory (Fullmer, personal communication, 1995).

The MJU-7(T-1), shown in **Figure 4.2-3**, is a simulator version of the MJU-7/B. It replaces the magnesium flare pellet with a smoke charge. The smoke charge is smaller than a flare (5 inches versus 8 inches long) and is held in place inside the flare case by cardboard spacers. It is composed of doughnut-shaped pellets 0.75 inches in diameter with a 0.37 inch hole, 0.5 inches thick, encased in a cardboard tube. The charge material is 20 percent powdered sugar, 36 percent



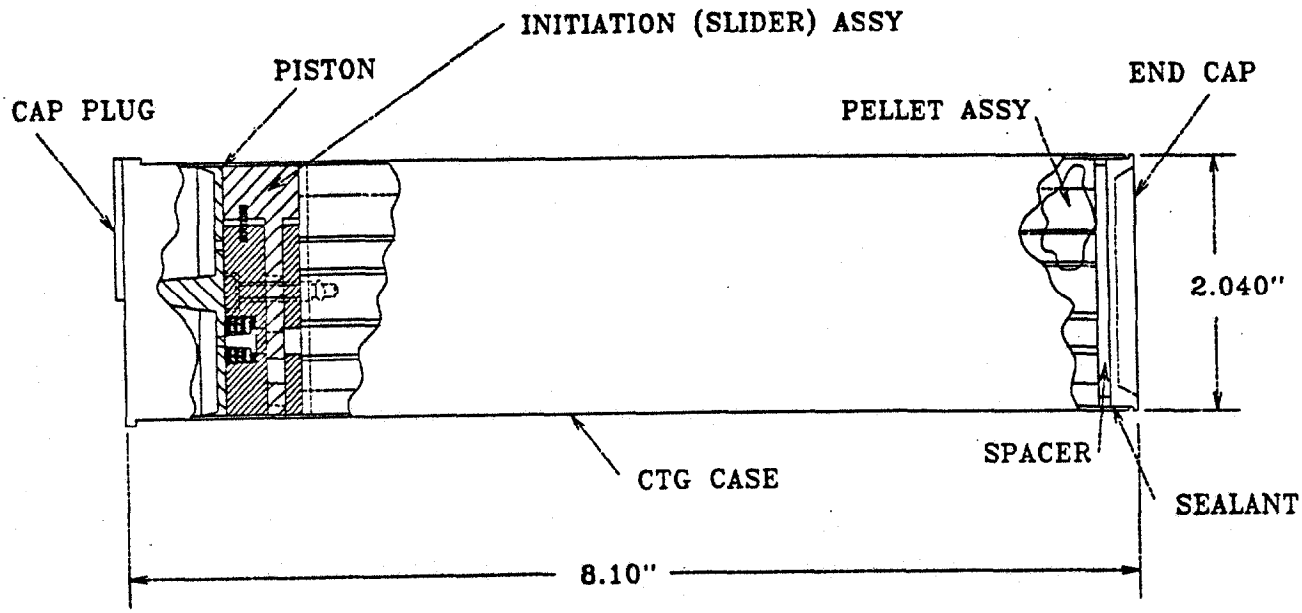
Source: T.O. 11A16-40-7

Figure 4.2-1. MJU-7B and MJU-7A/B Infrared Flare

Table 4.2-3. Impulse Cartridges Used With Flare Units

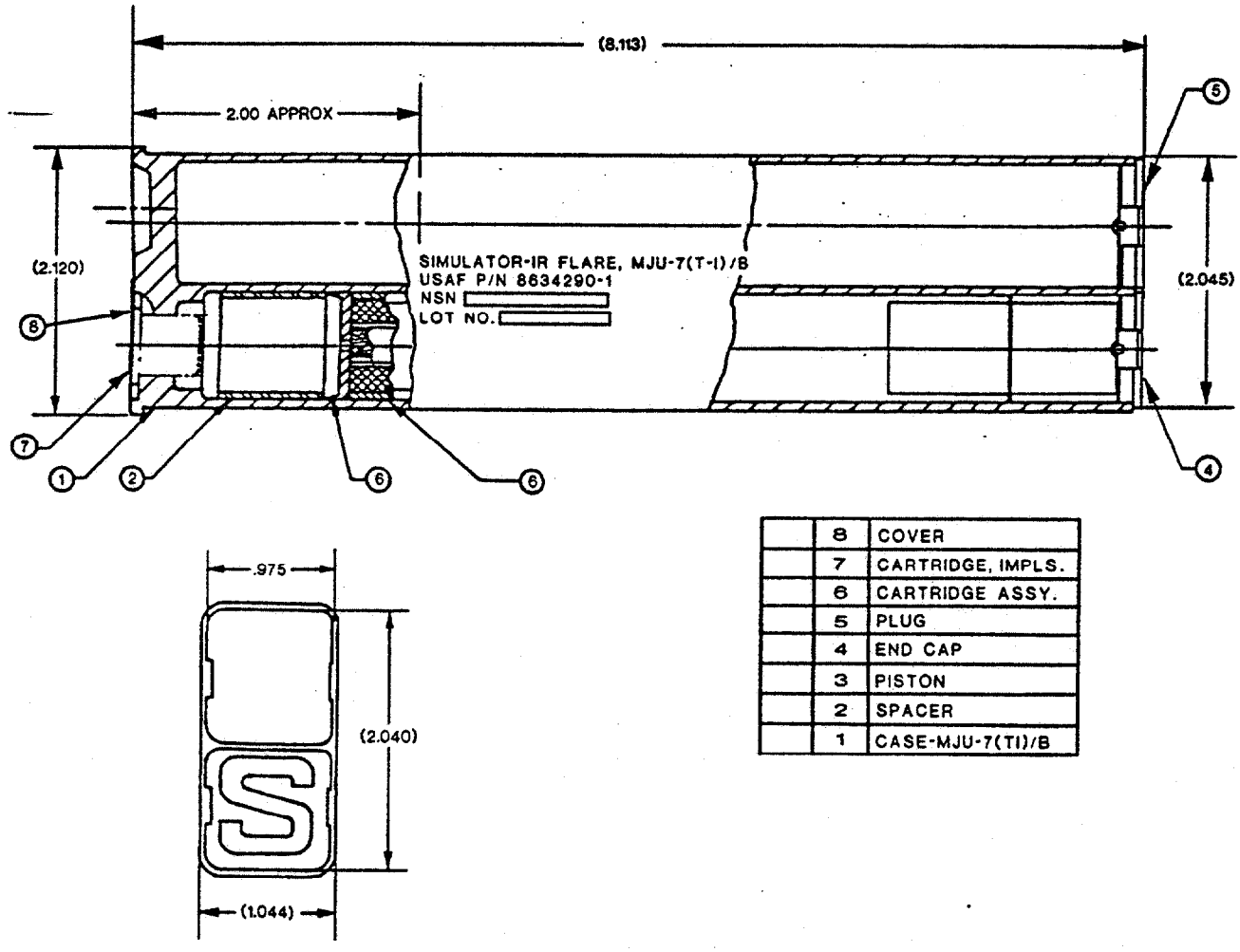
Component	BBU-36/B	BBU-46/B	M-796
Overall Size Overall Volume Total Explosive Volume	0.740 in x 0.550 in 0.236 cubic inches 0.081 cubic inches	1.224 in x 0.520 in 0.612 cubic inches 0.294 cubic inches	0.449 in x 0.530 in 0.104 cubic inches 0.033 cubic inches
Bridgewire	Tophet A	Tophet A	Tophet A 0.0025 in (diameter)
Closure Disk	scribed disc, washer	polyester film disc and plain discs for main charge and initiator	scribed disc, washer
Initiation Charge Volume Weight Compaction Composition	 0.01 cubic inches 100 mg 6200 psi 42.5% boron 52.5% potassium perchlorate 5.0% Viton A	 0.017 cubic inches to fill cavity 5100 psi 49.5% potassium perchlorate 49.5% titanium with potassium dichromate 1.0% Viton A or Fluorel	 0.011 cubic inches 100 mg 5500 psi 20.0% boron 80.0% calcium chromate
Booster Charge Volume Weight Compaction Composition	 0.01 cubic inches 150 mg 5100 psi 20% boron 80% potassium nitrate	 0.138 cubic inches 290 mg loose fill 23.7% boron 70.3% potassium nitrate 6% laminac binder	 0.011 cubic inches 70 mg 5500 psi 18% boron 82% potassium nitrate
Main Charge Volume Weight Compaction Composition	 0.061 cubic inches 655 mg loose fill Hercules #2400 smokeless powder *	 0.138 cubic inches 490 mg loose fill Hercules green dot powder	 0.011 cubic inches 185 mg loose fill Hercules HPC-1 (~40% nitrocellulose)

* Hercules #2400 smokeless powder contains nitrocellulose (50-77%), nitroglycerine (15-43%), and trace quantities of other materials.
in = inch
psi = pounds per square inch
Source: Air Logistics Center, Hill AFB, UT



Source: Ogden Air Logistics Center, Hill AFB, Utah

Figure 4.2-2. MJU-7 A/B Flare Assembly



	8	COVER
	7	CARTRIDGE, IMPLS.
	6	CARTRIDGE ASSY.
	5	PLUG
	4	END CAP
	3	PISTON
	2	SPACER
	1	CASE-MJU-7(TI)/B

Source: T.O. 11A16-40-7

Figure 4.2-3. Simulator Infrared Flare MJU-7(T-1)/B

$KClO_3$, 42 percent yellow dye (Chinoline Yellow-5), and 2 percent binder (Goodrich Hightemp, a dry rubber, and Teflon). It uses the M-796 impulse cartridge (**Figure 4.2-4**), which generates hot gases that push the piston down the case and simultaneously ignite a Quick Match cord (MIL-Q-378) in the center of the pellets. Resulting debris includes the plastic end cap and the remains of the cardboard spacers and piston.

The M-206 flare, shown in **Figure 4.2-5**, is the same length as the MJU-7 (8 inches), but half the cross-section (1 inch square). It uses a M-796 impulse cartridge that ignites the first fire mix simultaneously. The M-206 (T-1) is the simulator version of the flare. Approximately 120,000 M-206 and 4,000 M-206 (T-1) flares are used by ACC annually.

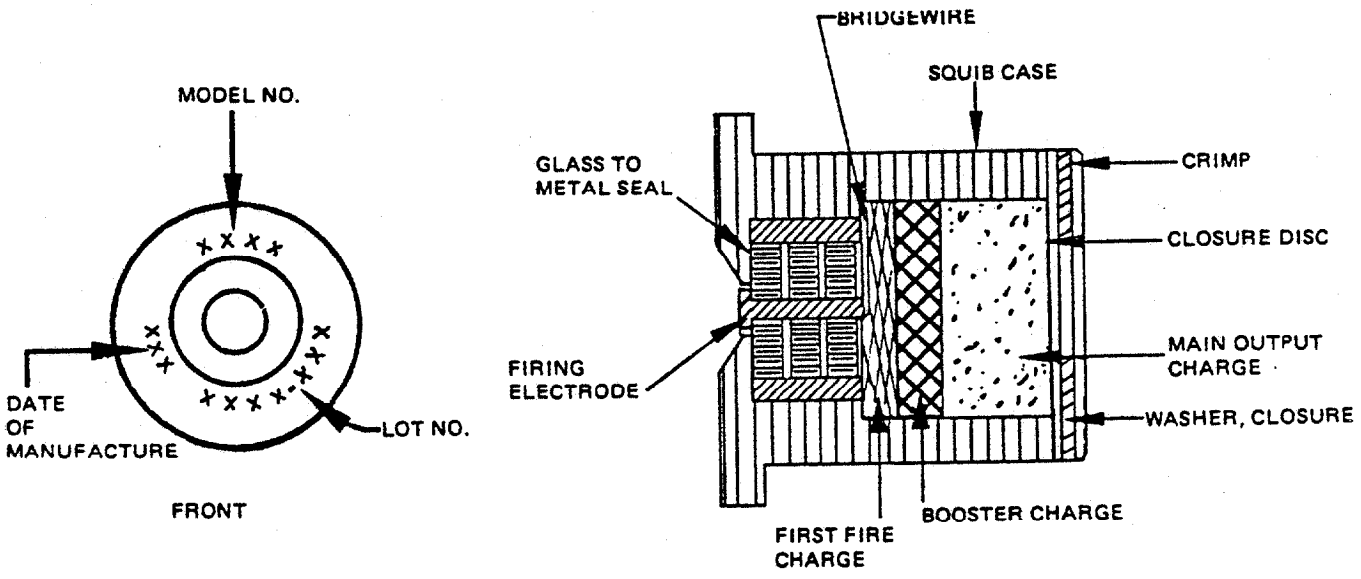
The MJU-10/B configuration, shown in **Figure 4.2-6**, is identical to the MJU-7A/B (containing the slider assembly), except the MJU-10/B is thicker (2.66 inches versus 1 inch), and it does not have a first fire mix. The first fire mix is also being eliminated in the MJU-7 to reduce cost and provide increased contractor safety by eliminating barium chromate. The MJU-10/B uses the BBU-36/B impulse cartridge. Approximately 2,000 of these flares are used by ACC units annually. There is also a simulator version, the MJU-10 (T-1), which uses the M-796 cartridge.

The MJU-23, shown in **Figure 4.2-7**, is a cylindrical flare used in small quantities on the B-1 aircraft. It is 10.5 inches long and 2.75 inches in diameter. It includes the same complex safety and initiation device as the non-parasitic version of the MJU-7/B. It has an aluminum end cap with 0.5 inches of black rubber potting compound designed to absorb the shock of hitting spring-loaded doors on the aircraft. It also uses an aluminum piston and includes strips of felt spacers on the side and circular felt spacers in the cylinder. The design is being simplified to reduce the relatively large quantity of debris. The MJU-23 uses the BBU-46/B impulse cartridge.

Three Navy flares could be used in ACC airspace: the MJU-2/B, the MJU-8A/B, and the Mark 46. The MJU-2/B is a cylindrical flare, 7.64 inches long and 1.57 inches in diameter. It is designed for F-4 aircraft and is in very limited use. The MJU-8A/B is 5.8 inches long and 1.42 inches in diameter. Its composition is similar to Air Force flares, except the end cap is aluminum instead of plastic, and a small aluminum cap (less than 0.5 inches in diameter) is used to contain the igniter composition. The inside diameter of the case forms a positive piston stop that reduces debris. The Mark 46 is identical to the MJU-8A/B except for burn time.

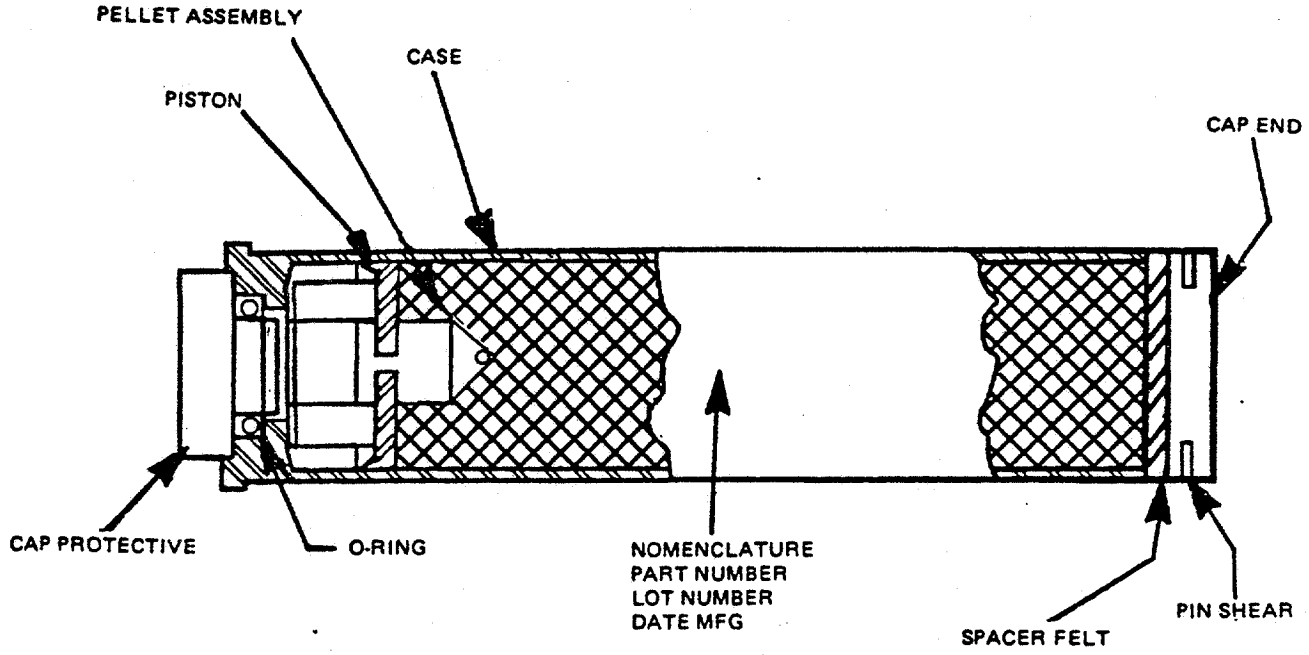
Flares are tested to ensure they meet performance requirements in terms of ejection, ignition, and effective radiant intensity. For example, MJU-7A/B flares must operate under the following conditions (ALC, Specification for Flare Assembly, MJU-7A/B, SP-7730620B, 27 March 1991):

- Temperature — 65 to 250 degrees Fahrenheit.
- Altitude — sea level to 35,000 feet.
- Humidity — up to 100 percent.
- Shock — test specified in MIL-STD-810B.



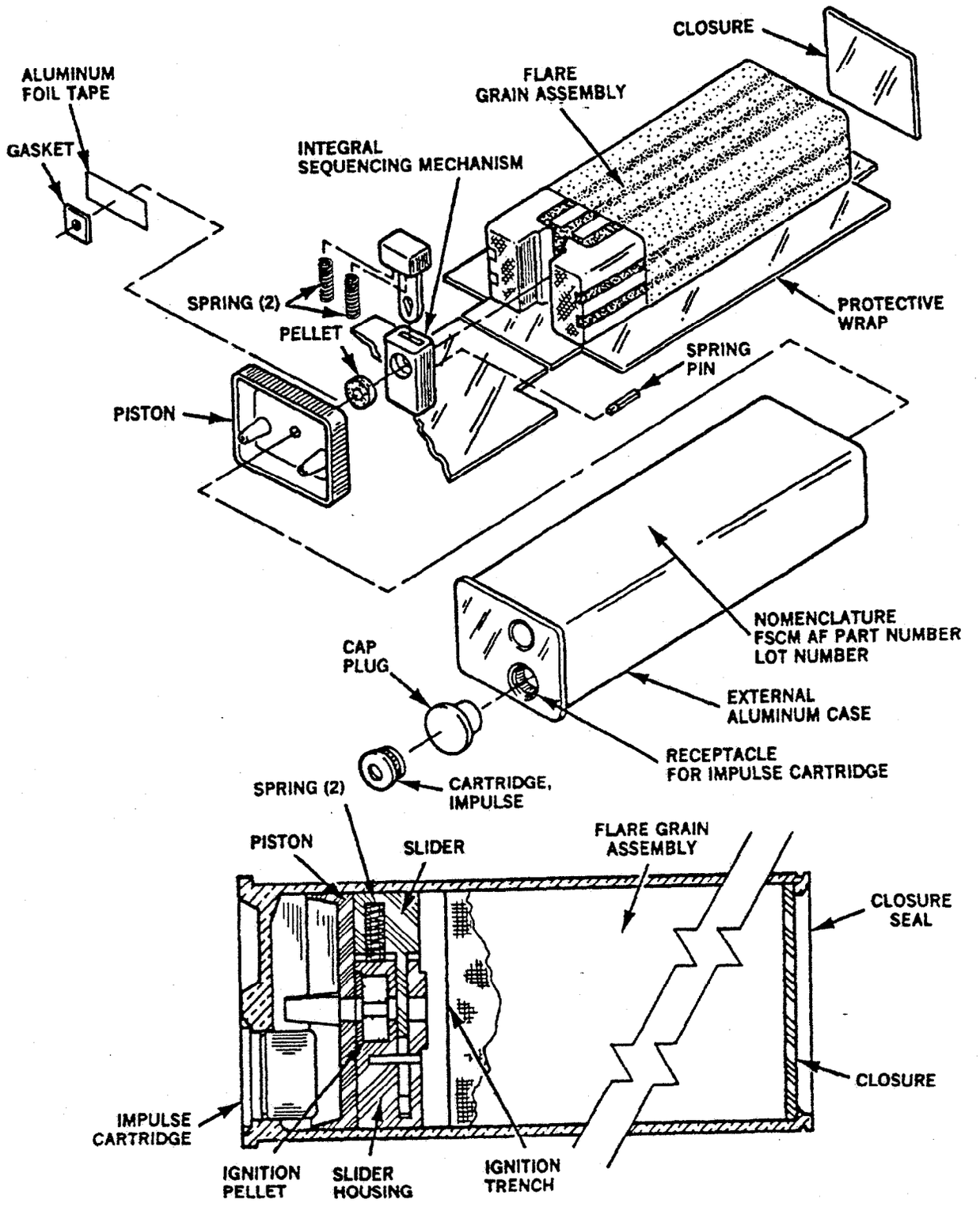
Source: T.O. 11A16-41-7

Figure 4.2-4. M-796 Impulse Cartridge



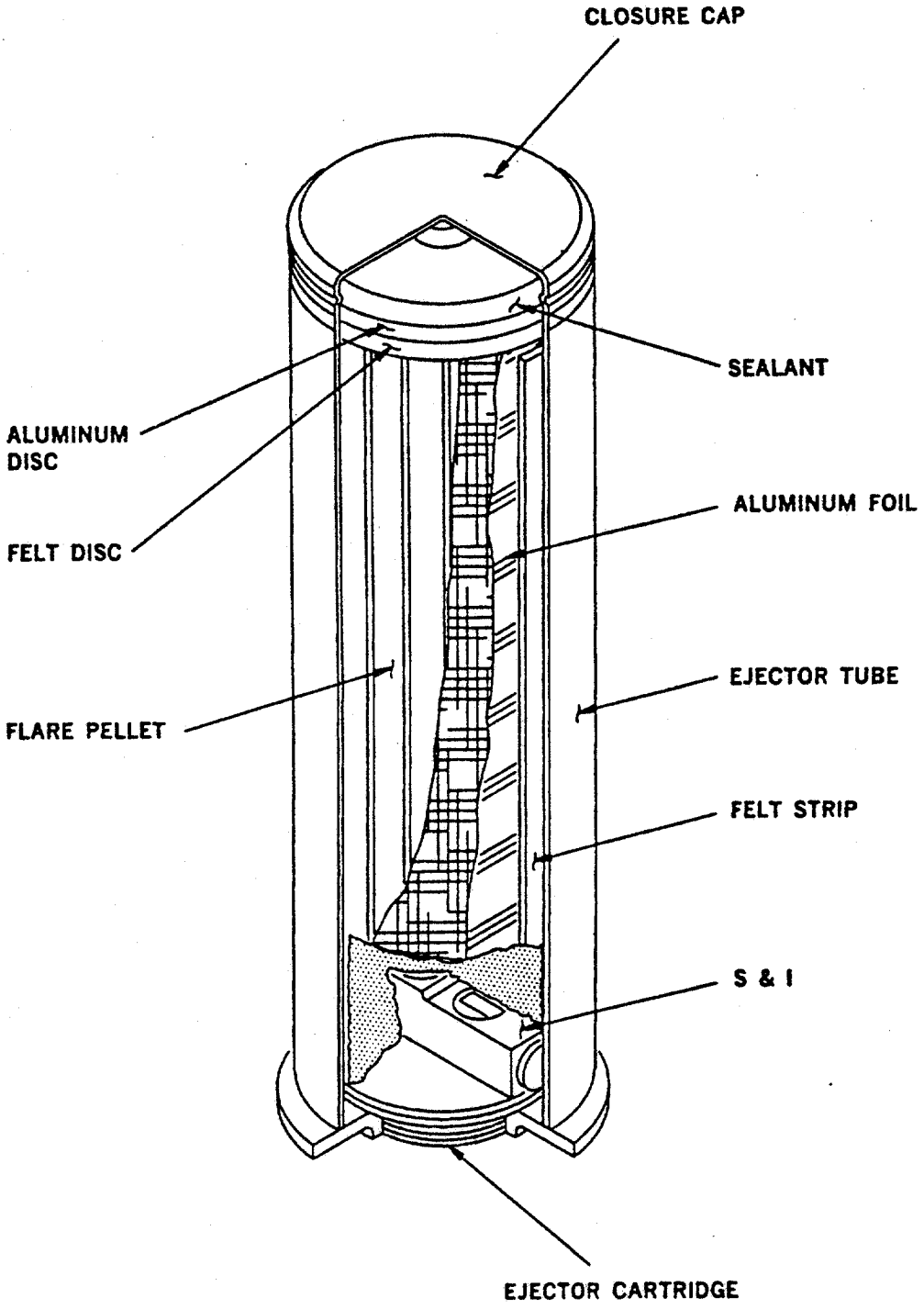
Source: T.O. 11A16-41-7

Figure 4.2-5. M-206 Flare



Source: T.O. 11A16-43-7

Figure 4.2-6. MJU-10/B Infrared Flare



S & I = safety and initiation device
Source: T.O. 11A16-41-7

Figure 4.2-7. MJU-23/B Infrared Flare

- Vibration — test specified in MIL-STD-810B.
- Crash Safety — load factors of 40 Gs longitudinal, 20 Gs vertical, 11 Gs in any direction.
- Drop Test — free-fall from 20 feet to hard surface.

Lot acceptance testing for the MJU-7A/B, the most heavily used flare (approximately 57 percent of all ACC flare use), examines the success of ignition and burn, pellet breakup, and indication of dispenser damage. The specification requires that lots pass an ignition and ejection test in accordance with MIL-STD-105, Inspection Level I, Acceptance Quality Level (AQL) of 1.0. In this test, with a sample size of 80, two failures would be acceptable, but three failures would not (Amey, personal communication, 1993). This means that the reliability of flares must be greater than 96.25 percent. However, to ensure that good lots are not erroneously rejected in these tests, the flares would have to be designed to a reliability of 99 percent (assuming a confidence level of 95 percent), which is consistent with an AQL of 1.0. Therefore, the reliability of the MJU-7A/B flare is expected to be closer to 99 percent.

4.3 TOXICITY OF FLARE MATERIALS

The principal material in flare pellets is magnesium. The toxicity of the residue from flare use depends on the quantity and concentration of exposure and the ability of an exposed organism to metabolize and excrete the matter. Magnesium is an essential nutrient often found in nuts, seafood, and cereals, and is a component in all types of chlorophyll. On the other hand, studies show that excessive amount of magnesium can cause neuromuscular irritability, cardiac and renal damage, and calcification. Acute magnesium toxicity studies in mammals show it to cause nausea and cardiovascular and central nervous disorders at high concentrations (HSDB 1993). Magnesium has been shown to be retained in skeletal, muscular, and soft tissues.

Based on a test of a MJU-10 flare conducted by Tracor, the primary products of flare combustion include magnesium oxide, magnesium chloride, carbon, and magnesium fluoride, plus traces of oxygen difluoride, carbon dioxide, and carbon monoxide. MgO is often found in diet; the compound is widely taken as an antacid or cathartic. Review of the HSDB database revealed that MgO can produce a moderate toxic effect. Probable oral lethal dose in humans is estimated to be between one ounce to one pound for an average 150 pound individual. Occupational exposure studies have shown that MgO dust may cause metal fume fever. Mammalian studies have shown that MgO is not readily excreted from the body and has the propensity to remain in the body for longer periods of time. $MgCl_2$ is a naturally occurring salt and is moderately toxic by ingestion and subcutaneous routes (Lewis 1991). One study indicated that normal kidney functions can readily excrete magnesium ions after oral ingestion. This implies that magnesium ions are not readily absorbed into the body through the intestines. Metallic fluoride compounds, in general, cause chemical burns and can cause systemic effects, including osteoscelerosis and skeletal fluorosis, by absorption of high concentrations through the skin (Sittig 1985). The OSHA standard for worker exposure for an 8-hour time weighted average is 2.5 mg of MgF_2 per cubic meter of air (HSDB 1993).

Oxygen difluoride is used in general as an oxidant in missile propellant systems. It is usually in a gaseous phase and is incompatible with numerous materials, including metal oxides and moist air. Potential routes of chemical exposure are via inhalation and dermal contact. At high concentrations, toxic health effects may include pulmonary edema, respiratory system irritation, and skin and eye burns (Sittig 1985). F_2O released during flare combustion is likely to dissipate or react with moisture or other substances in the atmosphere. The trace quantities resulting from flare combustion are not likely to exert toxic effects.

The cartridge residue was found to have small quantities of B_2O_3, K_2O, and Cr_2O_3. Although large quantities of B_2O_3 and K_2O can be toxic under certain conditions, the quantities from flare combustion (less than 0.05 gram) are too small to be of concern. Chromium is listed as a hazardous air pollutant under the Clean Air Act. Potential health effects are addressed in Section 4.6.

The first fire mix on most flares includes barium chromate, which is toxic if ingested, a respiratory irritant, and a dermal irritant. Barium chromate has not been evaluated for carcinogenicity, although hexavalent chromium compounds, which include $BaCrO_4$, are considered carcinogenic to humans. $BaCrO_4$ may be a characteristic reactive waste under RCRA. Aside from issues of hazardous air pollutants (see Section 4.6), environmental impacts from barium chromate could only result from dud flares with first fire mixes.

The non-parasitic MJU-7/B incorporates an initiator that contains a number of explosive compounds, including lead styphnate, lead azide, barium nitrate, and zirconium. N_2O_6Ba is toxic and may be a characteristic (toxic) hazardous waste under RCRA. SbS_3, also found in the MJU-7/B initiator, is a toxic pollutant under the Clean Water Act and listed under the Toxic Substance Control Act. Like the first fire mix, these compounds would be completely consumed on ignition and could only enter the environmental through dud flares.

Potassium chlorate and lead thiocyanate found in the M-2 squib used on ALA-17 flares are not considered a concern. The estimated total number of this model flare used in a year would include only 95 grams of $KClO_3$ and 76 grams of $C_2N_2PbS_2$.

4.4 SAFETY

4.4.1 Issues Addressed

Self-protection flares are pyrotechnic devices deployed by aircraft to mislead or confuse heat-sensitive or heat-seeking anti-aircraft systems. They burn rapidly, at high temperatures, providing a heat source other than the aircraft's engine to defeat surface-to-air and air-to-air missiles that use heat to guide to their target. Both ground support maintenance personnel and aircrews require regular training in flare system use and flare employment to maintain combat effectiveness and efficiency. Furthermore, aircrew training must simulate combat conditions (altitudes, speeds, maneuvers, etc.) to the maximum extent practicable. These training requirements, plus the need to frequently validate flare and flare system operational reliability requirements, create a potential for safety concerns and impacts due to the explosive and incendiary characteristics of the components.

This study addresses these potential impacts, and the safety issues they raise. They include the following:

- Flares and flare systems may malfunction, causing injury to maintenance personnel and aircrews and/or damage to equipment.
- Accidents or injuries may result from dud flares during handling and recovery for disposal.
- Injury or property damage may result from falling flares or debris from the flare system.

Effects that could result from these issues have the potential to impact both the human and natural environment. Any situation having the potential to injure personnel, damage aircraft or other property, or create risks to persons on the ground would also have the potential to generate adverse environmental impacts in areas underlying airspace approved for flare use if it created high risk of catastrophic aircraft or explosive mishaps.

4.4.2 Studies Conducted

Several studies were conducted to identify safety risks associated with flare use, to assess the severity of the risks related to the issues identified above, and to consider the probability of their occurrence. Risks of fires caused by burning flares or flare debris reaching the ground are addressed in Section 4.5. The studies conducted specifically for this safety review included:

- A review of available literature dealing with safety issues involving flare use and the operation of flare dispensing systems.
- A review of accidents, incidents, and mishaps associated with flares and flare dispensing systems.
- An analysis of flare-related safety issues using protocols established for Air Force safety analyses.
- An assessment of safety risks to persons and property on the ground underlying areas where flares are used.

Many studies and reports have assessed the potential impacts, consequences, and accidents that have resulted from flare use. A literature search was conducted as part of this study effort, which included review of applicable technical data as well as information available through various databases. While numerous reports and studies exist, no formal safety analyses of the flare system, SAR, or PRA could be located in any of the sources.

All flares and most flare systems involve one or more pyrotechnic components. Therefore, any malfunction or unusual incident occurring during handling, maintenance, or use of flares has the potential to create safety risks. The most comprehensive data concerning mishaps was received from Headquarters Air Force Safety Agency, the Air Force Directorate of Nuclear Surety, and Headquarters ACC Explosive Safety Section. The Air Force Safety Agency, prior to implementing a new computer database on March 1, 1993, maintained mishap data for 17 years. Under the new system, data are maintained for only 10 years. However, some pre-1983 data are available. These

data, as well as data developed from other research, were used to conduct a flare/flare system safety analysis.

4.4.2.1 Air Force System Safety Evaluation Process

This safety analysis categorized mishap data in terms of result severity as defined in AFI 91-204. The risk and relative incidence of potential mishaps were assessed in accordance with protocols used in Air Force System Safety Evaluations. Details regarding the specifics of developing these protocols are presented in Section 3.4.2 of this report.

When an accident or incident occurs, the Air Force describes it in terms of one of five mishap categories: Classes A, B, C, D, and High Accident Potential. Each event is classified in terms of result severity, ranging from those that result in death, permanent total disability, and major property and equipment damage or loss (Class A), to those that could cause some minor injury or damage (High Accident Potential). Mishaps that have occurred, as well as mishaps postulated to possibly occur, are identified by hazard severity categories and are evaluated in terms of the probability of occurrence of the event. Hazard Severity Categories and Hazard Level Classifications are defined in Section 3.4, **Tables 3.4-1** and **3.4-2**, respectively. These classifications are merged to form a Hazard Risk Index (HRI) matrix that provides a unique alpha-numeric designator assigned to events indicating each event's severity and probability of occurrence. This matrix is presented in **Table 3.4-3** and repeated in **Table 4.4-1** for ease of reference.

Table 4.4-1. Hazard Risk Index (HRI) Matrix

Frequency of Occurrence	Hazard Categories (MIL-STD-882B)			
	(1) Catastrophic	(2) Critical	(3) Marginal	(4) Negligible
(A) Frequent	1A	2A	3A	4A
(B) Probable	1B	2B	3B	4B
(C) Occasional	1C	2C	3C	4C
(D) Remote	1D	2D	3D	4D
(E) Improbable	1E	2E	3E	4E

Hazardous conditions identified as being of a serious nature require actions to either correct the hazard or reduce its HRI value to an acceptable level. HRI values of 3D or greater normally result in corrective action, with immediate corrective action required by ratings of 3A or higher. All specific responses, by level of hazard risk, are shown in **Table 3.4-4**.

4.4.2.2 Historical Mishap Data

Historic mishaps involving flares and flare systems have been both non-aircraft and aircraft related. From January 1983 to February 1993, the Air Force experienced 156 non-aircraft related mishaps involving flares. There were no Class A mishaps, 2 Class B mishaps, 21 Class C mishaps, 26 Class D mishaps, and 107 High Accident Potential events. These equate to annual averages of 0.2 Class B, 2.1 Class C, 2.6 Class D, and 10.7 High Accident Potential mishaps. The incidents occurred primarily during maintenance activities, such as removal of flares from or return to storage, routine maintenance and inspection, droppage, and bench testing/troubleshooting of flare systems. Those mishaps and their time of occurrence are shown in **Table 4.4-2.**

Table 4.4-2. Flare Mishaps (Non-Aircraft Related)

Mishap Class	Year										
	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
B	0	1	0	0	1	0	0	0	0	0	0
C	3	7	0	1	5	2	0	1	1	1	0
D	0	0	0	1	2	1	1	5	12	4	0
High Accident Potential	12	13	20	22	16	10	9	3	2	0	0

From 1983 to February 1993, there were no Class A or Class B aircraft related mishaps involving flares. However, in 1980, one Class A mishap did occur that involved an F-102G aircraft. The aircraft was on a target profile mission during the AIM-9M Missile Test Project. It was configured with ALE-28 flare dispensers and RR-119 flares. The flares were observed to be leaving the aircraft at uneven intervals. Then, an unknown object was observed falling from the airframe, and the wing man noted heavy smoke coming from the aircraft's fuselage. The pilot of the aircraft ejected after smoke entered the cockpit and he lost control of the aircraft. The pilot suffered a major injury, and the aircraft was destroyed. Between 1983 and 1993, there were 3 Class C mishaps and 101 High Accident Potential mishaps involving flares that were aircraft related. This constitutes a yearly average of 0.3 Class C and 10.1 High Accident Potential mishaps. None of those incidents resulted in serious injury. The occurrence of those events is shown in **Table 4.4-3.**

4.4.2.3 Risks from Dud Flares

Dud flares pose several safety concerns. When the flare system does not operate properly, there may be risks to maintenance personnel and equipment during activities to correct the malfunction. If flares are ejected from the aircraft and do not ignite, or ignite and burn improperly, risks may arise from accidental ignition on the ground, improper handling, or the possibility of striking a person on the ground. In order to assess risks associated with dud flares, the first issue that must be considered is the frequency of dud flares occurring. This is partly a function of the flare and flare system reliability rate.

Table 4.4-3. Flare Mishaps (Aircraft Related)

Mishap Class	Year											
	1980	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
A	1	0	0	0	0	0	0	0	0	0	0	0
C	Unk	0	0	1	0	1	0	0	1	0	0	0
High Accident Potential	Unk	9	14	13	19	14	6	9	6	7	4	0

Unk = Unknown

No data specifying absolute flare reliability rates were located. However, based on other data sources, some reasonable estimates may be derived. Lot acceptance testing for the MJU-7A/B flare involves an inspection of the overall condition of the unit and requires that lots pass an ignition and ejection test in accordance with MIL-STD-105, Inspection Level I, and an AQL of 1.0. This acceptance plan examines 80 samples. If two units or fewer fail the inspection, the lot is accepted; if three or more units fail, the lot is rejected. From these data, it may be concluded that for the 80 samples being tested, reliability must be at least 97.5 percent (two failures), and no worse than 96.25 percent (three failures). However, when other factors are considered, it would appear to be an overgeneralization to apply these reliability factors to the total number of flares in any delivery lot or to all of the flares in the Air Force inventory. This is due to the statistical procedure that forms the basis for specific quality assurance testing protocols.

When a quality assurance acceptance protocol is initially developed, three factors are considered. The first is the desired confidence level that is to be associated with the sampling procedure. Second, a representative random sample size (number of units) is determined. Finally, the assumed actual reliability rate is identified. This rate may be based on previous historic trends or from system specifications. The reliability rate is critical to developing the sampling plan and its associated "accept/reject" criteria. In developing the plan, it is used to compute the number of "expected defectives" that will be found in the selected sample of a specific size, which are then used in the equation to calculate the specific criteria associated with the inspection. "Accept/reject" values are computed by:

$$L = \bar{c} \pm Z \times \sqrt{\bar{c}}$$

Where: L = accept/reject limit

$\bar{c}$ = average historic or expected number of defectives, based on current sample size

Z = Z-score (associated with the area under a normal curve)

There are two unknowns associated with the currently available data. These are (1) the confidence level associated with the sampling (on which the Z-score is based) and (2) the average historic or expected number of defectives (which is a function of the reliability rate). Those unknowns were addressed by iterating a series of successive values through the above equation, and then evaluating the operating characteristic curve associated with each data combination for conformity with the identified acceptance protocol. The results of this analysis yielded one unique data set that meets all identified criteria. These data indicate that an overall system reliability of 99 percent, when applied against a sample size of 80, will, at the 95 percent confidence level, develop a quality assurance protocol of "accept two - reject three." Furthermore, an analysis of the operating characteristic curve for this confidence level shows that the AQL associated with these data combinations is identical to that established by MIL-STD-105.

It is important to note that this derived reliability rate applies to the flare system and is not necessarily a reflection of the reliability rate of the flare itself. System reliability is the product of the individual reliability of each component subsystem. For example, if a system contained two subsystems, and each had identical reliability, then each would have to have an individual reliability of 99.5 percent to yield an overall system reliability of 99.0 percent. While specific component reliability rates are unknown, for analysis, it would seem reasonable to consider flare reliability to be at least 99 percent, although it is probably higher.

There are direct and indirect safety concerns relating to the recovery of dud flares. Of the data researched, only one case of personnel injury resulting from activities involving a dud flare was documented. However, other unprecedented events could occur. For example, the principal component of flares is magnesium, which reacts with water to form magnesium oxide and hydrogen. In an open environment, hydrogen dissipates quickly. However, when contained, it can create a fire and explosion hazard. Direct contact with water is not necessary to initiate this reaction. Moisture absorbed while a flare is exposed to the environment could be adequate to generate an explosive mixture if enclosed in a sealed container. Laboratory tests described in Section 4.7 confirm that hydrogen gas is formed when dud flare material is exposed to water. While no official documentation indicate that this event has ever occurred, its potential suggests that dud flares recovered on the ground should not be placed in sealed containers or restricted environments prior to final disposal.

4.4.2.4 Risk of Injury from Falling Flare Debris

Falling dud flares and flare system debris can create safety concerns due to the possibility of hitting a person on the ground. Of all the system components, dud flares are probably the greatest concern because of their weight. The probability of flare components hitting a person on the ground is difficult to quantify, because it is dependent on so many variables. Under normal circumstances, much of the debris ejected from the aircraft when flares are employed weighs so little, and creates so much drag in comparison to its weight, no serious injury would be anticipated, even if a person were hit. No incidences of injuries from falling flares or debris have ever been recorded.

If ejected above 500 feet AGL, most system debris would decelerate to terminal velocity before reaching the ground. **Table 4.4-4** shows terminal velocities and momentum values for a range of

flares and flare debris. Terminal velocity and momentum calculations are discussed in more detail in Section 3.4.2. There is a 90 percent probability of brain concussions associated with a momentum of 0.70 pound-seconds, and less than one percent probability associated with impulses of less than 0.10 pound-seconds (Ommaya and Corrao 1968).

Table 4.4-4. Weight, Terminal Velocity and Momentum of Flare System Debris

Debris	Weight (pounds)	Terminal Velocity (feet/second)	Momentum (pound-second)
MJU-10 Dud	2.5	211	16.370
ALA-17 Bottom Cylinder	1.75	193	10.480
MJU-7 Dud	0.817	197	4.990
M-206 Dud	0.431	208	2.790
MJU-7/B Initiator	0.106	71	0.234
MJU-7A/B Slider	0.044	106	0.146
MJU-7 End Cap	0.009	21	0.006

These values represent a worst-case situation, since the calculations for terminal velocity and momentum for each component assume the minimum surface area or cross section of the component is constantly exposed to the airstream, thereby encountering minimum aerodynamic drag. In actuality, it is reasonable to assume that during free fall, the component would tumble, thereby being exposed to a range of aerodynamic forces, and terminal velocity and momentum would be somewhat less than the values indicated in **Table 4.4-4**. On the other hand, heavier components ejected from an aircraft traveling at 600 miles per hour at 500 feet altitude may not have decelerated to terminal velocity prior to impacting the ground.

As can be seen from **Table 4.4-4**, dud flares and some flare components could cause serious injury, or death, if they hit a person on the ground. For comparative purposes, the calculated momentum values for an MJU-10 dud flare would be equivalent to being struck by an eight pound sledge hammer dropped from a height of approximately 67 feet; for the ALA-17 bottom cylinder, approximately 28 feet; and, for the M-206 dud, approximately 2 feet. The probability of such an injury from falling flares is addressed in the next section.

4.4.3 Findings

Postulated safety events were assigned probabilities of occurrence based on historic data sources or reasoned assumptions. Probabilities of occurrences were calculated assuming an estimated average expenditure of 380,000 flares per year by ACC units. From these data, HRI ratings were assigned to each potential event, and requirements for corrective action were determined.

Table 4.4-5 identifies postulated events, their potential results (effects), probabilities of occurrence, and the estimated annual number of occurrences per year. In some cases, more than one effect may be associated with a single event.

Table 4.4-5. Probability of Safety Events Involving Flares

Event	Effect	Probability	Frequency (per year)
Flare system malfunction (non-aircraft related)	1. Class B Mishap	5.26×10^{-7}	0.2
	2. Class C Mishap	5.53×10^{-6}	2.1
	3. Class D Mishap	6.84×10^{-6}	2.6
	4. High Accident Potential	2.82×10^{-5}	10.7
Flare system malfunction (aircraft related)	1. Class A Mishap	2.37×10^{-7}	0.08
	2. Class C Mishap	7.89×10^{-7}	0.3
	3. High Accident Potential	2.66×10^{-5}	10.1
Dud/malfunctioning flare reaches ground	1. Personnel injury from falling debris	1.17×10^{-7}	0.0003

The probabilities assigned to the Class B, C, D, and High Accident Potential mishaps are based on historic data. The probability associated with injury from a falling dud flare is based on the assumption that 1 percent of flares could be duds. In this case, only flares released over land were considered, which constitute approximately 68 percent of flares used. Flares released in over-water Warning Areas are not considered to pose a risk of injuring a person.

The probability was calculated assuming an aircraft releasing a flare at 600 miles per hour and 650 feet AGL (to represent a conservative average). The potential area of impact of a dud flare is estimated to be approximately 2,550 feet long and 50 feet wide along the aircraft's ground track, resulting in a footprint of 127,500 square feet or about 3 acres. The envelope of potential injury to a person standing on the ground is estimated at 1.5 square feet, resulting in a probability of 1.17×10^{-5} of the dud hitting any given 1.5 square foot area. This was then combined with an estimated probability that there would be a person in the area underlying an aircraft releasing a flare. Since military training activities are conducted in airspace located over relatively sparsely populated areas, a population density of 100 persons per square mile (640 acres) was used. The resulting probability of a dud flare hitting a person is 1.17×10^{-7}.

No probability was calculated for injury from incidental falling debris, such as end caps, because the risk of injury is negligible (**see Table 4.4-4**).

Based on the estimated severity of the possible result and the probability of its occurrence, each postulated effect was assigned an HRI rating. The events, their effects, the assigned HRI, the indicated rating, and action required are shown in **Table 4.4-6**. Hazard level thresholds are presented in **Table 3.4-2**, and even though a computed probability of occurrence may still be

extremely low, if it is not equal to or less than the threshold probability, the hazard level is increased to the next higher rating.

Table 4.4-6. Hazard Rating Index/Rating and Action Required

Event	HRI	Rating	Action Required
Flare system malfunction (non-aircraft related)			
Class B Mishap	2E	Acceptable	Low Priority
Class C Mishap	3D	Undesirable	Corrective Action
Class D Mishap	3D	Undesirable	Corrective Action
High Accident Potential	4D	Acceptable	None Required
Flare system malfunction (aircraft related)			
Class A Mishap	1E	Acceptable	Low Priority
Class C Mishap	3E	Acceptable	Low Priority
High Accident Potential	4D	Acceptable	None Required
Dud/malfunctioning flare reaches ground			
Personnel injury from falling debris	1E	Acceptable	Low Priority

As shown, most of the identified areas of potential risk associated with flare use are relatively minor, or are anticipated to occur so infrequently as to render their level of risk acceptable, and do not require any specific corrective action. However, there are two exceptions: non-aircraft related flare or flare system malfunctions that resulted in Class C and Class D incidents. Although the calculated risk is low, the estimated frequency of these events and the marginal severity of possible consequences raises their HRI rating to higher levels. The expected frequency of these events was derived by taking an arithmetic average of the total number of historical events during a 10 year period. However, events of this type normally result in some form of corrective action being taken. The effectiveness of these actions is evident from the generally decreasing incidence of the more serious of these occurrences in recent years.

The assumptions used in calculating the potential for injury from a falling dud flare may need to be reverified in certain specific instances. If the density of personnel in an area where flares are being used is higher than 100 persons per square mile (for example, at a range), that will affect the probability. Given the severity of the possible consequences, any increase in probability from Improbable (Hazard Level E) would result in Undesirable HRI. The threshold for Hazard Level E is one chance in one million (10^{-6}). Any population density greater than 1,000 persons per square mile would trigger a higher Hazard Level and an Undesirable HRI.

The probability and resulting HRI of injury from picking up and handling a dud flare found on the ground were not calculated. This is because the methodology is designed to assess the likely occurrence of discreet events and does not readily accommodate cumulatively increasing probabilities. For example, the risk of falling debris striking a person occurs only while the debris is falling and disappears after the debris has reached the ground. Dud flares, on the other hand, remain

on the ground and could be found months or even years later, continuing to pose a potential hazard for an undetermined length of time. Therefore, as more flares are used, more duds will be produced, and the potential risk of injury will also increase. The cumulative level of risk cannot be precisely calculated.

While it is theoretically possible that all dud flares released over land could be picked up and pose a risk of injury, this is not a reasonable assumption for estimating HRI for this event. The vast majority of flares are released over DOD ranges, and duds are recovered by Explosive Ordnance Disposal (EOD) personnel. Furthermore, only one incidence of injury from a dud flare was uncovered in the data collection.

Although the historic incident data do not indicate a risk, the potential for a dud flare to be picked up by a person who is subsequently injured should be taken into consideration for flare use over non-DOD land. Over DOD land, appropriate corrective actions could include educating all personnel on proper procedure when encountering a dud flare, and ensuring that flare use areas are regularly surveyed by EOD personnel and all duds are disposed of properly.

4.4.4 Conclusions

Based on an assessment of available data and possible events, most safety risks associated with flare use are either low in probability or manageable through corrective action. When mishaps have occurred, they were confined mainly to Air Force personnel and property. Civilian impacts were minimal or nonexistent. Some risk is associated with non-aircraft related maintenance and handling operations. Due to the fact that flares and flare systems involve pyrotechnic components, constant vigilance and strict adherence to applicable technical data is essential in performing maintenance activities. Although the estimated number of incidents per year is low, the possible consequences of any incident involving explosives highlights this element of risk. On the other hand, the relatively low number of incidents involving aircraft indicate that there is minimal risk to aircrews, aircraft, and the public from an aircraft mishap being caused by a malfunction involving flares or the flare dispensing system.

Although death or serious injury could result if a person on the ground were hit by a dud flare or some of the flare system debris, the very low probability of such an event occurring indicates that the level of risk is acceptable, and no specific measures are required. The risk of a person being injured by a dud flare found on the ground is of more concern, however. The probability of such an event depends on how many dud flares are discovered by persons unknowledgeable about their risks or proper handling. This could not be statistically calculated. Because the majority of flares are dispensed over DOD ranges, corrective action can be taken to reduce the hazard to most exposed personnel (through education and periodic clean up). A potential hazard may still exist to members of the general public in areas underlying MOAs where flares are used. This issue should be addressed on a site-specific basis, considering the relative remoteness of areas where flares are used. In areas where flares are regularly dispensed over non-DOD owned land frequented by the general public, a public information program could be employed to alert people of the risks associated with dud flares and safe procedures if a dud is found.

4.5 FIRE HAZARDS

4.5.1 Issues Addressed

Fires resulting from flare use have the potential to cause impacts on a variety of resources. The degree of impact from fires will depend on the extent and intensity of the fire, the sensitivity of resources to damage by fire, and the value of the affected resources. Fire is part of the natural ecosystem of most plant communities (except for the antarctic, hot deserts, and tropical wetlands), and is a major force in all arid, temperate, boreal, and austral zones. The more fire-prone an ecosystem, the greater the role of natural fire in shaping the ecosystem. Land managers use techniques such as controlled burning as a way to lessen build up of fuels to reduce potential for large fires, and to reinvigorate growth of grasses where undesirable species have invaded. However, the potential consequences of unplanned fires caused by other than natural causes are not desirable in any situation. Therefore, the focus of this section is on examining the potential for a fire starting, spreading, and thereby resulting in significant impacts. The following key issues were identified in relation to the use of flares and potential for fire:

- The level of fire risks associated with flare use.
- Factors that affect the risk of fires from flares.
- The effectiveness of flare use procedures and restrictions in achieving acceptable levels of risk.

Training with flares is conducted on military ranges and in special-use airspace in relatively remote or rural areas. Any fires that might occur are likely to be on agricultural lands or uninhabited forest or rangeland. Fires from flares in dense residential or urban areas are not considered a significant issue, except as a result of wildland fire spreading into populated areas.

Avoidance of adverse impacts is a consideration in the selection of areas for training in air operations, so only incidentally should fire starts be possible under training areas. Specific restrictions and procedures have been established for flare use to minimize the potential for fire starts, including minimum ground clearance levels for dispensing flares to ensure adequate time for complete combustion and consumption of the flare pellet before reaching the ground. However, there are several situations that could result in a burning self-protection flare reaching the ground, including:

- The flare could be released at too low an altitude with inadequate surface clearance.
- The flare could descend unexpectedly rapidly due to vertical shear or wind burst.
- The flare could burn at an unexpectedly slow rate due to manufacture error.
- The igniter could malfunction, causing the flare to ignite late in the air or fall to the ground as a dud and ignite later.
- The flare could land on dead vegetation, such as a tree top, while still burning.

4.5.2 Studies Conducted

4.5.2.1 Regulatory Considerations

Existing legislation indicates that federal land managers have specific responsibilities to control fires that could threaten public land resources. The *Federal Land Policy and Management Act* (FLPMA) does not include specific fire protection responsibilities but does clearly indicate that the Secretary of the Interior will coordinate land use inventories, planning, and management activities of public lands. Other federal agencies and departments and state and local governments have similar plans and programs for lands under their management. The BLM and USFS develop Fire Management Plans to implement objectives for protecting and preserving resources in accordance with required resource management plans, to maximize multiple use and sustained yield of the land. Therefore, FLPMA provides for cooperative action between land managers and military departments to ensure that fire does not harm public lands.

The *Military Lands Withdrawal Act of 1986* provides for the withdrawal of public land for military use at six installations, including the Nellis and Barry M. Goldwater Air Force Ranges. It states that the Secretary of the military department responsible for the withdrawn lands shall take necessary precautions to prevent and suppress brush and range fires occurring within and outside the withdrawn lands as a result of military activities, and that the military department may seek assistance from the BLM in suppression of such fires. Responsibilities are detailed through Memoranda of Understanding between the Secretary of the Interior and the Secretary of the military departments. The BLM is provided with funds from the military department for fire suppression assistance.

Federal Aviation Regulation Part 91.15, General Operating and Flight Rules - Dropping Objects, prohibits pilots of civil aircraft from allowing objects that create a hazard to persons or property to be dropped from aircraft in flight, unless reasonable precautions are taken to avoid injury or damage to persons or objects. Activities that increase the potential for fires, particularly when fire risk is high, could be seen as creating a hazard to persons or property. AFI 11-206 is the Air Force counterpart regulation with the same provision.

4.5.2.2 Literature Review

The scientific literature on fire effects is extensive. Resources for studying potential effects of unwanted fires include three databases specifically designed to aid in the planning of prescribed fires and devising landscape and ecosystem scale fire management plans. One is the bibliographic database maintained by the International Association of Wildland Fire in Fairfield, Washington, which is supported by USFS, BLM, and the National Park Service.

The second database is the automated Fire Effects Information System, developed and maintained by the Intermountain Fire Sciences Laboratory (IFSL) of the USFS Intermountain Forest and Range Experiment Station in Missoula, Montana. This database contains up-to-the-minute research findings and is available to USFS organizations agency-wide and to other federal land management agencies and their contractors and cooperators. It replaced the defunct FIREBASE automated literature data base that had been maintained by the Boise Interagency Fire Center in Boise, Idaho.

The third database tracks data on fire occurrence. A system of national scope is in place that numerically gauges the relative danger of wildland fire starts in terms of the susceptibility of various wildland fuels to ignition and fire spread. This system, the National Fire Danger Rating System (NFDRS), is employed by federal, state, and local agencies with land management and fire protection responsibilities. The system uses historical and current real-time weather data collected by the National Weather Service from a system of Remote Automated Weather Stations (RAWS) and manned weather stations. It also uses historic information about fire occurrences in specified areas (where available). All federal land management agencies (USFS, BLM, National Park Service) and state agencies with responsibility for fire suppression collect data on fire starts.

Fire occurrence data are collected in a standardized format and tracked by the interagency fire occurrence database, overseen by the National Interagency Fire Center (NIFC) and managed by BLM. Typical information included in fire occurrence data includes the size of the fire, location, time, cause, action taken, property ownership, fire suppression action, elevation, and topographical data. BLM tracks nine fire cause categories: lightning, camp fire, smoking, fire use, incendiary, equipment use, railroads, children, and miscellaneous. Flare use and other military activities are not specifically addressed in these categories, and these fires are generally categorized as incendiary or miscellaneous. The incendiary category also includes legal and illegal fireworks.

A computer-based fire behavior prediction model, BEHAVE, is currently used by most agencies with wildland fire protection responsibilities. The BEHAVE system is a set of interactive computer programs designed to predict the behavior of a specific fire or potential fire (Andrews 1986; Andrews and Chase 1989). It is based on methods described by Rothermal (1983). The system is flexible and can be adapted to meet specific needs, utilizing the experience and judgment of fire managers. It is composed of two subsystems: FUEL, the fuel model subsystem, and BURN, the fire behavior subsystem. The components of the BEHAVE system and its use are described and illustrated in Appendix E.

BLM has developed and implemented the Initial Attack Management System (IAMS), a large computer-based system that became operational in 1985 (Andrews and Bradshaw, nd). IAMS covers all BLM lands in the contiguous 11 western states and most of Alaska. IAMS includes remotely sensed lightning occurrence data from the Automatic Lightning Detection System (ALDS), meteorological data from the RAWS, databases for fuel and topography, and several fire management computer systems. The ALDS consists of a series of electronic sensors that detect the occurrence, location, and polarity of lightning strikes. This information is immediately distributed to fire management offices. The RAWS system provides near real-time weather observations that can be used with the lighting data to indicate areas of highest fire occurrence probability. This is used by the BLM to direct aerial surveillance flights. The IAMS system distributes data from over 500 RAWS sites. BEHAVE has been incorporated into IAMS, providing an initial indication of potential fire behavior, given a lightning strike and weather, fuel, and terrain information.

4.5.2.3 Technical Study

A technical study was conducted to examine issues related to fire risk assessment and flare use, and to develop a process for evaluating fire risk and potential for impacts from flare-induced fires in

specific training areas. The study methodology and results are described in detail in *Technical Reports on Chaff and Flares, Technical Report No. 6, Flare Fire Risk Assessment* (USAF 1995). The purpose of the study was to evaluate the influence of various factors on fire risk including:

- The likelihood that a burning flare will start a fire, and whether the size of the fire can be predicted.
- Whether all potential avenues for flares to start fires are known.
- The effect of site-specific environmental conditions on fire hazards.
- The level of risk from flare training to areas valued for agriculture, timber, recreation, or conservation opportunities.
- Whether remote locations are more prone to larger fires due to lack of fire suppression services.
- How fires are managed in areas where flares are dispensed.
- The effectiveness of restrictions on flare use, including altitude restrictions, in reducing the risk of fire.

The study consisted of three main components: (1) a survey of fire history, including related environmental, procedural, and operating factors, at existing over-land flare training areas used by ACC units; (2) a methodology for evaluating risks associated with flare use (for both DOD and non-DOD areas); and (3) demonstration of a detailed, site-specific fire risk assessment using the BEHAVE model.

Data from existing flare use areas (ranges and MOAs), including regulations and restrictions on flare use, were obtained through interviews with range personnel and persons responsible for fire management, EOD, weapons safety, and natural and cultural resources management. The data collected included fire history, general environmental descriptions, and amount of flare use, where possible. In addition, fire history data were obtained from the NIFC database for flare training areas in the western states. The data were analyzed to see if any correlations could be identified between factors such as utilization level, release altitudes, and environmental conditions.

A methodology for assessing new areas proposed for flare use and for designing adequate procedures minimize fire risk was developed and is provided in Appendix E. The methodology is comprised of three phases. The first phase involves an initial risk assessment aimed at identifying whether the risk of fire from proposed flare use in a particular location is low to moderate, requiring little or no restrictions or high to extreme, requiring more detailed analysis to identify appropriate conditions for flare use. The second phase is a detailed analysis of areas determined through the initial assessment to have a potential for high to extreme risk during at least certain periods. This phase includes agency consultation, site-specific fire danger rating, and possible modeling. The third phase addresses preparation of documentation to comply with NEPA. A case study fire risk assessment was performed using the methodology and the BEHAVE fire prediction model applied to a selected flare training area in the Desert Elgin South MOA associated with the Nellis Air Force Range complex in Nevada.

4.5.3 Findings

4.5.3.1 Fire Risk Assessment

Very little has been done in the way of assessing the probability of ignition of a wildland fire by a single source (such as a flare). Since there can be such an abundance of ignition sources, the probability associated with a single source becomes irrelevant to fire management. One study performed at the USFS Riverside Fire Laboratory studied ignition of dry grass by burning cigarettes in a wind tunnel. After hundreds of trials, so few ignitions were achieved that the statistical significance of the findings were questionable (Frank Albini, personal communication, 1993). Similarly, the probability of any single flare starting a fire cannot be predicted to any level of statistical significance, particularly since it would depend on so many variables as to be totally situationally dependent.

For a flare to start a fire, it must reach a fuel source (e.g., vegetation) while still burning. **Table 4.5-1** indicates the free-fall time to impact from various altitudes, assuming the flare operates properly. As it shows, the release altitude would have to be above 1,500 feet AGL to ensure complete burn-out of a 10 second flare. The actual burn times of flares are classified, and based on that information, the safe altitude is likely to be significantly lower. Release altitude requirements in AFI 11-214/ACC Supplement 1 are designed to ensure complete combustion by specific flare models prior to reaching the ground. Furthermore, the times presented in **Table 4.5-1** do not consider drag or other aerodynamic forces that influence the rate of descent. **Table 4.5-1** does demonstrate, however, that areas susceptible to ignition (due to dry vegetation, for example) could be at risk from low-altitude flare drops.

If a burning flare reaches the ground or the canopy of a tree or shrub, it may or may not start a fire. The conditions that must be satisfied in order for a fire to start and spread include:

- The source must be very near to or in contact with a fuel element.
- The source must have sufficient residual energy to ignite the fuel element.
- Fuel conditions must support the spread of fire.

The first condition can be assessed on the basis of geometric consideration. The probability of a flare landing on the crown layer of a tree or shrub, for example, can be estimated as a function of the fraction of the surface area covered by trees and shrubs. A burning flare alighting in the crown layer of shrub cover may start a fire, but the crown layer must contain a sufficient density of dead foliage with low enough moisture content to support the spread of fire, or no fire will result.

Table 4.5-1. Free-Fall Time to Impact

Altitude (feet)	Time (seconds)
100	2.5
300	4.3
400	5.0
500	5.6
600	6.1
700	6.6
800	7.0
900	7.5
1,000	7.9
1,200	8.6
1,500	9.7

Wind conditions can both inhibit and accelerate the spread of fire. If there is a wind blowing on the heated element, flaming ignition is more difficult to initiate, as the reactive gaseous products of pyrolysis may be blown away before they exist in sufficient concentration to support a flame. But if flaming combustion is initiated, the surface fire will spread much more rapidly under the influence of the wind. When there is an actual flame present, ignition occurs at lower temperatures (approximately 325 degrees Celsius) and is less sensitive to windspeed.

If hot material comes in contact with rotten wood, smoldering combustion can be sustained at temperatures as low as 200 degrees Celsius under most favorable conditions. Fortunately, from the perspective of avoiding the risk of unwanted fire, the fraction of surface area covered by rotten wood is small in even a decadent forest stand (for example, recent studies indicate a maximum of 15 percent in wet sites in northern Idaho).

The probability of ignition given a hot inert item reaching the surface can be assessed based on the moisture content of "fuel" (vegetation and other combustible material on the ground), which in turn can be derived from local meteorological history and current conditions.

The NFDRS uses these variables to calculate fire hazards on a daily basis for the entire country. The system uses a selection of wildland fuel types that together can be used to characterize most forest and rangeland vegetation cover found in the continental U.S. and Alaska. The NFDRS is used primarily for presuppression planning over large geographic areas. Its indices give a general assessment of the daily fire potential through the fire season, based on weather observations taken over a network of weather stations forecasts from the National Weather Service. Fire weather observations are archived in a national database that provides a climatology of fire weather for use in analyzing and comparing different fire years (Andrews and Bradshaw, nd). The system's indices

are sensitive to the phenology of vegetation communities; historical precipitation, temperature, and humidity; and current temperature, humidity, and windspeed.

The NFDRS can be accessed by remote computer link to a local office of a federal or state agency (e.g., USFS Ranger District, BLM district office, National Park Service supervisor's office, state natural resource office). It can also be implemented locally on desktop computer. Using this system, ACC units could devise "no constraint" and "no flare release" guidelines for each training area. Under conditions when a fire would be expected to spread rapidly and/or to burn with high intensity, any risk of ignition may be deemed unacceptable, leading to a "no flare release" constraint. A balance can be struck between the risk of an unwanted fire start, possible consequences of an unwanted fire, and disruption of training operations.

Since NFDRS ratings are based on generalized vegetation types, fire prediction modeling (such as BEHAVE) can be used to determine fire risks at specific locations. In order to use the BEHAVE system, the fuel of an area underlying training airspace must be described in mathematical terms (size, quantity, arrangement, classification as living or dead, and moisture content), and terrain slope and windspeed must be specified. An assortment of representative fuel descriptions is already available in the FUEL subsystem of BEHAVE (as in NFDRS) that can be used with guidance from consulting local fire control authorities. Alternatively, model users can design a fuel description tailored to the area of concern. The BURN subsystem of BEHAVE includes several modules designed to calculate different outputs, such as rate of spread, flame length, fire intensity, spotting distance, area and perimeter growth, scorch height, and tree mortality.

Inputs into the BEHAVE model include site weather conditions. The range of meteorological conditions that are representative of any site should be available from archived Fire Danger Rating observations taken at the nearest station that takes these data. The observations are routinely archived at the USFS's Fort Collins Computer Center in Fort Collins, Colorado and can be retrieved in machine-readable form for a modest fee. There are six regional climate centers that collect daily weather data:

- New England — Ithica, New York, (607) 255-5950
- Southeast — Columbia, South Carolina, (803) 737-0888
- Midwest — Champaign, Illinois, (217) 244-8226
- South — Baton Rouge, Louisiana, (504) 388-5021
- High Plains — Lincoln, Nebraska, (402) 472-6706
- West — Reno, Nevada, (702) 677-3139

4.5.3.2 Fire History at Existing Flare Use Areas

A review of the fire history data in existing flare use areas is documented in *Technical Report on Chaff and Flares, Technical Report No. 6, Flare Fire Risk Assessment* (USAF 1995). The flare training areas examined covered a range of environments, both ecologically and in terms of management and regulations. In most areas, the percentage of fires caused by flares was unknown

but usually considered to be low to nonexistent. Fires caused by training operations occur in both dry and temperate or humid environments and can occur during times of relatively low fire hazard conditions if ignition sources are present.

Existing regulations and procedures reduce fire risk from flare use through altitude restrictions or suspension of activity during periods of high fire hazard. It is likely that effective minimum release altitude restrictions vary depending on the fire hazard. In Nevada, flare fires have occurred in areas where minimum release altitudes are 5,000 feet AGL. The MOAs associated with the Nellis Range complex have floors that are much lower than the permitted release altitude for flares, so aircrews must increase their flying altitude when dispensing flares. In the Moody MOAs in Georgia, even though local regulations permit flare use at 2,000 feet AGL over non-government land (in accordance with ACC regulations), the floor of the airspace is 8,000 feet AGL, so minimum releases must be above this altitude. No fires from flares have been recorded in areas under the Moody MOAs, indicating that this altitude provides adequate protection in a temperate environment. However, information for this area is limited.

In areas underlying MOAs in Idaho, where flare releases are authorized at 2,000 feet AGL and the wing adopts no-flare-use restrictions during times of high fire risk, fires started from flares are extremely rare. At the Melrose Range in New Mexico, where conditions are also dry during most of the year, the minimum release altitude is 1,000 feet AGL. Flare-caused fires are very infrequent within a small area which is observed and has on-site suppression services. At Poinsett Weapons Range, South Carolina, where minimum release altitudes are those set by ACC for government-owned or controlled land, no flare-caused fires have been recorded. However, at Avon Park Range in Florida, some fires are attributed to flares, even beyond the permitted release area. Fires also result from illumination flare use at this range.

Existing operating restrictions (altitude restrictions, fire rating restrictions, flare types permitted) tend to be greater in training areas over non-DOD land. For example, local restrictions at the Nellis Range complex set a 700 foot AGL minimum release altitude over DOD land and a 5,000 foot AGL altitude in MOAs overlying public land with similar environments. The lowest release altitudes are permitted in the most controlled range settings (e.g., Poinsett, Saylor Creek Range, Avon Park).

Fires have occurred on all the ranges surveyed. Range areas tend to have large numbers of small fires, primarily caused by munitions spotting charges, and few caused by flares. Techniques used on DOD-ranges to limit fires from spreading include controlled burning, fire breaks, on-site fire spotting, and fire suppression crews. Data about range impact areas are not representative of MOAs, however, because most impact areas are highly disturbed or cleared, with little to no vegetative cover. On non-DOD lands, such as those managed by BLM, fire hazard ratings focus heavily on build-up of vegetation (fuel) and moisture content.

Centralized fire occurrence databases used by federal and state fire managers do not include consistent records of fires on DOD ranges. Most DOD ranges keep fire logs, but the type of information recorded varies. Non-DOD fire occurrence databases generally do not include cause categories that make it possible to distinguish between military and other types of incendiaries

(such as fire works). Flare-caused fires are recorded as either "incendiary" or "miscellaneous," and these categories also include many other causes.

Operating parameters (such as release altitude, area, environmental conditions) were too diverse to isolate level of use as the only or primary factor affecting frequency of fires. For this reason, and because flare-caused fires are rare in any case, no statistical correlations could be made between utilization, environmental conditions, and fire occurrence. Some regulations restrict the types of self-protection flares that can be employed, but it was not possible to correlate flare-caused fires to specific flare types.

In general, fire management and suppression of any incendiary-caused fire was found to be most successful when the operating arena is confined, observed, and served by on-site suppression crews. This was indicated by fire management personnel and information from Saylor Creek Range, Poinsett Weapons Range, and Melrose Range. In areas overlying non-DOD land such as MOAs, fires from incendiaries may be larger, since suppression efforts are often delayed due to inaccessibility, distance, delay in detection, and shortage of fire crews in periods with high fire activity. Some fire hazard rating systems (e.g., Florida's) include suppression response capabilities as a priority factor in designating fire hazard levels. Fire management procedures need to be able to quickly implement effective restrictions when suppression services are thin. This indicates the need for communication between managers responsible for fire suppression and managers who set operational restrictions for special-use airspace areas.

4.5.3.3 Flare Fire Risk Assessment Case Study

Technical Reports on Chaff and Flares, Technical Report No. 6 (USAF 1995) demonstrated the process for performing a fire risk assessment through a case study using the Desert Elgin South MOA at the Nellis Air Force Range complex in Nevada. The Desert Elgin South MOA was selected for use as the model study area because of the amount and type of data readily available about the underlying area from both BLM and Air Force personnel, and from a recent systematic survey of chaff (USAF 1994d) and a field study conducted for Technical Report No. 4 (USAF 1994c).

For the initial fire assessment of the case study area, fire occurrence data from the BLM database were plotted to show the distribution of fires for a 13 year period. Incendiary and miscellaneous-caused fires were concentrated along roadways, around towns, and in recreation areas, suggesting that many fires were caused by cigarettes, matches, vehicle sparks, or fireworks. However, information from range personnel and investigative reports for specific fires indicates that fires from flares have occurred, even in areas where the minimum release altitude is 5,000 feet AGL. Specifically, one fire in Meadow Valley, which burned 21,600 acres in 1993, was attributed to flare use according to a BLM fire investigator.

The area underlying the Desert Elgin South MOA is characterized by a mixture of arid, shrubby species with relatively low density or ground coverage. The average fire size over a 13 year period was less than 100 acres. Although this is relatively small for unpopulated, arid, rangeland environments, it is considerably larger than the average fire size (less than 3 acres) on the Nellis Range, where fire damage is limited to small areas. The years that had a large number of total acres

burned were also years with one or more very large fires. For most years, the acreage burned by the largest fire accounted for most of the total acres burned.

The demonstration using the BEHAVE fire prediction model illustrated how fire size, spread rate, and intensity can be calculated using representative vegetation type, known or hypothetical weather conditions, fuel moisture content, and site characteristics. The demonstration showed that different vegetative types produced fires of varying sizes and intensity under the same weather, fuel moisture, and site conditions. Fuel types with high fuel loads, such as timber and tall grasses, can produce faster spreading fires with higher intensities. Tall grasses produced the fastest spreading fires. Vegetative types that combine high fuel loads, such as timber, with continuous cover of grasses produce fast spreading and hot fires. Fuel type alone does not account for fire size and spread rate. Unless the fuel moisture content is sufficiently low, fires will not start. The demonstration also showed that for each fuel type, variations in slope and wind conditions affect the rate of spread, although different vegetation types responded differently to similar conditions of slope or windspeed.

One model demonstration was used to reconstruct the fire behavior of an actual fire that occurred under the Desert Elgin South MOA. Actual weather conditions were used in combination with four different fuel types (not actual) to illustrate how different vegetation would have responded under the same meteorological conditions. The spread rates varied from as low as 16 to as high as 36 chains (a chain equals 66 feet) per hour. Thus, vegetation type is a major factor in fire behavior.

BEHAVE can be used to calculate the size of the fire at specified time increments after ignition, based on input parameters used to calculate spread rate. The model usually over-estimates fire size because it does not consider discontinuity in fuel, which generally occurs in natural contexts, or the effects of fire breaks. Because of these limitations, outputs from BEHAVE require interpretation by skilled technicians or fire managers.

4.5.4 Conclusions

Flares are known to have caused fires. The effects of flare-caused fires depends on a number of factors, including how far the fire spreads and the composition of the environment that is burned. If a fire starts and spreads, it can have a variety of environmental effects, including:

- Immediate fire effects.
  - ⇒ Destruction of surface vegetation.
  - ⇒ Morbidity and mortality of standing shrubs and trees.
  - ⇒ Demise of insects, small animals, and eggs.
  - ⇒ Effects on seeds, spores, and microbes in duff and soil.
  - ⇒ Temporary disruption of local surface travel, both by animals and humans.
  - ⇒ Smoke.

- Delayed fire effects
  - ⇒ Altered mineral nutrient levels and soil pH.
  - ⇒ Altered suitability of site to invasion by offsite vegetation.
  - ⇒ Increase in site vulnerability to wind and water erosion.
  - ⇒ Changed surface water runoff quantity and content of water, including effects on aquatic biota downstream.
  - ⇒ Loss of food and/or shelter for local and migratory wildlife.
  - ⇒ Altered vulnerability to opportunistic insects and diseases.
- Long-term fire effects
  - ⇒ Changes in landscape, with concomitant changes in patterns of land use by animals and humans.
  - ⇒ Long-term changes in the distribution of plant community species.
  - ⇒ Loss of critical habitat for threatened or endangered species.
  - ⇒ Changed productivity patterns due to topsoil transport.
  - ⇒ Permanent landform alteration by erosion.

In addition to physical effects, fires can damage property and commercial resources, such as crops and forests, and can threaten the safety of the public and fire suppression crews.

Federal and state land management agencies have already developed fire hazard rating and suppression/response procedures for most public and state-owned forest and rangelands. Fire hazard ratings are used to set restriction on permitted activities on the lands they manage. For example, firewood cutting activities and camp fires are prohibited during periods of high fire risk. Federal land managers also use modeling techniques to estimate the impact of smoke generation from fires on air quality, particularly in or near PSD Class I areas. This information is used to plan controlled burning activities. Comparable indices have generally not been developed for DOD ranges (although some may be covered by virtue of being adjacent to public or state lands). ACC units can use USFS, BLM, and state guidelines in determining when it is safe to use flares over their respective lands, depending on fire risks. Often, joint agreements are developed between units and local land management agencies to address flare use considerations and fire risk. In all cases, flare use should be curtailed during periods identified as high or extreme fire risk.

Because fire occurrence databases do not include a cause category that distinguishes between military sources and other types of incendiaries or miscellaneous causes, it is not possible to identify to what degree flares may be a cause of fires on non-DOD lands. Most information about flare-caused fires was provided by DOD personnel or from investigative reports for specific fires. However, under specific weather and environmental conditions, one fire start can result in much more damage than several small fires under less conducive conditions. Therefore, the most effective strategy for minimizing damage from flare-caused fires is to limit potential for fires spreading, rather than attempt to completely eliminate fire starts.

The information obtained on ranges and airspace areas where flares are currently employed by ACC units led to the following conclusions:

- Fires caused by flares are rare, incidental events that are not comprehensively or consistently recorded. As a result, sufficient data were not available to derive statistically significant correlation between flare utilization levels, types of flares, altitude of release, or underlying environmental conditions.
- Fire occurrence data for DOD-owned lands, such as ranges, are not systematically reported to national fire occurrence databases. Therefore, there is no comprehensive database that can be examined for incidents of fires caused by flares.
- Categories available in the national and local (e.g., state) fire occurrence databases are not conducive to determining how many fires are actually caused by flares. Flares are not a category that is tracked, nor are military operations as a whole specifically called out in the databases. Fires caused by flares or other military operations are lumped in categories of "incendiary" (which also includes items like fireworks) and "miscellaneous." Within those categories, there is no mechanism for identifying what percentage of fires are caused by flares.
- From the available data, it was not possible to correlate flare-caused fires to specific flare types. No conclusions could be reached about the effectiveness of restrictions on specific self-protection flare types.
- Although rare, flares do cause fires which have been known to spread and burn significant areas of land. Given the potential damage that uncontrolled fires can cause to property and sensitive environmental resources, effective measures need to be implemented to minimize the risk that flares will cause fires that can spread out of control.
- Authorized altitudes for flares use are generally lower for areas under positive observation and control, such as manned military ranges. Under those conditions, fires can be detected immediately, and response actions can be initiated before fires spread. Higher release altitudes may be needed in areas where detection may be delayed, allowing fires to spread before they are brought under control.
- The most prevalent procedures currently used to reduce fire risk from flares are suspension of flare use during periods of high fire risk and restricting the release altitude for flares.
- Suspending use of flares during high fire risk periods appears to be an effective procedure. It can reduce, but does not eliminate the risk of fire. Significant fires have occurred in times when fire danger was considered low or moderate.

- Release altitude restrictions are probably more effective when they are related to the floor of the airspace than when they are different from the airspace floor. For example, MOAs with medium to high altitude floors (e.g., 8,000 feet or higher) are less likely to experience inadvertent fires from flare use than areas underlying airspace with low altitude floors, even if the use of flares is restricted to higher altitudes. This is likely due to difficulty in ensuring that aircraft achieve the higher altitude when dispensing flares if the rest of their training regime includes lower altitude operations.
- Existing fire management procedures and resources employed by land management agencies such as BLM, USFS, and state forests provide an effective and efficient means for ACC units to gauge when fire hazard may be too high to permit flare use. In the absence of these resources, there are assessment methodologies and models available to assess fire risk on a site-specific basis.

General fire risk for an area can be determined through the NFDRS. Fire prediction modeling can calculate fire size for varying hypothetical conditions in advance, allowing fire (or range) managers to predict fire hazards under varying weather situations. This information would enable airspace managers to warn operational units of likely future restrictions on flare use when precipitation levels are below a certain threshold. The operational units would then be able to plan and sequence required training events to fit local operating constraints.

Modeling specific locations within an area can help refine flare use restrictions. Spot locations with different thresholds of tolerance for fire, resource sensitivities, or vegetation types can be identified and analyzed in detail. Fire ratings for sensitive locations may be higher than for surrounding areas and require more restrictions on flare use or increased surveillance, without imposing the same restriction on the entire training area.

The results of BEHAVE modeling demonstrate the importance of considering fuel types and weather in assessing day-to-day fire risk, particularly in areas where high fuel load vegetation conditions persist. Results such as these can be used to determine appropriate threshold conditions (e.g., wind speed and humidity) for suspending or restricting flare use.

Because of the type of fire information required (fuel type, weather conditions, and terrain) for fire hazard evaluation, risk assessments must be performed on a site-specific basis. The procedures for setting up a fire hazard evaluation, however, can be standardized. The fire hazard and behavior prediction models are in public domain software. Even so, modeling a local fire hazard involves considerable data collection and effort. As a first step, guidelines already developed by land managers for an area (e.g., USFS or BLM land under a MOA) can be adopted to determine when it is safe to drop flares. Consultation with federal land managers and state forestry departments can be used in developing site-specific operational guidelines. Fire prediction modeling would only need to be performed for areas where this approach is not adequate.

A central database and modeling capability could be established where the BEHAVE model would be resident, along with on-line access to weather data. ACC units could obtain output from the BEHAVE model to assist in evaluating site-specific hazards. Assistance would be required from

knowledgeable experts to interpret the data, but this could be obtained by contacting a local fire suppression agency (e.g., federal or state forestry agency).

A variety of actions may be employed to minimize the number of potential ignition sources and to limit the spread of fires. Acceptable levels of risk depend on a combination of factors. For any given area and for a specified time, the sensitivity of resources, management objectives, availability of fire suppression services, and fire danger should be considered in determining what activities are acceptable.

Considering the management responsibilities of military departments and federal land managers for protecting resources and controlling fires, defining acceptable operating procedures would be a cooperative process. Procedures need to be clearly established and flexible enough to respond to varying conditions of fire danger over time. Similarly, the effectiveness of various procedures should be evaluated periodically.

4.6 AIR QUALITY

4.6.1 Issues Addressed

Flares are comprised primarily of magnesium which, when ignited, provides a more intense heat source than an aircraft engine. Air quality impacts could occur from both the flare materials and the explosive charges used to eject and ignite the flares. Air quality issues pertaining to flare use that were addressed during this study include the following:

- The potential for noncompliance with the NAAQS due to the release of significant quantities of particulates or lead.
- The potential for release of hazardous air pollutant emissions regulated under Title III of the Clean Air Act.
- Potential for visibility impairment in PSD Class I areas.

To assess compliance with the NAAQS, it is necessary to evaluate whether criteria pollutants are generated or released from flare usage. Specifically, the flare combustion products must be assessed to evaluate compliance with the NAAQS for regulated compounds.

Title III of the Clean Air Act sets a mandate requiring the U.S. EPA to regulate the emissions of 188 listed hazardous air pollutants. Thus, it is necessary to assess whether any components of flares or the combustion products formed from explosive charges and ignited flares are considered hazardous air pollutants and may cause adverse health effects.

Flares emit a small quantity of visible smoke when ignited. Therefore, the potential for visibility impairment from flare usage merits consideration for PSD Class I areas. Class I areas under or and near flare training airspace are listed in Section 3.5, **Table 3.5-1**.

4.6.2 Studies Conducted

Regulatory considerations relevant to the effects of flare use on air quality are summarized in Section 3.5.2.1. Studies conducted for this analysis included a review of existing literature and a screening health risk assessment.

4.6.2.1 Literature Review

A data search was conducted using DIALOG databases centered on "flare" as the major topic. Key words were used to search ten DIALOG databases (Aerospace, CA Search, Current Technology, Inspec2, Janes Defense and Aerospace News/Analysis, NTIS, Pollution Abstracts, PTS Newsletter, and PTS Aerospace/Defense Markets and Technology). The DIALOG search did not uncover any data, research, or other documentation addressing emissions or air pollution associated with flare use, emission factors for hazardous air pollutants generated from flare use, or the effect of flare release on air quality.

The material composition of flares is presented in Section 4.2. Typically, flares contain a mixture of magnesium with Teflon and Fluorel binder (polytetrafluoroethylene-a) wrapped in aluminum-reinforced tape. Analytical data on the exact weight percentages of the flare components were not available, and the combustion products information was very limited. Most of the studies focused on flare burn time in association with release altitudes. The flare pellet, when ignited, burns at a temperature of 2000 degrees Fahrenheit. Actual burn times are classified but can be characterized as less than 10 seconds. Only one study provided data on typical compositions of combustion products from MJU-10/B flares. Analytical results of the MJU-10/B flare combustion products identifies the following compounds: magnesium oxide, magnesium chloride, magnesium fluoride, carbon, and trace amounts of carbon monoxide, carbon dioxide, and oxygen difluorine (see Section 4.2).

Some test burn analyses have been conducted to obtain information on flare residue. Results from a Moody AFB test burn of six MJU-7/B flares indicated that no residue or ash was produced and only the plastic end cap and felt spacer survived (USAF 1989). Flare debris reportedly consists of a plastic end cap and portion of the plastic piston, slider assembly, and felt spacers. Another evaluation of residue from MJU-7/B flares concluded that the magnesium flare pellet is totally consumed during the burning, plastic pieces weighing up to 2 ounces will usually be consumed, and a small "lead" bracket weighing 0.3 ounces may or may not reach the ground. No other source has confirmed that there are any lead components, other than in the ignition charges of the ALA-17 A/B and MJU-7/B. The flares item manager at Hill AFB has indicated that none of the metal brackets are lead (Amey, personal communication, 1993). The plastic and metal flare debris remains intact and is essentially non-biodegradable. Recent fire investigations on BLM land under the Desert MOA in Nevada found remnants of what appeared to be the aluminum tape wrapping of flares.

Several different types of impulse cartridges are used for flares. Typical flare impulse cartridges contain all or some of the following compounds: boron, potassium perchlorate, titanium with potassium dichromate, calcium chromate, and potassium nitrate (**see Table 4.2-3**). First fire mixtures on some flares also contain barium chromate. Information on the combustion products of

each type of flare and impulse cartridge was not available. This information is important because potassium dichromate and calcium chromate lead to the formation of chromium (III) and chromium (VI), which are classified as hazardous air pollutants under Section 112(b)(i) of the Clean Air Act Amendments of 1990.

Materials in the BBU-36/B impulse cartridge, which is used with the MJU-10/B, MJU-7/B, and MJU/7A/B flares, include boron, potassium perchlorate, Viton A, potassium nitrate, binder, loose fill, and #2400 smokeless powder. The laboratory analysis of MJU-10 cartridge residue provided by Tracor indicated trace amounts (less than 0.05 grams) of boron oxide, potassium, and chromium oxide. Neither boron oxide nor potassium poses any potential air quality impacts. The only compound which is regulated as an air toxic under the Clean Air Act is chromium oxide. Since the MJU-10 does not contain a first fire mix, the presence of chromium oxide in the analysis may be a result of using an older impulse cartridge with chromium products. The M-206 flare uses a M-796 impulse cartridge. As can be seen on **Table 4.2-3**, this cartridge contains calcium chromate (approximately 80 mg).

Although chromium is recognized as a carcinogenic material, an applicable emission standard has not been established by the EPA. At this time, the American Conference of Governmental Industrial Hygienists (ACGIH) recommends a threshold limit value for chromium (VI) of 0.5 ug/m^3.

The simulator version of the MJU-7/B, the MJU-7(T-1)/B, replaces the magnesium flare pellet with a smoke charge. The smoke charge material consists of 20 percent powdered sugar, 36 percent potassium chlorate, 42 percent yellow dye (Chinoline Yellow-5), and 2 percent rubber-teflon binder. The sugar and binder components are organic and should oxidize completely to form oxides of carbon, nitrogen, and sulfur. The potassium chlorate provides oxygen for the reaction, decomposing to form potassium chloride. Chinoline Yellow-5 is a dye, as opposed to a pigment, and therefore a complex organic substance which will decompose to form oxides of mostly carbon and nitrogen. It is likely that the dye decomposes and loses its color immediately upon ignition. It does not pose an air quality issue.

Flares emit a small quantity of visible smoke when ignited, but because of the small quantity and the large area over which they are dispensed, no adverse impacts are anticipated (USAF 1983). Therefore, the potential for visibility impairment was not further evaluated.

4.6.2.2 Screening Health Risk Assessment

Based on current data, the total annual use of M-206 flares is estimated at about 120,000 flares dispensed by ACC units throughout the United States. One initiation charge is utilized to eject and ignite each flare. Thus, the annual total amount of chromium that is discharged into the atmosphere throughout the United States is estimated at 3.2 kilograms, or 7 pounds.

An estimated 85,000 M-206 flares are deployed annually in the Barry M. Goldwater Range/Sells MOA and provide a worst case scenario for evaluation. This annual flare usage would generate 5.014 pounds per year of chromium emissions. For the worst case scenario, all of the chromium was assumed to be chromium (VI). Although these emissions are quite small, due to the high

toxicity of hexavalent chromium, additional investigations, including a screening health risk assessment, were conducted to evaluate potential air quality/health impacts from the use of flares with chromium in the initiator cartridges.

The MJU-7/B uses an electrically fired pyrotechnic squib for ignition. To initiate the process, a firing pin strikes the primer assembly firing the ignition charge, a 15 mg charge consisting of basic lead styphnate, lead azide, barium nitrate, antimony trisulfide, and tetracene. The ignition charge fires the output charge, which is composed of a 40 mg mixture of zirconium, molybdenum trioxide, and potassium perchlorate. The output charge then ignites the flare pellet. The ALA-17 A/B also uses an electrically fired squib that contains potassium chlorate and lead thiocyanate. Additional investigations, including a screening health risk assessment, were also conducted to evaluate impacts from impulse charges which contain lead compounds.

The purpose of the screening health risk assessment was to estimate, through quantitative analysis, whether the emission levels of chromium and lead from flare use could cause significant long-term or short-term health impacts. A health risk assessment is an air quality analysis that specifically evaluates the potential health risk impacts resulting from emissions using air dispersion simulations and risk modeling. A detailed description of the methodology and results is presented in *Technical Reports on Chaff and Flares, Technical Report No. 3, Screening Health Risk Assessment of Chromium and Lead Emissions* (USAF 1994b).

Health Hazards Addressed by Screening Assessment

Hexavalent chromium and lead are both listed as known human carcinogens by the EPA. The potential for adverse human health effects from exposure to carcinogens is expressed in terms of cancer risk. Cancer risk results from this screening assessment were compared against a cancer risk significance level to determine annual emission rate and flare use thresholds. A multipathway cancer risk analysis was performed for chromium (VI) emissions, which included exposure through inhalation, soil ingestion, and skin (dermal) contact. Other potential exposure pathways, such as water ingestion, crop ingestion (direct deposition and root uptake), fish ingestion, homegrown produce, and mother's milk were not considered for this screening analysis.

Exposure to non-carcinogens is evaluated by calculating an inhalation hazard index for acute (short-term) and chronic (long-term) adverse health effects. The potential for short-term adverse human health effects from exposure to toxic non-carcinogens was compared against corresponding significance levels to determine hourly emission rate and flare deployment thresholds. Acute health effects were evaluated for lead emissions only. Because no other target organ is affected by lead, an acute inhalation hazard index was evaluated for the central nervous system only. Chromium is not known to cause acute health effects.

The potential for long-term adverse human health effects from exposure to toxic non-carcinogens was evaluated for both chromium (VI) and lead. The non-cancer human health effects resulting from chronic exposure to chromium are dermatitis, penetrating ulcers on the hands and forearms, perforation of the nasal septum, inflammation of the larynx, lung congestion, and liver and kidney damage. Chromium (VI) was evaluated for the respiratory system, the kidneys, and the gastrointestinal/liver system. Chronic exposure to inorganic lead has distinct toxicological effects

such as lead encephalopathy, colic, neurological disorders, and male reproductive distress such as hypospermia and decrease function of the prostate. Lead was evaluated for the cardiovascular/blood system, the central nervous system, the reproductive system, the kidneys, and the immune system.

Screening Health Risk Assessment Methodology

The EPA has conducted dose-response assessments to determine the correlation between the exposure of lead or chromium to the likelihood of an adverse health impact. The risk assessment model used in this health screening analysis was developed by the State of California as part of its air toxics legislation requiring health risk analysis. For applicability with the EPA-accepted national standard, the risk calculations were adjusted subsequent to the model runs to reflect the EPA-accepted inhalation risk factor for hexavalent chromium.

Emission rates were based on weight estimates of lead and chromium compounds provided by the item managers at Hill AFB and Picatinny Arsenal. **Table 4.6-1** presents a summary of weights for lead and chromium from the MJU-7/B and M-206 flares.

Table 4.6-1. Weights of Lead and Chromium in the MJU-7/B and M-206 Flares (grams)

Listed Substance	MJU-7/B			M-206		
	First Fire Mix	Impulse Cartridge	Initiation Device	First Fire Mix	Impulse Cartridge	Initiation Device
Chromium VI	0.26	-	-	0.26	0.027	-
Lead	-	-	0.005	-	-	-

A series of emission release scenarios were developed to account for the variability in altitude and size of the areas where flares are employed. A 1-hour scenario was developed for comparison with short-term acute health effects. Three annual scenarios were developed for comparison with cancer risk and long-term chronic health effects. For each scenario, a representative minimum and a maximum release altitude was identified, resulting in a total of eight emissions release parameters. **Table 4.6-2** presents a summary of emission release parameters used in the assessment.

To simulate a worst-case 1-hour concentration, a "puff" scenario was developed, in which an instantaneous mass emission (in grams per cubic meter) is released at a minimum release altitude of 400 feet or a maximum of 30,000 feet AGL. To simulate annual concentrations, typical target area, range/MOA, and large airspace (e.g., large complex or Warning Area) scenarios were developed. A minimum release altitude of 400 feet AGL was selected for all three scenarios. The maximum release altitude for the range/MOA and large airspace scenarios was set at 50,000 feet AGL, while that for a target area was established at 900 feet AGL.

Table 4.6-2. Emission Release Parameters

Scenario	Assumed Underlying Ground Area of Release	Analysis Period	Minimum Release Altitude (feet AGL)	Maximum Release Altitude (feet AGL)
Puff	N/A	1-Hour	400	30,000
Target Area	10,000 acres	Annual	400	900
Range/MOA	490,000 acres	Annual	400	50,000
Large Airspace	1,600,000 acres	Annual	400	50,000

N/A = not applicable

A two-step approach was used to predict human health impacts from flare releases. To quantify the exposure, an air dispersion model was used to simulate the emission release from a single flare and calculate maximum 1-hour ground-level concentrations. Air modeling was performed using an emission rate normalized to 1 gram per second to obtain a dispersion factor used for input into the risk model that calculated cancer risk and non-cancer acute and chronic health hazards.

The result of this modeling approach is a correlation between the normalized emission rate and health risk. Once the correlation was established, the results of the air dispersion modeling were used as input into the risk assessment model, and an estimate was made of the maximum allowable number of flare releases, based on the chromium and lead emission rates that could occur on an hourly and annual basis, without leading to exceedance of significant health impact levels.

4.6.3 Findings

The results of the screening health risk assessment indicate that, using the EPA cancer risk potency values and the quantity of chromium in the first fire mix and impulse cartridges, emission thresholds for causing significant increased cancer risk, for all annual release scenarios, are unlikely to occur under typical military flight exercises during a given year. The significance levels which were used are generally accepted as conservative levels, based on statistical risk analysis for human populations, and may be considered health-protective.

Table 4.6-3 presents a summary of annual thresholds. In applying emission and flare thresholds, it is important to consider the size of the area in which flares are being used, which is not necessarily the size of the entire range or MOA. Based on results of this screening health risk assessment, the annual deployment of flares is limited by cancer risk (primarily resulting from hexavalent chromium emissions). Specifically, the most stringent limit on the annual deployment of flares is based on the minimum release altitude scenario within an area equivalent to a target area (10,000 acres) such as Saylor Creek Range or Piney Island. Under this scenario, approximately 62,000 grams of hexavalent chromium, or 217,000 flares, could be released annually without

significantly increasing the risk of cancer over a 70-year lifetime exposure at the maximum impact location (using the EPA cancer risk potency value).

Table 4.6-3. Annual Thresholds for Flare Utilization

Scenario	Release Altitude (feet AGL)	Annual Emission Threshold (grams/year)*	Annual Flare Threshold (flares/year)**
Target Area	400	6.2×10^4	220,000
	900	6.9×10^4	240,000
Range/MOA	400	4.5×10^5	1.6 million
	50,000	1.3×10^9	4.5 billion
Large Airspace	400	8.3×10^5	2.9 million
	50,000	2.4×10^9	9.2 billion

* Assuming a cancer risk significance level of 1.0×10^{-6}, or one in one million.
** Assuming a hexavalent chromium content of 0.287 grams/flare.

The least stringent limit on annual deployment, based on cancer risk, is the maximum release altitude scenario for a large airspace area (1.6 million acres) such as the Nellis Air Force Range complex. In this size airspace, approximately 2.4 billion grams of hexavalent chromium, or 8.2 billion flares, could be released without significantly increasing the risk of cancer.

All other emission rate and flare deployment thresholds lie somewhere between the minimum and maximum release altitudes for these two release scenarios.

Table 4.6-4 presents a summary of maximum 1-hour thresholds. Based on the screening model results, lead emissions in excess of 333 grams/hour may result in a significant acute health hazard. Using a 333 grams/hour emission rate threshold, the screening results show that as many as 67,000 of the MJU-7/B flares can be dispensed within any 1-hour period before any acute health effects may be created. It is doubtful that such large numbers of flares would be used by the Air Force during such a short duration at a single location. Since the M-206 flare uses a non-lead bearing initiation cartridge, its use does not result in an acute health impact.

Table 4.6-4. Maximum 1-Hour Thresholds for Flare Utilization

Scenario	Release Altitude (feet AGL)	Hourly Emission Threshold (grams/hour)*	Hourly Flare Threshold (flares/hour)**
Puff	400	3.33×10^2	67,000
	900	1.00×10^4	2 million

* Assuming an acute hazard index significance level of 1.0.
** Assuming a lead content of 0.005 grams/flare.

4.6.4 Conclusions

A review of available literature revealed that a limited number of studies have been performed related to environmental impacts of flares. In particular, there were limited data with regard to typical compositions of combustion products from flares. Although one study claimed that no residue or ash was produced from flare burning, it would appear that, upon cooling, the magnesium would condense from its vapor state into solid particulates. Consequently, it is believed that the flare mass which is burned is released as particulates into the atmosphere. Since information related to the condensation phenomena and/or the particulate size generated during condensation was not available, it would be hard to speculate whether respirable particles (PM_{10}) are produced. However, emissions from flare usages occur over large areas and over long periods of time, and are therefore not expected to result in noncompliance with the NAAQS.

Several types of impulse cartridges are used with flares by the U.S. Air Force. Some of these impulse cartridges release hazardous air pollutants such as chromium and lead. A screening health risk assessment performed to assess the potential health impacts from these emissions concluded that it is highly unlikely flare use could result in short-term or long-term health impacts.

Impacts on visibility in PSD Class I areas from flare deployment are expected to be minimal. When ignited, flares release a small quantity of visible smoke. Since the actual burn time is typically less than 10 seconds, flares are not expected to cause visibility impairment in PSD Class I areas. Unlike stationary sources (such as power generating plants) that produce continuous emissions, flares are used intermittently at altitudes greater than 400 feet and over large areas.

4.7 PHYSICAL RESOURCES

4.7.1 Issues Addressed

This section addresses the potential effects of flares on soil and water resources. The principal issues include:

- Effects of flare materials and by-products, including dud flares and flare ash, on soil and water chemistry.
- Potential for flare duds and flare ash to accumulate in areas where they could affect soil and water.

Factors that influence the potential for flares and flare ash to affect soils and water chemistry include the chemical composition of flare material and ash, the chemical reactions that those materials may have with moisture, the density of dud flares, the quantities of flare ash produced by burning flares and its distribution on the ground, and the background environmental conditions in areas where flares and flare ash are deposited. Chemical changes, particularly in water bodies, affect habitat conditions and aquatic organisms. Chemical changes in soils can affect vegetative cover and result in increased erosion and sedimentation.

Ignition cartridges for the MJU-7/B contain lead compounds, barium nitrate, antimony trisulfide, tetracene, zirconium, molybdenum trioxide, and potassium perchlorate. Squibs that ignite ALA-

17A/B flares contain small quantities of potassium chlorate and lead thiocyanate. Some of these explosive by-products may be hazardous waste.

Both chemical changes and increased erosion and downstream sedimentation can result from fires caused by flares. However, this issue is not unique to flares and was not addressed in this study.

4.7.2 Studies Conducted

Studies conducted to examine the potential effects of flare use on soil and water included a review of relevant legislation, review of existing literature, and a laboratory analysis of flare material and flare ash in a range of surrogate environments.

4.7.2.1 Regulatory Considerations

The principal laws regulating discharges on land and into water are summarized in Section 3.6.2.1. These include RCRA, the Clean Water Act, and the Marine Protection, Research, and Sanctuaries Act. Their applicability to flares is similar as described for chaff, except that dud flares are more likely to qualify as hazardous waste, and flare use is less likely to qualify as disposal.

Flares, which are principally composed of magnesium, may qualify as characteristic hazardous waste under RCRA under the category of ignitability. Ignitability is defined under 40 CFR Part 261 as "not a liquid and capable, under standard temperature and pressure, of causing fire through friction, absorption of moisture, or spontaneous chemical changes and, when ignited, burns so vigorously and persistently that it creates a hazard." Duds or partially burned flares can be regarded as ignitable, especially since they burn fiercely on contact with water. Flare duds also contain lead and chromium compounds, which are listed hazardous substances.

However, flares themselves are not technically disposed of in the environment. They are designed to be completely consumed when used properly, leaving no residual waste other than non-hazardous endcaps and pistons. Therefore, compliance with RCRA does not appear to be required for occasional dud flares that reach the ground or water. When duds are collected by EOD personnel, however, they should be treated as hazardous waste, including storage in properly permitted facilities if not disposed of within 90 days.

The Clean Water Act prohibits the discharge of pollutants from any point source into the waters of the United States. In addition to solid waste, the definition of pollutant includes munitions. Self-protection flares may qualify as munitions, since they are used in combat and serve no civilian or peacetime purpose, other than for training. Dropping ordnance from aircraft into waters of the United States was found in at least one case (Weinberger v. Romero-Barcelo) to require a permit. However, burning flares are not intended to reach the surface, and dud flares are not intentionally discharged into water bodies. Flare ash, on the other hand, may be considered solid waste.

4.7.2.2 Literature Review

There have been a number of environmental assessments and other documents addressing the effects of flare use in certain airspace areas. Authorization to use self-protection flares requires an

environmental assessment. Most of those documents have concluded that the flares are fully consumed after ignition, and there would be no residual debris. Others acknowledge that there is remaining debris, and one indicated that approximately 2,500 pounds of flare related debris, not including duds, accumulated at Nellis Air Force Range in 1989 (Morphew 1991a).

There have been few laboratory or field studies that address the potential impacts of flares on soils or water resources. Most potential impacts discussed in the available literature revolve around associated fire hazards. Some documents addressed flare debris as a solid waste issue, commonly concluding that the debris is dropped over such a large area that it does not affect the environment. Impacts to water resources were addressed in only one environmental assessment (Taylor 1983). Most of the documents reviewed came to the conclusion that no impacts would occur but did not support their findings with empirical data.

Flare dud rates are not known. There have been no laboratory tests to specifically test for duds. Based on lot acceptance criteria, however, it is surmised that the failure rate is less than 1 percent (see Sections 4.2 and 4.4). Field estimates of dud frequency and recovery were developed for the Nellis and Fallon ranges in Nevada (DOD/DOI 1991; Morphew 1989a). Areas surveyed at Nellis were limited to areas within 1,000 feet of targets and 100 feet of access roads. A total of 50 duds were recovered over a three year period. At Fallon, 20 duds were estimated to accumulate per year. Both domestic and foreign models were found. A recent survey of the Desert Elgin South MOA associated with the Nellis complex uncovered no duds (USAF 1994d), and no duds were found in a field study conducted for this project (USAF 1994c).

4.7.2.3 Laboratory Analysis

Laboratory tests were conducted to identify the types and quantities of chemicals that could leach from dud flares and flare ash under various conditions. The tests were conducted by applying a series of surrogate environment treatments to M-206 flare pellet material and an uncontrolled sample of flare ash recovered from a chamber in which flares had been previously burned. A controlled burn sample was not generated for this study. Each of the samples was reacted with four extracting solutions to simulate acidic (pH 4), neutral (pH 7), alkaline (pH 10), and marine (pH 7.8 synthetic seawater) conditions. A modified TCLP was used for the extractions. The samples were analyzed for magnesium, aluminum, boron, barium, and chromium. The flare ash extracts were also examined for ammonia, nitrate, and nitrite. In addition, hydrogen gas formation was measured from the flare pellet sample. Details of the study methodology and results are presented in *Technical Reports on Chaff and Flares, Technical Report No. 5, Laboratory Analysis of Chaff and Flare Material* (USAF 1994e).

The samples were prepared and extracted according to TCLP guidelines in a sodium acetate buffer solution. The buffered solution was used to maintain as constant a pH as possible. Analytes for the flare pellet samples were selected based on the known composition of the material. Whereas the chemicals in flares are well documented, the composition of flare ash was speculative. It was reasoned that the only inorganic materials present in the ash by-product would be those also present in the flare itself. It was also reasoned that the carbon-fluoride-based polymer used to bind the magnesium might produce organic compounds during the combustion process. The high heat of

combustion (2,000 degrees Fahrenheit) would most certainly destroy or volatilize any lightweight components formed, although it was considered possible that heavier organic compounds might be produced.

Pure sources of flare ash produced specifically by M-206 flares similar to those used in the flare pellet tests were not available, so residual ash was collected from pervious test burns conducted at a U.S. Army test facility. No information was available about the specific flares burned to produce the ash, so certain assumptions had to be made about the chemical composition of the samples. The potential for contamination of these samples is relatively high. Debris, including paper clips, wire, and plant tissue, had to be removed from the samples prior to analysis.

Quality control procedures included analyzing all samples in duplicate and preparing a matrix spike for the organics, a matrix spike and matrix spike duplicate for the inorganics, a blank, a blank spike, and a laboratory quality control spike for all samples in each extraction medium. All laboratory data were reviewed and validated to EPA Level III standards according to the *Laboratory Data Validation Functional Guidelines for Evaluating Inorganic Analysis* (EPA 1988a) and the *National Functional Guidelines for Organic Data Review, Multi-Media, Multi-Concentration and Low Concentration Water* (EPA 1991).

Variation was found in the barium and chromium duplicate samples, and matrix spike recoveries of boron, barium, and aluminum were low. As a result, findings with respect to boron, barium, and aluminum are considered approximate. Boron and magnesium contamination was found to varying degrees in most of the laboratory blanks. Concentrations of elements occurring in samples associated with the contaminated blanks were consequently qualified as non-detects if the sample concentrations were less than five times the blank concentration.

One pH 7 buffer solution extraction of flare ash was analyzed for semi-volatile organics. All quality control checks were consistently within established control limits. No organic contaminants were detected other than minor amounts of common laboratory contaminants. Therefore, the data on organics are considered accurate and precise.

4.7.3 Findings

Table 4.7-1 presents the average concentrations found in the tests of flare pellet materials and flare ash. Only two of the elements analyzed in the flare pellet extracts, magnesium and barium, were detected in all the treatments. Chromium was detected only in the pH 4 treatment. The other elements are depicted in **Table 4.7-1** as less than the detection limit for the test. Magnesium, boron, barium, and chromium were detected in some or all of the flare ash treatments. Magnesium concentration was strongly affected by the solution pH in both the flare pellet and flare ash treatments, but particularly in the pH 4 treatment of the flare pellet.

Boron occurred at much higher concentrations in the flare ash than in the flare pellet extracts (where it was not detected at the detection limit). Barium was very high in the pH 4 solution. Unlike the flare pellet, chromium was not detected at pH 4 but was found in the pH 10 and synthetic seawater solution. In addition to the metals detected, all flare ash extracts contained measurable levels of ammonia and nitrate, and nitrite was detected in the pH 10 treatment.

Both the flare pellet and the flare ash extractions affected the pH of the leaching solutions. All of the post-extraction solutions for flare duds had pH levels close to 10, including the pH 4 solution.

Three samples of flare pellet material were reacted with the pH 4 solution for a 72-hour period to assess the formation of hydrogen gas. All three samples resulted in comparable quantities of gas (522 to 539 liters per kilogram). The gas was colorless and highly flammable and presumed to be primarily hydrogen. However, it was not odorless and may have contained some other volatile contaminant.

4.7.4 Conclusions

The effects of dud flares and flare ash on the environment depend on the quantity of material deposited in a particular environment, the characteristics of the receiving environment (e.g., pH), and the sensitivity of the environment to contaminants of concern. Dud flares are rare and incidental events, so it is extremely unlikely that any given location would experience long-term cumulative effects from a build-up of flare material. Flare ash is widely dispersed by wind, and the likelihood that a sufficient quantity would accumulate in a particular pond, stream, or estuary to measurable affect its chemical make-up is also remote.

Table 4.7-1. Average Element Concentrations from Flare Samples Subjected to Surrogate Environmental Solutions

Treatment	Concentration (mg/l)				
	Mg	Al	B	Ba	Cr
Flare Pellet					
pH 4	2945	<0.1	<0.1	3.0	0.29
pH 7	4.4	<0.1	<0.1	2.7	<0.02
pH 10	2.4	<0.1	<0.1	2.6	<0.02
SSW	640	<0.1	<0.1	2.6	<0.02
Flare Ash					
pH 4	857	<0.1	17.9	185	<0.02
pH 7	186	<0.1	18.0	1.4	<0.02
pH 10	202	<0.1	89.0	1.0	0.01
SW	948	<0.1	68.0	<0.5	0.03

SSW = synthetic seawater
Less than (<) values indicate the element was not present or occurred below the method detection limit.
Concentrations represent average of two samples each.

Flare ash is more susceptible to weathering than flare duds, just based on particle size and exposed area. The magnesium in flare material is clearly least stable in acidic environments. The dissolution of either flare material or flare ash will be greatest where water content is high. The following paragraphs summarize conclusions relative to soil chemistry and water resources.

4.7.4.1 Soil Chemistry

Elements of concern for flares include magnesium, boron, barium, and chromium. The laboratory test results indicate that the potential for release of these elements is strongly related to pH, the highly acidic media producing higher concentrations (with the exception of barium in the flare pellet samples, which did not vary appreciably with pH). Impacts from dud flares are not considered of significant concern because the incidence of duds is rare, and the number that would have to land in a single location to have an effect is on the order of tens of thousands.

The principal element in flares and in flare ash is magnesium. Magnesium occurs naturally in soil at a mean concentration of 9,000 mg/kg. The highest concentrations produced by the surrogate environment laboratory tests were 3,050 mg/l for a dud flare and 861 mg for flare ash at pH 4. At higher pH, the concentrations dropped off dramatically, to an average of 186 mg/1 at pH 7 and 202 mg/1 at pH 10 for flare ash (the reductions were even more dramatic with flare pellet samples).

Flare ash samples also produced detectable quantities of boron, barium, and, in some samples, chromium. Barium was detected in the pH 4, 7, and 10 treatments, with the highest levels found in the most acidic solution. The unexpectedly high quantities of barium detected in the flare ash samples raise questions about potential contamination of the ash used, which was not produced in a controlled environment.

Barium mobility and uptake by plants have not been well studied, since barium generally occurs sparingly in solutable forms and at low concentrations in most soils. Test results indicate it will become more mobile in low pH environments. Barium can be toxic to animals when ingested in forms other than the insoluble barium sulfate. The elevated barium concentration in the pH 4 extracts of the flare ash suggest that barium may present a localized hazard for sensitive organisms. There are no RCRA reportable quantities for barium, but the critical TCLP limit in 40 CFR Part 261.24 is 100 mg/l. This level was exceeded in only one of the laboratory findings, in the pH 4 extract of flare ash (the next highest finding was 3 mg/l) (Munk 1994a).

Boron toxicity can occur in alkaline environments, and the laboratory tests of flare ash produced the highest concentrations in the alkaline (pH 10) solution. There are no RCRA reportable quantities or critical TCLP limits for boron. Based on a mean background soil content of 33 mg/kg, the amount of flare ash that would be required to raise the boron concentration to triple the background level in the upper inch of soil was estimated at over 1,500 kg/acre (Munk 1994a). This represents about 4,000 flares.

Chromium was detected in low concentrations in the pH 10 treatment of flare ash. The low quantities detected indicate that chromium is not a significant issue. The RCRA reportable quantity for chromium is 2,273 kg, and the critical TCLP limit is 5 mg/l. In contrast, the highest detected concentration in the laboratory test of flare ash was 0.03 mg/l (Munk 1994a).

Three replicate samples of flare pellet material were analyzed to measure production of hydrogen gas. An average sample of 1.1 grams of flare produced an average of 580 milliliters of hydrogen gas. Assuming an average flare weight of 370 grams, a complete flare falling into water could produce 195 liters of hydrogen gas. Hydrogen gas is highly explosive if in a confined area, although

it would dissipate rapidly in an open environment. Hydrogen gas production from dud flares would not pose an environmental threat, but it could be a safety hazard if a wet flare were placed in an enclosed container.

4.7.4.2 Water Resources

Of the five metals measured in the flare pellet material, only magnesium showed sufficiently high levels to warrant consideration. Aluminum, boron, barium, and chromium did not extract in sufficient quantities to be of concern to aquatic organisms. Magnesium was measured at almost 3,000 ppm at pH 4, dropping to 4.4 ppm at pH 7, which more closely approximates typical aquatic environments. There are no aquatic criteria for magnesium, but a review of the on-line AQUIRE data service showed a 50 percent lethal concentration (LC50) response in water fleas (*Daphnia magna*) at 140 to 160 ppm. It is not possible to extrapolate precisely the level of magnesium that would be extracted over a pH range of 5 to 9, which would cover most aquatic environments, however, it appears that effects would only occur in the more acidic environments. Even then, the occurrence of dud flares is so rare as to be highly unlikely to have an impact.

The elements of concern in the flare ash extracts are magnesium, barium, and boron. Aluminum and chromium were either undetected or in insufficient quantities to threaten aquatic life. There are no established water quality criteria for barium, but the AQUIRE database showed that values as low as 14.5 ppm were toxic to water fleas, while higher values (690 ppm) were necessary to cause 50 percent mortality in mosquito fish (*Gambusia affinis*). Both species live in environments that generally have a pH of over 6.9 and would not be affected at the levels found in the pH 7 laboratory test. No data are available concerning toxicity of barium for aquatic life that live in lower pH environments.

There are no water quality criteria established for boron. However, in a comparison of the TCLP laboratory data against a U.S. Fish and Wildlife Service publication on toxicity effects of boron (USFWS 1985), the levels of boron extracted in the pH 10 samples of flare ash would be sufficient to cause lethal or chronic effects in several aquatic species. Again, this is more alkaline than would be found in a natural environment.

Flare ash extracts also contained measurable levels of ammonia. The values ranged from 2.8 to 3.2 ppm and are at or above levels reported by EPA as toxic to aquatic life (EPA 1985). In addition, both the flare dud and the flare ash samples had a significant effect on the pH of the solutions with which they reacted. The 1.1 gram samples of flare ash raised the pH of 225 milliliters of buffered sodium acetate solution from pH 4 to pH 9.6. While flare ash quantities likely to settle in a body of water are very small, a dud flare falling into a small, confined pond could raise the pH and adversely affect aquatic life in the water. This is an extremely unlikely event, however.

Incidental flare duds falling into marine environments would not be expected to generate adverse effects due to the small amount of chemicals released. The only chemicals detected in the flare ash samples were magnesium, boron, and chromium. Unlike the freshwater extracts, no barium was detected. Magnesium levels were as high as 86 ppm, after correction for the high background level of magnesium in seawater (about 867 ppm). No magnesium toxicity data are available for seawater.

The boron extract had a value of 68 ppm, which could be sufficient to cause effects in some aquatic species (USFWS 1985). Chromium was not detected in sufficient quantities for concern.

In conclusion, impacts from flares on water resources would only be of potential concern in small water bodies subject to substantial, repeated flare use, and which support organisms sensitive to these chemicals. Deposition of flare ash in the concentrations used for the laboratory analysis could be toxic to aquatic organisms. However, these concentrations (material to solution ratio of 1:20) were far higher than could occur as a result of military training. Site-specific analysis should be considered if any area that could be affected is known to provide habitat for a threatened or endangered species. Two approaches could be taken:

- The quantity of flare ash deposition could be projected, based on anticipated number of flares to be used, and resulting chemical effects could be estimated and compared to acute or chronic values or to toxicological data for the organisms of concern.
- The sensitive water body of concern could be subjected to a sampling program to determine whether flare use is affecting its chemical composition.

4.8 BIOLOGICAL RESOURCES

4.8.1 Issues Addressed

Flares have the potential to affect biological resources directly through visual responses in wildlife and indirectly through vegetation loss and habitat modification resulting from fires started by flares. The significance of flare impacts on biological resources vary in relation to the sensitivity of the environment affected including the presence of threatened or endangered species. The following issues were identified and addressed in this study:

- Startle effects on birds and other wildlife (behavioral response).
- Chemical effects of flare debris on plants through soil (physiological response).

As discussed in Section 3.7 for chaff, flares releases would likely add minimally to startle responses to aircraft overflights.

Chemicals in flare debris that falls to the ground may have the potential to enter soils and affect plants. The debris includes dud flares (primarily magnesium), flare ash, foil wrappers, and plastic or metal hardware. Effects would be very localized, due to the small size of flare debris.

Fires resulting from flares could adversely affect vegetation and wildlife habitat by removal of plant cover (short-term effect) or altering the plant community (long-term effect). Removal of vegetation can also lead to increased erosion and downslope sedimentation that can cause long term environmental change. The level and extent of effects on biological resources are site specific and depend on factors such as type of plant community (i.e., adaptation to fire), season, and frequency of fires. This issue is not unique to flares, however, and was therefore not analyzed in detail.

4.8.2 Studies Conducted

4.8.2.1 Regulatory Considerations

Regulatory considerations relevant to biological resources are summarized in Section 3.2.3.1.

4.8.2.2 Literature Review

There is virtually no literature addressing the effects of flares on biological resources. Substantial literature exists on the effects of fire; however, as noted above, this information was not reviewed in detail, since these effects are not unique to fires caused by flares.

4.8.2.3 Field Studies

Evidence of flare debris and fires was recorded during the field studies at Nellis Air Force Range.

4.8.3 Findings

The literature review found no studies specifically addressing startle effects on wildlife. The potential for fires to result from flare use is discussed in Section 4.5. Responses of different plant communities and associated wildlife to fire, independent of cause, have been studied and were not included in this review because the responses are generally specific to each plant community. Based on the toxicological studies reviewed in Section 4.3 and the TCLP studies described in Section 4.7, chemical effects from flare debris are not expected to affect biological resources or habitat. The only remaining issue is the potential for flare ash to affect certain small aquatic habitats. This could be of concern if the habitat supported listed or candidate threatened or endangered species.

Field surveys were conducted at the Nellis Air Force Range complex. The field surveys were not designed to collect data on flare intensity and duration as measured from the ground, or to measure responses of wildlife to flares. Incidental observations, however, indicate that flares released from low altitudes at night are very bright, but the light is of short duration (less than 10 seconds). Flare debris observed during the field surveys included plastic caps, foil wrappers, and plastic cartridges. No dud flares were found.

Observations of bird nests and rodent burrows/nests found no evidence of flare debris use by wildlife. Some species, such as crows and ravens, are known to selectively pick up shiny material like foil flare wrappers and may use these materials in their nests. No nests of these species were found during the surveys. Wood rats are also known to collect a wide variety of materials to put in their nests. No flare debris was found in the seven woodrat nests inspected on the Nellis complex.

4.8.4 Conclusions

Based on the limited amount of information available, startle effects of flares on wildlife are expected to be negligible. Noise from the aircraft is more likely to elicit a startle response than would ignition of flares.

Chemical effects of flare debris on vegetation are expected to be negligible due to the small amount of debris reaching the ground and the generally low toxicity of residues. In areas with small, confined aquatic habitats that support sensitive species, consideration may need to be given to assessing potential impacts from the proposed level of flare use (see Section 4.7).

4.9 LAND USE AND VISUAL RESOURCES

4.9.1 Issues Addressed

The effects of flare use on land use and visual resources can result from four causes; flare ignition, flare debris, dud flares, and fire damage. The following is a summary of the issues:

- Debris from flare cartridges creates litter on the ground. This might affect users' attitudes and uses of outdoor recreation areas.
- Dud flares lying on the ground could create a hazard and/or interfere with certain land uses.
- Large numbers of burning flares may affect sensitive visual resources.
- Fires caused by flares could displace existing land uses.
- Fires caused by flares could effect the visual quality of an area.

The potential sensitivity of particular land uses to the effects from flares is summarized in **Table 4.9-1**. The sensitivity of various land uses to accumulation of flare debris would be similar to that described for chaff debris in Section 3.8. If a dud flare were found and improperly handled by an untrained person, it could ignite and cause injury or damage to property. It is assumed that fire could have a significant adverse effect on any land use, so the sensitivity to fire reflected in **Table 4.9-1** is related primarily to potential for hazard to people or ecological damage.

The degree to which a fire affects land uses and visual resources depends on the damage caused by the fire, land use objectives, aesthetic value, and the number of people exposed to a hazard. Federal land managers usually set fire management objectives for different vegetative areas, based on the propensity of fires to start and spread and the sensitivity of resources to fire damage. For example, areas with historic wooden structures or habitat for threatened or endangered species may be managed to suppress all fires, whereas in sparse, low sagebrush open rangeland areas, it may be sufficient to keep fires from spreading beyond 500 acres. Impacts of fire on visual resources depend on the scenic quality of the area, size and intensity of the fires, and noticeability of the burned area.

Smoke from fires may obscure views and reduce scenic quality, but those impacts would be temporary and not result in permanent changes to visual resources. Smoke damage to structures (other than cultural resources) may have an economic consequence, but is not expected to affect enduring land use or visual attributes.

Table 4.9-1. Sensitivity of Land Uses to Flare Impacts

Land Use or Specially Designated Area	Potential Resource Effect			
	Debris Accumulation	Duds	Physical Fire Damage *	Aesthetic Fire Damage *
Wilderness	M/H	M	M/H	M/H
Wild and Scenic River	M/H	M	M/H	M/H
Coastal Zone	M	L	M/H	M
Wildlife Protection Area/Refuge	M	L	M/H	M
National Park/Monument	M	H	M/H	M/H
Wellhead Protection Area	L	L	M/H	L
Areas of Critical Environmental Concern	L	L	M/H	M
Outstanding Visual Resource Area	M	M	M	H
Forest	L	L	M	M
Cropland	L	L	M	L
Rangeland	L	L	M	L
Recreational	M	M/H	M/H	M/H

H = High M = Medium L = Low

* Effects depend on the extent of the fire damage and the time it takes for vegetation to recover.

4.9.2 Studies Conducted

4.9.2.1 Regulatory Considerations

There are no laws specifically addressing the use of flares. However, fire caused by unnatural sources has the potential to cause damage to property and natural resources and make the land unsuitable for specific (including legislated) uses. Section 3.8.2.1 summarizes legislation that may apply to land management and protection of specially designated areas. Of particular applicability is FLPMA, which establishes criteria for management of public lands. Consequently, BLM, USFS, and other agencies that manage public lands have internal policies and requirements to develop and implement resource management plans that include fire management, visual resource management, and smoke management plans.

The MLWA (P.L. 99-606) provides for the development of a management plan by the Secretary of the Interior (in consultation with the Secretary of the military department concerned) for the public

land areas withdrawn under that act for specified military uses. It also states that the Secretary of the military department responsible for withdrawn lands shall take necessary precautions to prevent and suppress brush and range fires occurring within and outside the withdrawn lands as a result of military activities. Responsibilities are detailed through Memoranda of Understanding between the Secretary of the Interior and the Secretary of the military departments.

4.9.2.2 Literature Review

A literature search of the DIALOG database did not yield any information on flare use in relation to land use or visual resources. However, literature on related topics, such as fire and forest management, effects of fire on user landscape preferences, and visual resource assessment is abundant. Research papers have presented methods and results from surveys to evaluate public attitudes towards wilderness fire management policy (McCool and Stankey 1986) and methods to assess the impact of fire on forest recreation (Vaux et al. 1984).

Assessing the impact of fire on scenic quality and recreation is difficult due to the number of variables affecting individual preferences. Recreationists may choose areas because of their scenic quality, but landscape preferences vary, landscapes change over time, and users consider other attributes, such as distance, affordability, amenities, and suitable alternatives (Vaux et al. 1984). From a photo-based survey using images of selected locations (some affected by fire and others unaffected), viewers indicated their preferences towards the scenic conditions at different points in time. Some successional stages of burned areas exhibited appealing scenic quality to viewers, and some stages in a natural succession were found undesirable, particularly when foreground and middle ground areas were overgrown with a thick understory of small trees, shrubs and dead vegetative debris. Studies have shown that informed visitors are generally accepting of managed fires and perceive them as beneficial (McCool and Stankey 1986).

4.9.2.3 Field Studies

Flare debris has the same potential to accumulate and become visible in the environment as chaff debris. Field studies were conducted at the Nellis Air Force Range complex and Townsend Air to Ground Gunnery Range to examine the visibility of flare debris in natural settings. The field investigations were designed to assess the noticeability of various types of debris, determine the distances at which the debris became visible, identify variables affecting visibility, and compare the visibility of debris in arid versus temperate environments. Selected areas were surveyed to look for evidence of flare debris, and flare duds and debris items (e.g., end caps, wrappers) were placed in different contexts for analysis. The methods used and results are described in detail in *Technical Reports on Chaff and Flares, Technical Report No. 4, Field Studies* (USAF 1994c).

4.9.3 Findings

The results of the field surveys indicated that small flare debris components (e.g., endcaps) have low visibility in natural settings (**Table 4.9-2**). Dud flares were not found *in situ* during the surveys, but they were detected and distracting when placed in natural settings, due to their size, reflectivity, and shape. In optimal viewing conditions, dud flares were noticeable at distances up to 120 feet.

Table 4.9-2. Summary of Visibility of Flare Items Placed in Arid and Temperate Environments

Item	Area Description	Viewing Conditions	Noticeable (feet)	Distinguish-able (feet)	Distracting (feet)
Arid Environment					
Flare wrapper	Basin, low sage	Optimal Average	65 5	20 5	15 5
Dud flare 2.7 x 2 x 8 inches	Joshua Tree, low sage	Optimal Average	75 20	50 20	40 20
Dud flare 1 x 2 x 8 inches (wrapped in used foil wrapper)	Piñon-juniper slopes	Optimal Average	100 20	35 10	35 10
Dud flare 2.7 x 2 x 8 inches (wrapped in used foil wrapper)	Piñon-juniper slopes	Optimal Average	100 25	55 20	55 20
Temperate Environment					
Flare wrapper	Upland forest, along old logging road, shady, dark soil, varied colors on surface from leaf debris	Optimal Average	30 23	15 10	15 10
Dud flare 1 x 2 x 8 inches (wrapped in used foil wrapper)	Upland forest, along old logging road, shady, dark soil, varied colors on surface from leaf debris	Optimal Average	45 18	45 18	25 7
Dud flare 2.7 x 2 x 8 inches (wrapped in used foil wrapper)	Upland forest, along old logging road, shady, dark soil, varied colors on surface from leaf debris	Optimal Average	120 25	90 25	40 25

Small endcaps were the least noticeable, generally only visible at distances of 3 to 7 feet, particularly in arid environments where contrast was reduced by surface texture.

Like the chaff debris (see Section 3.8.3), flare debris was often indistinguishable from natural and human made look-alikes. In arid environments, long, twisted, weathered flare wrappers appeared similar to exposed, sinewy sagebrush roots. Weathered flare wrappers were also similar to empty tobacco pouches. Common litter items, such as empty cans and bottles, foil wrappers, and bottle caps had similar visibility as flare debris.

Flare training over non-DOD land is conducted at altitudes above 2,000 feet AGL, in accordance with Air Force regulations, airspace operating restrictions, or agreements with other agencies. Flare-caused fires in these areas are not common, but they tend to be larger than on DOD ranges. Consequently, the potential for adverse land use and aesthetics effects is greater in areas underlying special-use airspace where DOD does not control the land.

4.9.4 Conclusions

In general, flare debris, such as small endcaps, is not easily detected and would not affect overall scenic quality or outdoor experiences. Because dud flares are more easily noticed and attract attention in natural settings, however, they are more likely to be picked up and could pose a hazard to hikers and recreationists. Dud flares and other litter could be a curiosity if found by recreationists. Campfires would provide an external heat source, hot enough to ignite a dud flare. Dud flares may be stored in a plastic bag with other trash, which could create explosive conditions, or carried home and transported into other environments, increasing the likelihood of the dud eventually being ignited or improperly handled. Similarly, dud flares could attract attention and be picked up if they landed in rural agricultural and residential areas.

Dud flares could pose a safety hazard in areas where people congregate or where human activity covers large areas of land (e.g., cattle ranching). Impacts to land uses would depend on probability of exposure and resultant safety risk. On a site-specific basis where flares are proposed for use in areas with residential development or concentrations of people, the density of dud flares should be estimated and considered when assessing compatibility with underlying land uses.

Although flare debris does not appear to accumulate in quantities that would result in significant visual impacts, it could be more noticeable and undesirable in areas specifically protected to preserve naturalness and pristine qualities, such as Wilderness Areas and Wild and Scenic Rivers, where any human-made object would be incongruous and unexpected, and where people walking, camping, and hiking would be within viewing distances of debris items on the ground.

The visual impact of illuminated flares would be short term and temporary and not expected to significantly affect sensitive visual resources, unless large numbers of flares were dispensed over scenic areas on a frequent basis. Impacts to scenic resources are generally not a concern at night. However, flares dispensed at night could be perceived as an intrusion and disturbing to people in recreation areas and Wilderness Areas.

Since flare releases would be accompanied by the sound of high speed military aircraft, viewers would assume that the brightly burning flares have some military application, but they may erroneously fear a spread of fire or impact from unidentified ordnance to result from the flare. This kind of activity could lead to negative public attitudes about using certain areas for outdoor recreation.

The most sensitive land uses and areas of outstanding visual quality are often in remote locations where access for fire suppression is difficult and response times longer. These areas often have timber vegetative types with high fuel loads that can produce large fires with high intensity, causing damage to these areas. Fires can also cause significant economic damage and pose a safety hazard in agricultural and residential areas. Residential pockets in remote areas are particularly susceptible to hazards from forest fires.

Minimum flare release altitudes are imposed to reduce the potential for flare-caused fires. Fires tend to spread and damage larger areas in timber and grassland environments, including specially protected areas such as Wilderness Areas, Wilderness Study Areas, Wild and Scenic Rivers, wildlife and habitat protection areas, and areas of designated outstanding visual quality.

Areas specifically designated for preservation of natural qualities have low tolerance for changes brought on by non-ecological conditions, including litter and fires, and would be least suitable as flare training areas. Depending on the risk of fires, unrestricted flare use over those areas could be incompatible with land uses that concentrate human activity, including parks, monuments, recreational facilities, and residential areas. While fire is a part of ecological cycles, fires originating from non-natural sources can be ill-timed and limit land managers' ability to implement fire management programs aimed at balancing ecological necessity with human safety. Over areas with high fire hazard ratings and high recreational use, scenic value, or protective goals, acceptable operating parameters should be developed in coordination with appropriate land managers.

4.10 CULTURAL RESOURCES

4.10.1 Issues Addressed

The effects of flares on cultural resources discussed in this section include the following:

- Effects of flare-related fires.
- Potential impacts from fire suppression and rehabilitation activities.
- Effects of smoke.
- Effects from flare debris and duds.

Cultural resources are defined as any prehistoric or historic district, site, building, structure, or object considered important to a culture, subculture, or community for scientific, traditional, religious or any other reason. The cultural resources discussed in this section include prehistoric and historic archaeological resources, architectural resources, and traditional resources. To be considered significant, archaeological and architectural resources must meet one or more of the criteria (as defined in 36 CFR 60.4) for inclusion on the National Register of Historic Places. There

are no legally established criteria for assessing the significance of a traditional Native American resources.

Under the National Historic Preservation Act of 1966 and implementing regulations, impacts could result if damage or alterations to cultural resources which meet National Register criteria occurred as a result of a flare-caused fire. The presence (and potential hazard) of dud flares on land or sites with traditional or ceremonial uses or values may restrict Native Americans from believing, expressing, or exercising traditional religions under the American Indian Religious Freedom Act.

4.10.2 Studies Conducted

Key federal laws and regulations that manage cultural resources include the National Historic Preservation Act of 1966, the Archaeological and Historic Preservation Act of 1974, the American Indian Religious Freedom Act of 1978, the Archaeological Resources Protection Act of 1979, Executive Order 11593, and the Native American Graves Protection and Repatriation Act of 1990. These are described in Section 3.9.2.1.

Existing literature about flares and fire was reviewed to evaluate their potential effects on cultural resources. The literature search uncovered no information specifically addressing the effects of flares on cultural resources. No field observations or experimental studies were conducted as part of this analysis.

4.10.3 Findings

4.10.3.1 Effects of Fire on Cultural Resources

Although existing ACC procedures require employment of flares at or above altitudes selected to ensure complete consumption of the flare before contacting the ground surface, a potential exists for inadvertent low releases of flares, and under certain conditions, fires could start. The risk of fire depends on local vegetative and climatic conditions, as well as the probability of burning flares striking a susceptible location. While the environmental conditions conducive to fire can be predicted, the probability of fires caused by flares cannot.

One study concerning the effects of fire on cultural resources examined a number of variables affecting archaeological site formation processes in wildfire areas (Rogers and Francis 1988). The study used a fire value classification system (low, medium, or high intensity) based on the type and amount of vegetation burned. It determined that the impact of low intensity fires on prehistoric archaeological sites would be minimal, and the impact of medium or high intensity burns would be high, due to alteration of the physical characteristics of the soil and loss of surface vegetation. Loss of vegetation can result in the exposure of some archaeological sites, increased erosion and soil deposition at archaeological sites, and displacement of artifacts. It was also reported by Rogers (1988) that fire can alter the archaeological record by causing thermal fractures and cracks in non-cultural lithic materials that cause them to resemble artifacts. Also, the results of radiocarbon and obsidian hydration dating and other special analysis techniques could potentially be distorted by introducing modern carbon, by altering lithic materials, or by causing other physical or chemical changes to cultural resources.

The impact of fire on architectural resources is straight forward. Fires can cause the complete or partial destruction of an architectural resource.

Existing literature and information on the effects of fire on traditional cultural resources, such as plants and wildlife, are quite extensive. Potential impacts could include destruction of native vegetation; introduction of opportunistic "exotic" species; a reduction of natural habitats, leading to a reduction or change in animal species; and death or displacement of wildlife (Helvey et. al. 1985; Little and Klock 1985; Wright 1972). The loss or reduction of particular plant and animal species could adversely affect attempts by Native Americans to sustain their traditional activities.

4.10.3.2 Effects of Fire Suppression and Rehabilitation

The effects of fire suppression on archaeological sites and historic buildings were examined in a *USDA Forest Service General Technical Report* (Swan and Francis 1989). This report concluded that fire suppression policies and activities have resulted in a build-up of fuel, leading to fewer, yet more intense fires with a greater capacity for altering lithic artifacts on archaeological sites.

Another major effect of suppression activities is the disturbance or destruction of archaeological sites by fire suppression personnel and rehabilitation crews. Cultural resources can be damaged by activities undertaken to suppress fires and rehabilitate burned areas, such as cutting fire breaks and mechanical reseeding. Unless care is taken in the creation of fire breaks and in replanting activities, the potential to impact cultural resources is high. In particular, archaeological sites and Native American traditional use areas could be severely impacted by the use of mechanized suppression equipment. There is no information available on the effect of fire retardant use on cultural resources.

Several federal land management agencies (e.g., BLM, USFS) have stated policies to guide the protection of cultural resources during and after fires. These policies consider cultural resources during pre-suppression planning, normal fire rehabilitation plan development, post-suppression damage assessment, and emergency fire rehabilitation. Such activities are guided by Section 106 of the National Historic Preservation Act and related regulations.

4.10.3.3 Effects of Smoke on Cultural Resources

Smoke from fires could temporarily impact cultural resources by affecting the context and setting of historic buildings and Native American traditional use areas. This would be considered a short-term impact.

Smoke could permanently affect some archaeological sites, particularly rock art sites, and could result in physical damage to some architectural resources.

4.10.3.4 Effects of Flare Debris

Surviving debris from flares may include plastic and metal components and dud flares. It is unlikely that the deposition of these materials would adversely affect archaeological, architectural, or traditional Native American resources, except possibly in terms of aesthetics. This potential

effect would be adverse only on cultural resources where setting is a contributing characteristic of site significance, as evaluated under National Register criteria. However, as described in Section 4.9, flare debris has not been found to have significant effects on visual resources.

In some locations, EOD clean-up crews could cause potentially adverse impacts to cultural resources through inadvertent damage or through intentional collection of artifacts.

4.10.4 Conclusions

The primary potential effect to cultural resources caused by the use of flares would be associated with fire and accompanying suppression and rehabilitation activities. The effects of smoke and debris are considered less likely to be adverse. The likelihood of flare-related effects to cultural resources in a particular location is directly related to the probability of unintentional fires.

5.0 ENVIRONMENTAL ASSESSMENT OF CHAFF AND FLARE USE

5.1 OVERVIEW

The purpose of this section is to provide guidelines that can be used by ACC units and facilities to assess the environmental impacts associated with proposals for chaff and flare use and to prepare documentation to comply with NEPA. The guidelines are based on the findings and conclusions of this study concerning the potential effects of chaff and flares on health, safety, air quality, physical resources, biological resources, land use and visual resources, and cultural resources. Fire risk was also addressed for flare use. The conclusions fall into two categories:

- Issues that were found to have little or no potential for significant environmental impacts, which can be addressed by incorporating the findings of this report by reference.
- Issues that need additional site-specific information or analysis.

This study has drawn from existing literature, historic information from existing training areas, and results of modeling, field studies, and laboratory studies to reach conclusions about potential for significant impact. In some cases, the level of impact on specific resources depends on the quantity and type of chaff or flares dispensed and the existence of sensitive resources in underlying areas. The resource analyses have identified sensitive resources that may need to be evaluated on a site-specific basis when chaff and/or flare use is proposed.

Potential environmental impacts caused by chaff and flare use are described for affected resources in the preceding chapters. **Table 5.1-1** summarizes conclusions reached about the potential for impacts identified within each resource area. A conclusion of no significant impact is indicated if the study has concluded that chaff or flare use is unlikely to result in a significant impact or in conditions exceeding regulatory thresholds. Site-specific analysis is indicated to determine if particular sensitive resources or conditions occur in underlying areas, or where potential impacts could result depending on level of proposed use or on operating parameters included in the proposal.

The following section focuses on resource-specific issues requiring site-specific analysis in order to determine impacts from proposed chaff and flare use.

5.2 GUIDELINES FOR SITE-SPECIFIC ANALYSES

5.2.1 Safety

5.2.1.1 Chaff

The only safety issue requiring site-specific consideration for chaff use is the potential for interference with air traffic control radar. Air Force procedures require all proposals for chaff use to be coordinated with the FAA.

Table 5.1-1. Potential for Impact from Chaff and Flare Use

Resource/Issue	No Significant Impact		Site-Specific Analysis		Conditions Needing Analysis
	Chaff	Flares	Chaff	Flares	
Safety					
Interference with communications/tracking systems	X	N/A	-	N/A	
Disruption or interference with FAA or other radars	-	N/A	X	N/A	All areas not already approved.
Damage to or disruption of electrical power distribution system	X	N/A	-	N/A	
Pilot distracted by chaff deployment from other aircraft	X	N/A	-	N/A	
Damage to aircraft from chaff system malfunction	X	N/A	-	N/A	
Injury to person or property from falling chaff or flare debris	X	X	-	-	
Injury from dud flare during handling or disposal	N/A	-	N/A	X	Non-DOD land areas with public access.
Injury to personnel or damage to equipment from flare system malfunction.	N/A	X	N/A	-	
Fire Risk					
Effect of quantity of flares used on fire risk	N/A	-	N/A	X	All non-DOD land areas with low altitude airspace (flare use only).
Effect of weather on fire risk	N/A	-	N/A	X	
Effect of topography on fire risk	N/A	-	N/A	X	
Effect of vegetation on fire risk	N/A	-	N/A	X	
Effect of fire management capabilities on fire risk	N/A	-	N/A	X	
Effectiveness of minimum flare release altitudes on fire risk	N/A	-	N/A	X	
Air Quality					
Non-compliance with NAAQS	X	X	-	-	
Health effects from hazardous air pollutant emissions	X	X	-	X	Very high use of flares in small area.
Visibility impairment in PSD Class I area	X	X	-	-	
Physical Resources					
Effects of chaff and flare deposition on soil chemistry	X	X	-	-	
Potential for chaff or flare ash to leach toxic chemicals or change chemical composition of water	-	-	X	X	Small, confined fresh water aquatic environments with sensitive species.
Effects of chaff or flares on drinking water sources and systems	X	X	-	-	

Table 5.1-1. Potential for Impact from Chaff and Flare Use (cont.)

Biological Resources					
Startle effect on birds and other wildlife	X	X	-	-	
Ingestion effects on wildlife	X	N/A	-	N/A	
Inhalation effects on wildlife	X	N/A	-	N/A	
Impacts on waterfowl and aquatic organisms	-	-	X	X	Water bodies with significant waterfowl use or
Physical effects of chaff from external contact	X	N/A	-	N/A	protected species.
Interference with wildlife activities	X	N/A	-	N/A	
Chemical effects on plants through soil	X	X	-	-	
Alteration of habitat through fire	N/A	-	N/A	X	Areas with high or extreme fire risk and sensitive species or critical habitat (flare use only).
Land Use and Visual Resources					
Effects of accumulation of chaff fibers on land use	X	N/A	-	N/A	
Effects of accumulation of chaff and flare debris on land use	-	-	X	X	Wilderness Areas, Wild and Scenic Rivers, parks, coastal zones, outstanding visual resource areas.
Effects of accumulation of chaff and flare debris on visual resources	X	X	-	-	
Effect of dud flare hazard on land use	N/A	-	N/A	X	Residential areas and areas with concentrated use (flare use only).
Effect of burning flares at night on sensitive visual resources	N/A	-	N/A	X	Recreation areas and Wilderness Areas (night flare use only)
Effects of fire on land use	N/A	-	N/A	X	Areas with high or extreme fire risk (flare use only).
Cultural Resources					
Effect of accumulation of chaff and flare debris on cultural sites	X	X	-	-	
Potential for chaff to physically or chemically damage cultural	X	N/A	-	N/A	
resources	-	-	X	X	Native American traditional use areas.
Effects of chaff and flare use on traditional Native American properties and land uses	N/A	-	N/A	X	Areas with high or extreme fire risk
Effects of fires on cultural resources	N/A	-	N/A	X	(flare use only).
Impacts from fire suppression and rehabilitation activities	N/A	-	N/A	X	
Effects of smoke on historic structures and rock art					

N/A Not Applicable

5.2.1.2 Flares

Most safety risks associated with flare use are acceptable or correctable with management action. The only proposal-specific issue is the potential for a dud flare to be found, picked up, and handled improperly, resulting in injury to personnel. This risk can be reduced for flare use over DOD land by educating personnel on the proper procedures if a dud flare is found. Although there has been only one recorded incident of injury from a dud flare, in areas where heavy flare use is proposed (leading to larger potential numbers of dud flares) and there is public access to and use of underlying areas, consideration is warranted. This should be addressed on a site-specific basis by estimating the number of dud flares that could be generated by the proposed action and assessing the probability of a dud being recovered, based on the relative remoteness of the area. This information can be used to develop any operating procedures that might be appropriate.

5.2.2 Fire Hazard

Fire risk is only a concern when assessing the potential impacts of flare use. No fire risk has been identified for chaff use. Fire risk and behavior and its consequences are completely situation dependent. The number of variables that can affect whether a fire starts and, if so, whether it will spread and cause significant damage, are so numerous that meaningful analysis can only be performed on a site-specific level. The only exception may be flare use proposed for medium-to-high altitude airspace areas where there is no possibility of flares being dispensed at low altitude (i.e., the airspace floor is above altitudes of concern).

Therefore, fire risk assessment to some level of detail is recommended for virtually any proposal to dispense flares over non-range/target areas. A methodology for assessing risks from flare-caused fires is provided in Appendix E. The methodology is aimed at defining actions where risks are minimized through selection of appropriate locations for training, and adoption of appropriate operating procedures based on the sensitivities of the area.

5.2.3 Air Quality

5.2.3.1 Chaff

The studies and tests conducted concluded that chaff does not produce statistically significant levels of PM_{10} or TSP or any other criteria pollutants, and chaff use would not result in an exceedance of the NAAQS.

5.2.3.2 Flares

The smoke produced by flares is too small to create a concern with respect to compliance with the NAAQS. Some flares are ejected by pyrotechnic devices or contain first fire mixtures or initiation devices that contain chromium and/or lead compounds. Both chromium and lead are listed as hazardous air pollutants under the Clean Air Act. The results of health screening assessments for flare use determined that up to 67,000 flares could be released in a peak hour, and, for a typical target area of 10,000 acres, 220,000 flares could be released annually without significantly increasing short- or long-term health risks from hexavalent chromium or lead. The annual threshold

levels depend on the size of the area where flares are dispensed and on the altitudes of employment. The annual threshold for a large airspace area, for example, exceeds a million flares. A range of thresholds is provided in Section 4.6. If proposed utilization is higher than these levels (or concentrated in a smaller area), additional health risk assessment may be required.

5.2.4 Physical Resources

5.2.4.1 Chaff

In general, chaff fibers were not found to dissolve or leach toxic chemicals in quantities that would pose a health risk or significantly alter soil or water chemistry. Although no copper was detected in the laboratory tests of chaff, the chaff sample used for the laboratory testing may not have contained copper, whereas other manufactures could. The amount of copper that could be contained in a bundle of RR-112 chaff (the largest model) is roughly equivalent to the copper found in a penny. Thus the potential for adverse effects is remote in most circumstances.

The freshwater acute value for copper is 0.018 ppm. A very small, contained body of water that supports sensitive aquatic species could be adversely affected by repeated, concentrated exposure to chaff deposition. If such an environment exists in an area proposed for chaff use, the presence of threatened or endangered aquatic species should be identified through consultation with the local office of the U.S. Fish and Wildlife Service and the state fish and game or fish and wildlife department. If protected aquatic species or their habitats are known to occur or could be in the area, the environmental assessment should include a quantification of the amount of copper that they might be exposed to and resulting concentrations that could be expected in the affected water bodies under the proposed action.

5.2.4.2 Flares

The chemicals that could leach from either a dud flare or flare ash deposited on land or water are not expected to significantly affect soil or water chemistry in most environments. Dud flares are so infrequent that further consideration of the potential effects on physical resources are not needed. Flare ash, on the other hand, is a normal by-product of flare use. Flare ash produces barium, boron, and ammonia, which can affect freshwater aquatic environments. Furthermore, laboratory tests of flare pellet material and flare ash indicated that they can radically change the pH of water. Therefore, deposition of flare ash in high concentrations could be toxic to some aquatic organisms.

In areas that would be exposed to repeated flare use, any threatened or endangered freshwater species or their habitats that are sensitive to the chemicals of concern should be identified in the same manner as described above for chaff. If any specific sites are identified within the proposed flare use area, an ecological risk assessment could be performed based on anticipated levels of flare use. If there is a sensitive body of water small enough that its pH may also be affected, this should be addressed by the risk assessment. Alternatively, water bodies of concern could be sampled for chemical and biological effects if needed. Two approaches to determining impacts are outlined in Section 4.7.

5.2.5 Biological Resources

5.2.5.1 Chaff

Chaff is not anticipated to result in significant adverse effects on biological resources. Whether chaff that accumulates along the shorelines of wetland areas and water bodies or on the bottom could adversely affect surface-feeding waterfowl or bottom feeding species was not determined. Therefore, information on water bodies that support significant waterfowl populations, are used by migrating waterfowl, or provide habitat for threatened or endangered aquatic species should be identified as part of the site-specific assessment of proposed chaff use.

5.2.5.2 Flares

Flare use is not anticipated to result in significant adverse effects on biological resources, except if it causes a fire. Fires caused by flares could result in mortality of plants and animals and significantly alter habitat, both directly and indirectly through chemical changes and increased erosion and sedimentation. Therefore, the habitat of threatened and endangered species underlying proposed flare use areas should be identified and considered in establishing flare use procedures. This information can be obtained from the local U.S. Fish and Wildlife office or state fish and wildlife/fish and game department and any concerns should be resolved through consultation with these agencies.

5.2.6 Land Use and Visual Resources

5.2.6.1 Chaff

Field investigations indicate that chaff and chaff debris are not highly visible and would not have a significant impact on sensitive land uses or visual resources. Even relatively high-use areas displayed little noticeable accumulation of debris. However, in some areas that are specifically designated for preservation of pristine natural qualities, such as Wilderness Areas and Wild and Scenic Rivers, any litter that is clearly human made could be considered intrusive. These areas are not likely to experience large quantities of chaff use. During field studies, chaff and flare debris was only found about once per day in low-use, arid areas underlying MOAs. In areas where vegetative ground cover is dense, observations are likely to be less. This level of litter is not likely to affect a user's recreational experience or alter the use of an area.

Assessments of proposals that contain potentially sensitive areas, including Wilderness Areas, Wild and Scenic Rivers, national and state parks and recreation areas, coastal zones, and outstanding visual resource areas, should consider impacts to those areas, particularly from more visible debris components such as the packaging from non-pyrotechnic chaff.

5.2.6.2 Flares

Dud flares have a much higher visibility than chaff or other flare debris and can be a hazard if incorrectly handled. As noted above under the safety discussion, the potential for injury from dud flares depends in part on the likelihood of a dud being found, picked up, and handled in such a way

as to present a hazard. At the site-specific level, the proposed volume of flare use should be analyzed to identify the potential number of dud flares that could occur. The local population density and level of visitation (for recreation areas) should then be determined and compared to the hazard risk assessment criteria presented in Section 4.4 to determine whether the level of risk is acceptable.

If flares are to be dispensed over sparsely populated areas used primarily for cattle grazing, ranchers could be notified of proper procedures if military debris is found. In recreation areas, similar public education measures could be considered.

5.2.7 Cultural Resources

5.2.7.1 Chaff

Although the potential for chaff to have chemical effects on cultural resources has not been specifically investigated, the probability is considered remote. The only concern may be the aesthetic effect of chaff debris on resources sensitive to such effects. Resources for which setting is a contributing factor in their eligibility to the National Register of Historic Places would be of concern. However, based on the visual resources analysis, is not anticipated that chaff and chaff debris would accumulate in quantities that could affect the aesthetic qualities or historical context of significant cultural resources.

Native American groups that conduct traditional activities in areas underlying airspace proposed for chaff use should be consulted to identify their concerns and perceived impacts on traditional resources. These concerns should be taken into consideration in defining chaff use areas and procedures and addressed in the environmental assessment.

5.2.7.2 Flares

Flare use is not expected to generate chemical effects that could impact cultural resources. The primary concern is the potential for flare-caused fires and associated suppression activities to adversely affect cultural resources that are eligible to the National Register of Historic Places. The presence of such resources in areas underlying proposed flare use airspace, or the likelihood of such resources occurring, should be identified and considered in assessing appropriate conditions and restrictions on flare use relative to fire risks.

Native American groups that conduct traditional activities in areas underlying airspace proposed for flare use should be consulted to identify their concerns and perceived impacts on traditional resources. Traditional resources are also vulnerable to adverse effects from fire. These concerns should be taken into consideration in defining flare use areas and procedures and addressed in the environmental assessment.

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APPENDIX A

CHAFF AND FLARES DOCUMENT DATABASE

Author	Title	Organization	Date	Document Type	Number of Pages	Document Number
25 FTTS/WFF, Ellsworth AFB	Message to Aircrews	US Air Force (USAF), Air Combat Command (ACC)	2/23/93	Message	2	
347 TFW/DO, Moody AFB	MJU-7/B Flare Environmental Assessment (EA)	USAF	1/23/89	AF Form 813	15	31
9 AD, Shaw AFB	Flare Employment	USAF Tactical Air Command (TAC)	6/1/90	Memo	1	49
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AFSC-ASD	(Specification for) RR-136 Chaff	USAF ASD	nd	Specifi-cations and drawings	6	311
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Poaffetto, G., S. Parodi, M. DeFerrari, R. Troiano and G. Brambilla	Direct interaction with cellular targets as the mechanism for chromium carcinogenesis	Tumori	1/1/77	Article	10	247
Pokrovskaya, L.V. and N.K. Shabynina	Carcinogenic hazards in the production of chromium ferro-alloys	Gig. Tr. Prof. Zabol	1/1/73	Article	4	246
Rogers, A.B.; Francis, C.M.	Fire Effects on Prehistoric Sites: Hot Today, Gone Tamale	Society for California Archaeology	1/1/88	Report	9	267
Rothermel, Richard C.	A mathematical model for predicting fire spread in wildland fuels	USDA, Forest Service, Intermountain Forest and Range Experiment Station	1/1/72	Research Paper INT-115	40	93
Rothermel, Richard C.	How to predict the spread and intensity of forest and range fires	USDA, Forest Service, Intermountain Forest and Range Experiment Station	1/1/83	Gen. Tech. Rep. INT-143	161	291

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Rothermel, Richard C.; Andrews, Patricia L.	Fire behavior system for the full range of fire management needs	USDA, Forest Service, Intermountain Forest and Range Experiment Station	1/1/87	Proceedings	6	292
Royle, H.	Toxicity of chromic acid in the chromium plating industry	Environ. Research	1/1/75	Article	23	248
Ryan, Bill C.	Potential fire behavior in California: an atlas and guide for forest and brushland managers	USDA, Forest Service, Pacific Southwest Forest and Range Experiment Station	1/1/84	General Technical Report PSW-77	15	94
Salazar, Lucy A.; Bevins, Collin D.	Fuel models to predict fire behavior in untreated conifer slash	USDA, Forest Service, Pacific Southwest Forest and Range Experiment Station, Forest Station	1/1/84	Research Note PSW-370	6	95
Salazar, Lucy A.; Bradshaw, Larry S.	Changes in fire weather distribution: effects on predicted fire behavior	USDA, Forest Service, Pacific Southwest Forest and Range Experiment Station	1/1/84	Research Paper PSW-174	11	97
Sano, T. and Mitohara, I.	Occupational cancer among chromium workers	Japanese Journal of Chest Disorders	1/1/78	Article	12	249
Satoh, K., Fukuda, Y., Torii, K., and Katsuno, N.	Epidemiologic study of workers engaged in the manufacture of chromium compounds	Journal of Occupational Medicine	1/1/81	Article	4	250
Sax, N. Irving; Lewis, Richard Sr., J.	Hazardous Chemicals Desk Reference	Van Nostrand Reinhold Company, NY	1/1/87	Book	8/1000	33
Schuler, A.; Meadows, J.C.	Planning Resource Use on National Forests to Achieve Multiple Objectives	Journal of Environmental Management	1/1/75	Article	16	167
Schweitzer, Dennis L.; Andersen, Ernest V.; Mills, Thomas J.	Economic efficiency of fire management programs at six National Forests	USDA, Forest Service, Pacific Southwest Forest and Range Experiment Station	1/1/82	Research Paper PSW-157	29	98
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Science and Engineering Associates (SEA), Inc.	Environmental Effects of Air National Guard Chaff Training Activities	National Guard Bureau, Environmental Division, Andrews, AFB, Maryland	12/1/90	Report	20	41
Selevan, S.G.; Landrigan, P.J.; Stern, F.B.; Jones, J.H.	Mortality of lead smelter workers	American Journal of Epidemiology	1/1/85	Article	11	207
Silverstein, M.; F. Mirer; D. Kotelchuck, B. Silverstein and M. Bennett	Mortality among workers in a die-casting and electroplating plant	Scand. J. Work Environ. Health.	1/1/81	Article	10	251
Sittig, M.	Handbook of Toxic and Hazardous Chemicals and Carcinogens	Noyes Publications	1/1/85	Handbook	950	174
Stebbins, R.C.	Western Reptiles and Amphibians	Boston: Houghton Mifflin	1/1/85	Field Guide		341
Stickney, Peter F.	Database for early postfire succession on the Sundance Burn, northern Idaho	USDA, Forest Service, Intermountain Research Station	1/1/85	General Technical Report INT-189	121	99
Stickney, Peter F.	First decade plant succession following the Sundance Forest Fire, northern Idaho	USDA, Forest Service, Intermountain Research Station	1/1/86	General Technical Report INT-197	26	100
Stinson, Thomas	Rural Fire Protection Facilities	USDA, Economic Research Service	9/1/86	Report	24	169
Stoeppler, M. (Editor)	Hazardous Metals in the Environment	Elsevier Science Publishers	1/1/92	Book, Ch.15	4	43
Sutton, A. and M. Sutton	Eastern Forests	New York: Alfred A. Knopf	1/1/87	Book		342
Swan, L.; Francis, C.M.	Fire and Archaeology	USDA, Forest Service	1/1/89	General Technical Report PSW-109	7	268

Author	Title	Organization	Date	Document Type	Number of Pages	Document Number
Swan, Larry, and Charles Francis	Fire and Archaeology, in Proceedings of the Symposium on Fire and Watershed Management	US Forest Service Pacific Southwest Forest and Range Experiment Station. General Technical Report PSW-109	1989			369
Systems Consultants, Inc. (Block, R.M.; Schiff, S.C.)	Effects of aluminized fiberglass on representative Chesapeake Bay marine organisms	Systems Consultants Inc. for Naval Research Lab	11/23/77	Report	70	143
Taylor, F. H.	The relationship of mortality and duration of employment as reflected by a cohort of chromate workers	American Journal of Public Health	1/1/66	Article	11	252
Tootell, Chris	Jette stocking plots: a design and methodology for uneven-ages stocking plot studies on the Flathead Indian reservation	BIA Branch of Forestry, Flathead Agency and Salish and Kootenai Tribes		Study	29	101
Tracor, Inc.	Data on Flare Combustion Products	Tracor, Inc. and Aeronautical Systems Division, Wright-Patterson	7/12/78	Data sheet	1	264
Tsuda, H. and K. Kato	Chromosomal aberrations and morphological transformation in hamster embryonic cells treated with potassium dichromate in vitro	Mutation Research	1/1/77	Article	8	253
Tull, David A.	Wright Labs Advanced Chaff/Flare F&D	SAIC	2/22/93	Memo	2	142
United Kingdom Health and Safety Executive for the Ministry of Defense (UKHSEMD)	Chaff in the Environment at RAF Spadeadam	United Kingdom Health and Safety Executive for the Ministry of Defense	1/1/88	Report		272
United States Air Force	B-52 Use of Chaff & Flares for Mt. Home AFB CW	USAF-Strategic Air Command (SAC)	12/2/91	Memo	1	44

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United States Air Force	Self-Protection Flare Training	USAF-TAC	5/1/88	Report	4	46
United States Air Force (USAF)	Use of R6406 and R6407 for Chaff/Flare Drops, Environmental Assessment	USAF 388 TFW, Hill AFB	1/19/83	AF Form 813 and 815	14	32
United States Air Force (USAF)	Technical Order 11 A16-40-7 (MJU-7B, MJU-7A/B)	USAF - ACC	nd	Technical Order	4	135
United States Air Force (USAF)	Air Force Regulation (AFR) 50-46 Weapons Ranges	USAF	6/8/87	Regulation	78	140
United States Air Force (USAF)	Effects of Chaff on Animals	USAF SCS/O, Aircraft Test Division	6/8/73	Report	45	141
United States Air Force (USAF)	Technical Report Summaries	USAF 99th TTW/TIC	2/19/93	Bibliography	44	145
United States Air Force (USAF)	DROLS Bibliography on Chaff and Flares	USAF HQ AFCESA/TIC	1/8/93	Bibliography	67	147
United States Air Force (USAF)	AFR 127-4, Investigating and Reporting US Air Force Mishaps	USAF HQ AFISC/SEPX	1/3/90	USAF Reg.	176	150
United States Air Force (USAF)	HQ Strategic Air Command, Message on Chaff	USAF SAC	11/15/91	Message	2	257
United States Air Force (USAF)	Air Force Regulation (AFR) 55-44: Performing Electronic Counter measures in the United States and Canada	USAF	12/6/78	Regulation	portions	258
United States Air Force (USAF)	Air Force Regulation (AFR) 55-79: Aircrew and Weapons Director Procedures for Air Operations	USAF	8/17/92	Regulation	portions	259

Author	Title	Organization	Date	Document Type	Number of Pages	Document Number
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United States Air Force (USAF)	Air Combat Command Regulation (ACC) 55-79; Aircrew/Weapons Controller Procedures for Air Operations	USAF - ACC	10/23/87	Regulation	portions	261
United States Air Force (USAF)	RR-170 Chaff Clearance 91-005	USAF SAC	1/7/92	Message	2	262
United States Air Force (USAF)	HQ TAC Message: Self-Protection Flare Training	USAF TAC	5/2/88	Message	2	263
United States Air Force (USAF)	Final Environmental Impact Statement for the U.S. Air Force in Idaho	USAF HQ ACC	1/1/92	Report		269
United States Air Force (USAF)	Technical Order 11A16-39-7 Cartridge, Chaff Countermeasure, RR-170 A/AL and RR-188/AL (Training)	USAF	nd	Technical Order	2	298
United States Air Force (USAF)	Technical Order 11A16-46-7, MJU-23/B Flare (portion)	USAF	nd	Drawing from technical order	1	302
United States Air Force (USAF)	Technical Order 11A16-41-7, M-206 Flare (portion)	USAF	nd	Technical order	3	303
United States Air Force (USAF)	Technical Order 11A16-43-7, MJU-10/B Flare	USAF	nd	Technical order	3	304
United States Air Force (USAF)	Technical Reports on Chaff and Flares, Technical Report No. 4 Field Studies	HQ Air Combat Command	10/1/94c	Report		315
United States Air Force (USAF)	Technical Reports on Chaff and Flares, Technical Report No. 2 Chaff Particulate Test	HQ Air Combat Command	4/1/94a	Report		320

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United States Air Force (USAF)	Technical Reports on Chaff and Flares, Technical Report No. 3 Screening Health Risk Assessment of Chromium and Lead Emissions	HQ Air Combat Command	4/1/94b	Report		321
United States Air Force (USAF)	Technical Reports on Chaff and Flares, Technical Report No. 5 Laboratory Analysis of Chaff and Flare Materials	HQ Air Combat Command	11/1/94e	Report		322
United States Air Force (USAF)	Technical Reports on Chaff and Flares, Technical Report No. 6 Flare Fire Risk Assessment	HQ Air Combat Command	1/1/95	Report		323
United States Air Force (USAF)	Desert Eglin South Chaff Survey Clark and Lincoln Counties, Nevada	USAFWTC/EV	2/10/94d	Draft Technical Report	19	324
United States Air Force (USAF)	Technical Reports on Chaff and Flares Technical Report No.1 Review of Available Data	HQ Air Combat Command	10/1/1993a	Report		325
United States Air Force (USAF)	M-X Environmental Technical Report: Wildlife	HDR Ecosciences	1/1/81	Technical Report		335
United States Air Force (USAF)	Environmental Impact Statement Realignment of Cannon AFB, Curry County, New Mexico	USAF TAC	1/1/90	EIS		357
United States Air Force (USAF)	Final Environmental Impact Statement, Proposed Relocation of the 37th Tactical Fighter Wing and Other Tactical Force Structure Actions	USAF TAC	1/1/91	EIS		358
United States Air Force (USAF)	Final Environmental Impact Statement, Beddown of a Composite Wing at Moody AFB, GA	USAF ACC	1/1/93	EIS		359

Author	Title	Organization	Date	Document Type	Number of Pages	Document Number
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United States Air Force (USAF)	Draft Environmental Impact Statement, Idaho Training Range	USAF ACC	1/1/93	EIS		361
United States Air Force (USAF)	Final Environmental Assessment, Proposed Expansion of Poinsett Weapons Range	USAF ACC	1/1/94	EA		362
United States Environmental Protection Agency (EPA)	Drinking Water Regulations and Health Advisories	US EPA, Office of Water	1/1/92	Regulation	portions	193
United States Environmental Protection Agency (EPA)	National Functional Guidelines for Organic Data Review, Multi-Media, Multi-Concentration and Low Concentration Water	US EPA Contract Laboratory Program	1/1/91	Guideline		316
United States Environmental Protection Agency (EPA)	Laboratory Data Validation Functional Guildelines for Evaluating Inorganic Analyses	US EPA Contract Laboratory Program	1/1/88a	Guideline		317
United States Environmental Protection Agency (EPA)	Ambient Aquatic Life Water Quality Criteria for Ammonia NTIS PB85-227114	US EPA	1/1/85	Report		318
United States Environmental Protection Agency (EPA)	Workbook of Screening Techniques for Assessing Impacts of Toxic Air Pollutants (Revised), EPA-454/R-92-024	US EPA, Research Triangle Park, NC	1/1/92	Guidelines	70	328
United States Environmental Protection Agency (EPA)	Screening Procedures for Estimating the Air Quality Impacts of Stationary Sources, EPA-450/4-88-101	US EPA, Office of Air Quality Planning and Standards, Research Triangle Park, NC	1/1/88	Guidelines	60	329
United States Environmental Protection Agency (EPA)	Guideline on Air Quality Models (Revised), EPA-450/2-78-027R	US EPA, Research Triangle Park, NC	1/1/86	Guidelines	200	330

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United States Forest Service (USFS)	Fire management notes, vol. 45, no. 3	USDA, Forest Service	1/1/84	Notes	31	102
United States Forest Service (USFS)	When the mountain roared: stories of the 1910 fire	USDA, Forest Service		Paper	38	103
United States Forest Service (USFS)	Rural Community Fire Protection	USDA, Program Aid -1196	10/1/77	Report	12	170
United States Forest Service (USFS)	National Forest Landscape Management, Volume 1. Agriculture Handbook 434	USDA, Forest Service	1/1/73	Handbook		343
United States Forest Service (USFS)	National Forest Landscape Management, Volume 2, Ch. 1. Agriculture Handbook 462	USDA, Forest Service	1/1/74	Handbook	47	344
United States Forest Service (USFS)	The Visual Management System, FSM Section 2383, R-5 Supplement #102, Title 2300--Recreation Management	USDA, Forest Service	1/1/78	Handbook		345
US Salinity Laboratory Staff	Diagnosis and Improvement of Saline and Alkali Soils. USDA Agricultural Handbood 60	USDA	1/1/54	Handbook		346
USAF	Aircraft Self Protection Flare Use in MOAs	USAF - HQ ACC/DO, Langley AFB	7/20/92	Memo	1	124
USAF	ECM Clearance Request for Chaff Drops	USAF- HQ TAC	4/1/90	Info sheet	2	51
USAF	Self Protection Flare Training	USAF-TAC/DOO	3/1/89	Memo	2	48

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USAF	Use of Self-Protection Chaff and Flares on USAF Air-to-Ground Gunnery Ranges	USAF HQ TAC/DOO	3/9/84	AF Form 813	4	13
USAF	Environmental Assessment: Use of R6406 and R6407 for Chaff/Flare Drops	USAF	1983			370
USAF Aeromedical Laboratory	Toxicity of Chaff to Livestock	Aero Medical Laboratory	1/1/52	Report	2	17
USFS	Proceedings: Symposium on Fire in Wilderness and Park Management	USDA Forest Service, Intermountain Research Station	9/1/95	General Technical Report INT-GTR-320	282	371
Van Esch, G.J.; Kroes, R.	The induction of renal tumors by feeding of basic lead acetate to mice and hamsters	British Journal of Cancer	1/1/69	Article	7	208
Van Gasbeck, David C.	Chaff Toxicity to Cattle-Keep	USAF HQ-TAC/DEEV	3/19/84	Report-survey	5	138
Vaux, H.J.; Gardner, P.D.; Mills, T. J.	Methods for Assessing the Impact of Fire on Forest Recreations	USDA, Forest Service, Pacific Southwest Forest and Range Experimental Station	1/1/84	General Technical Report PSW-79		309
Vaux, Henry J. Jr; Gardner, Philip D.; Mills, Thomas J.	Methods for assessing the impact of fire on forest recreation	USDA, Forest Service, Pacific Southwest Forest and Range Experiment Station	1/1/84	General Technical Report PSW-79	13	104

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Watanabe, S.; Y. Fukuchi	An epidemiological survey on lung cancer in workers of a chromate-producing industry in Hokkaido, Japan	Presented at International Congress on Occupational Health	1/1/75	Report		255
Watson, Alan; Roggenbuck, J.; Williams, D.	The Influence of Past Experience on Wilderness Choice	Journal of Leisure Research	1/1/91	Article	14	161
Webster, W.D., J.F. Parnell, and W.C. Biggs, Jr.	Mammals of the Carolinas, Virginia, and Maryland	Charlotte: The University of North Carolina Press	1/1/85	Book		347
Weickman, Helmut K.	Impact Statement on Lightning Suppression Project	Nat'l Oceanic and Atmospheric Administration (NOAA), Atmospheric Physics and Chemistry Laboratory	10/1/72	Impact Statement	6	14
Wilson, Ralph A.	A reexamination of fire spread in free-burning porous fuel beds	USDA, Forest Service, Intermountain Forest and Range Experiment Station	1/1/82	Research Paper INT-289	28	105
Wright, H. A.	Shrub response to fire, in Wildland and Shrubs	USDA, Forest Service	1/1/72	General Technical Report INT-1	14	106
Wright, H. A.	The effect of fire on vegetation in ponderosa pine forests	Texas Tech University Range and Wildlife Information Series No. 2, USDA, Forest Service	1/1/78	Publication No. T-9-199	21	108
Wright, H. A.	The role and use of fire in the semidesert grass-shrub type	USDA, Forest Service, Intermountain Forest and Range Experiment Station	1/1/80	General Technical Report INT-85	24	109
Wright, H. A.	Landscape development, forest fires, and wilderness management	Science, vol. 186, no. 4163	1/1/74	Article	8	107

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Wright, H.A. and A. W. Bailey	Fire Ecology: United States and Southern Canada	John Wiley and Sons Inc. New York	1/1/82	Book		364
Wright, H.A., and A.W. Bailey	Fire ecology and prescribed burning in the Great Plans -- A research review	USDA, Forest Service, Intermountain Forest and Range Experiment Station	1/1/80	Gen. Tech. Rep. INT-77		363

APPENDIX B

DATABASE RESOURCES

DATABASE RESOURCES

Aquatic Information Retrieval (AQUIRE)

Dialog Information Services, Inc., incorporating the following databases:

- National Technical Information Center
- PTS A/DM&T, 1986-1993
- Aerospace, 1962-1993
- Commerce Business Daily, 1982-1992
- Investext, 1982-1993
- Janes Defense & Aerospace News/Analysis, 1993
- McGraw-Hill Publications Online, 1985-1993
- Business Dateline, 1985-1993
- PTS Newsletter Database, 1987-1993
- INSPEC 2, 1969-1993
- EI Compendex Plus, 1970-1993
- IHS International Standards and Specifications
- Federal Research In Progress, 1992
- Academic Index, 1976-1993
- ICC IBR, 1992

Defense Research On-Line System (DROLS)

Defense Technical Information Center (DTIC)

Inital Attack Management System (IAMS)

National Interagency Fire Center (NIFC)

Toxicological, Occupational Medicine and Environmental Series (TOMES), incorporating the following databases:

- Hazardous Substances Database (HSDB)
- Registry of Toxic Effects of Chemical Substances (RTEC)
- Oil and Hazardous Materials/Technical Assistance Data System (OHM/TDS)
- Integrated Risk Information System (IRIS)

APPENDIX C

RANGE AND AIRSPACE DESCRIPTIONS

RANGE AND AIRSPACE DESCRIPTIONS

The following is a description of the ranges and associated Restricted Areas, MOAs, MTRs, Warning Areas, and other designated areas where chaff and/or flares are used by Air Combat Command aircraft. Also noted are any procedures or restrictions that have been established to supplement Air Force or Command directives. Local procedures may be updated periodically and should therefore be verified for specific operating locations.

Fallon Ranges — The different ranges and MOAs that make up the Fallon Range Training Complex lie to the northeast, east, and south of Fallon, Nevada. This airspace generally operates daily from 7:15 a.m. to 11:30 p.m., with altitudes ranging from the surface (over the ranges).

Goldwater Range Complex — This complex is located southeast of Phoenix, Arizona adjacent to the Mexican border and includes R-2301E, R-2304, R-2405, and the Sells MOA. The Restricted Areas operate from the surface to 80,000 feet MSL in R-2301E and to 24,000 feet MSL in R-2304 and R-2305. The Sells MOA is stratified with the lower floor at 3,000 feet AGL and the upper ceiling at 17,999 feet MSL. R-2301E is active Monday through Friday, 6:30 a.m. to 10:30 p.m. R-2304 and R-2305 are active seven days per week from 7:00 a.m. to 11:00 p.m. The Sells MOA is active Monday through Friday from 6:00 a.m. to 7:00 p.m. All areas of the Goldwater Range Complex may operate at different times through NOTAM changes.

Melrose Range — This range is approximately 30 miles west of Clovis, New Mexico and includes R-5104 A and B, and R-5105. R-5104 is stratified, with the lower floor at surface and the upper ceiling at 22,999 feet MSL. R-5105 operates from the surface to 10,000 feet MSL. Both Restricted Areas are active seven days per week from 8:00 a.m. to midnight and may operate at other times through NOTAM. Chaff and flare expenditures are authorized within the range area at an altitude of 10,000 feet MSL or less, and flares must be released above 1,000 feet AGL, and only with Range Control Officer approval. Aircrews will not dispense chaff when forecast winds are above 50 knots at or below their expected level of release. Minimum altitude for flare employment is 1,000 feet AGL.

Nellis Range Complex — The Nellis Range Complex lies to the north and northwest of Las Vegas, Nevada and includes R-4809, R-4807A and B, R-4806W and E, and the Reveille and Desert MOAs. All Restricted Areas operate without time or altitude constraints except R-4806E. This area is active Monday through Saturday from 5:00 a.m. to 8:00 p.m. at altitudes from 100 feet AGL to unlimited. Both MOAs are active from 100 feet AGL up to, but not including, 18,000 feet MSL, sunrise to sunset, Monday through Saturday. Both MOAs may also operate at other times with notification through NOTAM.

In accordance with Nellis AFB Supplement 1 to AFI 13-212, chaff may be employed in all ranges and MOAs between 300 feet AGL and 10,000 feet AGL except Range 63, Range 65, Range 74A, Wilderness Areas, Wilderness Study Areas, National Parks, and populated areas. Chaff drops are authorized up to 25,000 feet AGL in R-4807, EC West, Coyote, and Reveille/ATCC and up to

20,000 feet AGL in Caliento/ATCAA, Elgin, and R-4806. Additional restrictions may be imposed dependent on weather conditions. MJU-2, MJU-7A/B, MJU-10, MJU-23B, and M-206 flares are authorized in the numbered and electronic combat (EC) ranges. Flare use in the MOAs is limited to the M-206 and MJU-7B lots marked "MBT," MJU-7A/B for certain aircraft, and MJU-10 only if specified in a test plan. Other flares will not be dropped over manned sites, ground parties, or within 3 nm of forested areas. Altitudes will be used that allow vertical drop to burn out plus 100 feet. The minimum flare employment altitude in MOAs is 5,000 feet AGL and the minimum altitudes for the numbered ranges and the EC ranges is 700 feet for all aircraft except F-111 (800 feet AGL) and B-52 (900 feet AGL).

Poinsett Range — This range is located within R-6002 approximately 5 nm south of Shaw AFB, South Carolina. The range airspace extends from the surface to 13,000 feet MSL and is active intermittently from 6:00 a.m. to 12:00 midnight, Monday through Friday, and 8:00 a.m. to 4:00 p.m. on Saturdays. Only M-206 flares have been authorized for use on the range. Chaff use is not authorized due to air traffic control conflicts.

Saylor Creek Range — The Saylor Creek Range is located south of Mountain Home AFB, Idaho. The range is within R-3202A, which extends from the surface to 18,000 feet MSL. Two other restricted airspace segments, R-3202B and C, extend south of this range and provide an approach corridor to the target area. The Bruneau, Sheep Creek, and Saylor MOAs surround the restricted areas and provide supporting airspace for both range and air-to-air training. The Saylor Creek Range is active 8:00 a.m. to midnight, Monday through Friday, and as required on weekends. Nonexplosive chaff can be dropped anywhere within the Saylor Creek Range and all MOAs above 5,000 feet AGL. Explosive chaff can only be dropped within the range impact area. Flares can be used year round and can only be dropped within the range impact area at those minimum altitudes established in ACC Supplement 1 to AFI 11-214. Flares must be released above 2,000 feet AGL in the MOAs in Idaho (see Owyhee and Paradise MOAs).

Superior Valley/China Lake Complex — There are three Restricted Areas associated with this complex: R-2505, R-2524, and R-2509. These areas are located in the high desert north of Edwards AFB, California. All three areas operate from the surface to unlimited altitude on a continuous basis.

Utah Test and Training Range (UTTR) — The UTTR Range Complex is west, southwest of Salt Lake City, Utah. Chaff and flare activities are allowed only over DOD land in R-6404, west of a line running north and south along Lambert Boulevard, and in R-6406A and R-6407. These Restricted Areas operate on a continuous basis from the surface up to 58,000 feet MSL. Bundle/burst chaff and self-protection flares are authorized from the surface to 58,000 feet MSL (FL 580). Chaff drops will comply with pertinent FAA regulations, and flares will be dropped from an altitude so as to burn out prior to impact with the ground.

White Sands Missile Range (WSMR) — This range complex is located west of Holloman AFB, New Mexico and includes the Red Rio, Oscura, and McGregor weapons ranges. Restricted Area airspace overlying these ranges extends from the surface to unlimited altitudes and is shown as being in effect continuously. Flares are limited to use within the lateral limits of the Lava area

overlying the Oscura Range and the Yonder impact area and may be dropped between 1,000 feet AGL to 50,000 feet MSL. Chaff is authorized in accordance with the chaff permit issued to the 49th Fighter Wing.

Yuma (R-2301W) — R-2301W is contiguous to the U.S./Mexico border, southeast of Yuma, Arizona. The area operates 24 hours per day, 7 days per week from the surface to 80,000 feet MSL. Although R-2301W is adjacent to R-2301E, it is not considered part of the Goldwater Range. Flare use is in accordance with the altitude restrictions in ACC Supplement 1 to AFI 11-214 except that minimum release altitude for all types is 1,000 feet AGL by local regulations. The only area authorized for chaff use is R-2301E. Chaff can be dropped from the surface to 5,000 feet AGL when winds are 25 knots or less in the direction of Phoenix, and 5,000 to 15,000 feet AGL if winds are 13 knots or less towards Phoenix.

R-4305 — This restricted area, also known as the Lake Superior Range, is located northeast of Duluth, Minnesota. The range operates on a continuous basis from the surface to 45,000 feet MSL. Lake Superior underlies the entire restricted area. The range is bordered on the west by the Snoopy East MOA with the Ontonagon MOA on the east and south borders. R-4305 has Det 1, HQ ACC/DOSR, Offutt AFB, Nebraska, listed as the using agency.

Ada MOA — This MOA is located north of Salina, Kansas and extends from 7,000 feet MSL up to but not including 18,000 feet MSL. Published days of use are, Monday through Friday and occasionally on weekends.

Big Ben/Hays MOA — This airspace overlies an area triangulated by the cities of Havre, Glasgow, and Lewistown, Montana. The MOA contains airspace from 300 feet AGL up to 17,999 feet MSL. The MOA operates on an intermittent basis and is activated by NOTAM.

Moody 1/3 MOAs — The Moody MOAs are located in southern Georgia. Moody 1 MOA is adjacent to and overlies Restricted Area R-3008. Moody 3, which is not contiguous to Moody 1, is located further west. Both MOAs extend from 8,000 feet MSL up to 18,000 feet MSL and operate from 7 a.m. to 11 p.m., Monday through Friday, and occasionally on the weekends. Both chaff and flare use are permitted in the MOAs.

Owyhee and Paradise MOAs — These MOAs are located over portions of southwestern Idaho, northern Nevada, and southeastern Oregon. The Owyhee MOA extends from 100 feet AGL to 14,500 feet MSL and is completely within Idaho. The Paradise MOA extends from 14,500 feet MSL up to, but not including, 18,000 feet MSL. The Paradise MOA lies over the Owyhee MOA and extends into Nevada and Oregon. The MOAs are active from 8:00 a.m. to midnight, Monday through Friday, and as required on weekends. Nonexplosive chaff can be dropped above 5,000 feet AGL. Flares can be released above 2,000 feet AGL. Chaff is not authorized over the Duck Valley Reservation, and flares can only be released during the day and above 20,000 feet AGL over the Reservation.

Powder River A&B MOAs — These MOAs are located between Miles City, Montana and Rapid City, South Dakota. Both operate on an intermittent basis activated by NOTAM. Powder River A operates from surface up to but not including 18,000 feet MSL. Powder River B operates from

1,000 feet AGL up to but not including 18,000 feet MSL. Chaff use is confined to the MOAs below 15,000 feet AGL and is used for air-to-air engagements only. Flares are not used.

Salem MOA — This MOA is located south of St. Louis, Missouri and extends from 100 feet AGL to but not including 8,000 feet MSL. It is used intermittently as activated by NOTAM.

Tiger MOA — The Tiger North and South MOAs are contiguous and are northeast of Minot, North Dakota and northwest of Grand Forks, North Dakota. These MOAs are directly south of the Canadian border and are operated on an intermittent basis through NOTAM. Tiger North activities are carried out from 300 feet AGL up to 17,999 feet MSL. Tiger South operating altitudes are from 6,000 feet up to 17,999 feet MSL.

Ellsworth Chaff Area — This large area covers the western half of Montana and Wyoming, two-thirds of each of the states of North and South Dakota, and slightly less than one-half of the state of Kansas. The clearance for the use of this area authorizes daily use with chaff drops from 500 feet AGL to 25,000 feet MSL.

W-102 — This is a large Warning Area off the coast of Maine. This area is stratified and operates from surface to 60,000 feet MSL at intermittent times and on intermittent days.

W-105 — This Warning Area parallels the northeastern coast from Washington, DC to Providence, Rhode Island. The area is subdivided to overlie five surface areas operating from the surface to as high as 50,000 feet MSL. The days and time of use are both on an intermittent basis.

W-107 — There are six Warning Areas within the W-107 series, W-107A, B, C, D, E, and F. All are located off the coast of Atlantic City, New Jersey and operate from the water surface up to an unlimited ceiling. There are two exceptions, W-107B which has a ceiling of 1,999 feet and W-107C which has a ceiling of 17,999 feet. All of these areas are active on an intermittent basis.

W-108, W-386, W-72, and W-122 — These are a series of Warning Areas along the eastern seaboard, extending from the Delaware Bay south to Charleston, South Carolina. They are active from the surface to unlimited altitude. Small portions of these areas, such as the southwest corner of W-386 and the western portion of W-72, contain altitude ceilings to accommodate domestic commercial air traffic.

W-151 — These four Warning Areas, 151A, B, C, and D, are directly south of Panama City, Florida and operate from the surface to unlimited altitude on an intermittent day and time basis.

W-157A — This Warning Area is off the Atlantic coast, southeast of Savannah, Georgia and is active on a continuous basis from the surface to 43,000 feet.

W-161 — Warning Areas 161A and B are off the Atlantic Coast, west of Charleston, South Caroline, and contain airspace from the surface to 6,200 feet MSL. They operate daily from sunrise to 1 a.m.

W-168 A/B — Warning Areas 168A and B are over the Gulf of Mexico, southwest of Tampa, Florida. W-168A contains unlimited airspace from the surface upwards. W-168B extends from the surface to 29,000 feet MSL. Both areas operate intermittently under the control of Miami Center Control.

W-177A/B — Warning Areas 177A and B are off the Atlantic Coast, south of Myrtle Beach, South Caroline. W-177A contains airspace from the surface to 50,000 feet MSL, and W-177B from surface to 24,000 feet MSL. Both areas operate daily from sunrise to 1 a.m.

W-285 — Paralleling the coast of California from San Jose to Paso Robles, W-285A and B contain the airspace from surface to 45,000 feet. Both of these areas operate Monday through Friday from 5:00 a.m. to 9:00 p.m.

W-470 — Warning Area 470 covers five surface areas of the Gulf of Mexico southeast of Panama City, Florida. There are no altitude constraints on these areas. Time and days of use are published as intermittent.

W-570 — This Warning Area is located off the coast of Oregon and overlies an area of the Pacific that extends south from the mouth of the Columbia River to a point approximately opposite the City of Eugene, Oregon. W-570 includes airspace from the water surface up to 50,000 feet MSL. The time of use is not consistent and is activated by NOTAM.

IR-293 — This route operates continuously and is scheduled by Det 1, HQ ACC/DOSR, Offutt AFB, Nebraska. IR-293 initiates at 17,000 feet MSL, or as assigned, west of the Wendover Auxiliary Field and terminates on the southern edge of R-6405 within the UTTR. The altitude block along the route is from the surface to 12,000 feet MSL and varies in width from 8 nm to 6 nm.

IR-300 — The beginning point of IR-300 is in southeastern Oregon over the Lakeview VOR. Hours of operation are continuous and the route is scheduled by Det 1, HQ ACC/DOSR, Offutt AFB, Nebraska. The IR is entered at 15,000 feet MSL, or as assigned, and is flown in altitude blocks from the surface to 11,000 feet MSL with one segment blocked from 8,000 feet MSL to 15,000 feet MSL. Route width varies from a maximum of 13 nm to a minimum width of 7 nm. The termination point is west of the Boise, Idaho airport.

IR-302 — The route begins east of the Boise, Idaho airport with an entry altitude of 13,000 feet MSL. The route operates continuously and is scheduled by the 124 FG/DO ANG Boise Air Terminal, Boise, Idaho. The width of the route varies from a maximum width of 16 nm to its narrowest point of 8 nm. The block altitude along the route is 100 feet AGL to 13,000 feet MSL. IR-302 terminates west, southwest of Mountain Home AFB, Idaho.

IR-320 — IR-320 operates continuously and is scheduled by Det 1, HQ ACC/DOSR, Offutt AFB, Nebraska. The route beings approximately 42 nm south of Junction, Colorado at an altitude of 23,000 feet MSL or as assigned. The route altitude block varies from surface to 19,000 feet MSL. Route width is a minimum of 7 nm to a maximum of 8 nm. The route terminates approximately 62 nm north of Winslow, Arizona.

IR-800 — This route begins along the New England coastline approximately 52 nm southeast of Bangor, Maine. IR-800 also operates continuously and is scheduled by Det 1, HQ ACC/DOSR, Offutt AFB, Nebraska. The route has a maximum width of 12 nm and narrows to a 4 nm width along one segment. The minimum altitude in the block is from the surface to a maximum designated of 15,000 feet MSL. IR-800 terminates approximately 50 nm east of Burlington, Vermont.

APPENDIX D

LAWS, REGULATIONS, AND CITATIONS

LAWS, REGULATIONS, AND CITATIONS

10 USC 2672, Minor Land Acquisitions

AFI 11-206, General Flight Rules, July 1994 (formerly AFR 60-16)

AFI 11-214, Aircrews and Weapons Director and Terminal Attack Controller Procedures for Air Operations, 25 February 1997 (formerly AFR 55-79)

AFI 11-214/ACC Sup 1, 30 May 1997

AFI 13-201, US Air Force Airspace Management, July 1994 (formerly AFR 55-34, Reducing Flight Disturbance, 27 Feb. 1984)

AFI 13-212, Volume I, Weapons Ranges, July 1994 (formerly AFR 50-46)

AFI 32-7061, Environmental Impact Analysis Process, January 1995

(formerly AFR 19-2)

AFI 51-501, Tort Claims, July 1995 (formerly AFR 112-1)

AFI 91-204, Safety and Investigations Reports, October 1995 (formerly AFR 127-4, Investigating and Reporting U.S. Air Force Mishaps)

AFR 127-4, Investigating and Reporting U.S. Air Force Mishaps

AFR 55-44, Performing Electronic countermeasures in the U.S. and Canada, 6 Dec. 1978 (change #1 July 1980, change #2 Aug. 1983)

AFR 55-79, ACC Supplement 1 to AFR 55-79, Aircrew and Weapons Director Procedures for Air Operations

AFR 92-1, Fire Protection Program, 19 Nov. 1981

Air Commerce Act of 1926, 44 Stat. 568 (since repealed by the Federal Aviation Act of 1958)

American Indian Religious Freedom Act 1978, 42 USC section 1996 (1978)

Archaeological and Historic Preservation Act of 1974

Archaeological Resources Protection Act of 1979, 16 USC Section 470

Branning v. U.S.

Clean Air Act Amendments (1990), P.L. 101-549 (codified in 42 USC 7401 et. seq.)

Clean Air Act, 42 USC 7401 et. seq.; P.L. 90-148 (1970); P.L. 101-549

Clean Water Act, 33 USC 1261 et. seq.

Coastal Zone Management Act, P.L. 92-583, 16 USC 1451–1454; 15 CFR Part 930

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund), 42 USC 9601 et. seq.

Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, P.L. 93-254

Council on Environmental Quality NEPA Regulations, 40 CFR Part 1500–1508

DOI Endangered Species Act Regulations, 50 CFR 450–452

DOI Marine Mammals Protection Act Regulations, 50 CFR 220–230

DOI Regulations Implementing Migratory Bird Treaty Act, 50 CFR Part 21

Endangered Species Act, P.L. 93-205, 16 USC 1531–1544

Engle Act, 43 USC 155–158

EPA CERCLA Regulations, 40 CFR 300–373

EPA Clean Air Regulations, 40 CFR Parts 50–87

EPA Clean Water Regulations, 40 CFR 104–501; Part 122 (NPDES)

EPA Ocean Dumping Regulations, 40 CFR 227–228

EPA RCRA Regulations, 40 CFR 200–268; 270–272; 280–81

EPA Solid Waste Disposal Guidelines, 40 CFR 240.100

Executive Order 11593 (1971) Federal Agencies to Identify and Nominate Cultural Resources to National Register, and Avoid Damaging Resources

Executive Order 11990, Protection of Wetlands

Executive Order 12088, Federal Compliance with Pollution Control Standards

Executive Order 12630, March 18, 1988, Government Actions and Interference with Constitutionally Protected Property Rights

FAA Regulations on Air Traffic, 14 CFR 91–93; on Airspace (500 foot rule at 91.119); 71–73 (Special Use Airspace at 73)

FAR Part 91.15, General Operating and Flight Rules - Dropping Objects

Federal Aviation Act of 1958, P.L. 85-726, 49 USC App. 1301 et. seq.; 44 Stat. 568

Federal Aviation Regulation (FAR), Part 91-6

Federal Land Policy and Management Act of 1976 (FLPMA or the BLM Organic Act), 43 USC 1701 et. seq. (land withdrawals at 1714; management and denial of special use permits for military activities at 1732)

General Tort Claims Act, 28 USC 1346, 28 USC 2671–80

Marine Mammals Protection Act, P.L. 95-522, 16 USC 1361–1407

Marine Protection, Research, and Sanctuaries Act of 1972, 33 USC 1401–1445; 30 CFR 227-228

Maynard v. U.S., 430 F. 2d 1264 (9th Cir 1970)

McColloch v. Maryland, (4 Wheaton 316)

Migratory Bird Treaty Act, 16 USC 701 et. seq.

Military Lands Withdrawal Act of 1986, P.L. 99-606

National Environmental Policy Act of 1969, P.L. 91-190, 42 USC 4321–4370a

National Historic Preservation Act, 16 USC Section 470–470(m); 36 CFR 800; Criteria for Inclusion on National Register at Section 60.4

Native American Graves Protection and Repatriation Act of 1990

NOAA Coastal Zone Regulations, 15 CFR 921–933

Peterson v. United States, 673 F,2d 237 (7th Cir 1982)

Resource Conservation and Recovery Act, 42 USC 6901 et. seq.

Solid Waste Disposal Act and Amendments of 1980

The Military Claims Act, 10 USC 2731–2737

Tucker Act, 28 USC 1491(a)

U.S. Constitution, Amendment V, Just Compensation Clause

U.S. v. Causby, 328 U.S. 256 (1946)

U.S. v. Dahlehite, 346 U.S. 515 (1953)

Weinberger v. Romero-Barcelo, 456 U.S. 305 (1982)

Wild and Scenic Rivers Act, 1968, P.L. 90-542

Wilderness Act, P.L. 88-577, 16 USC 1131–1136

Wildwood Mink Farm v. U.S., 1963

APPENDIX E

FIRE RISK ASSESSMENT METHODOLOGY

FIRE RISK ASSESSMENT METHODOLOGY

This appendix presents a methodology for assessing fire risk from proposed flare use in a specific location. It outlines a process that starts with an initial risk assessment, continues through detailed risk analysis, and culminates in an environmental assessment (EA) leading to a decision on whether to employ flares in a certain airspace and, if so, under what conditions. The primary objective of this methodology is to provide a tool that can be used to assess fire risk and potential resource impacts in areas to be used for flare training, and to identify ways to minimize those risks and impacts.

Figure E-1 illustrates the overall methodology, which includes three phases. The purpose of the first phase is to conduct an initial risk assessment by characterizing the area, identifying resource sensitivities in the area, and reviewing fire history, in order to generally determine the potential risk of proposed flare operations. The initial assessment may lead to adjustments in the proposed action in response to the assessment's findings. After the initial assessment is complete, the proposed action is categorized as either low to moderate risk or high to extreme risk. If the risk is determined to be high to extreme, a more detailed assessment is performed in the second phase, and predictive fire risk modeling is used to aid in further development of the proposal and specific operating procedures. In the third phase, the EA is prepared, culminating in either a Finding of No Significant Impact (FONSI) or a decision to proceed with an Environmental Impact Statement (EIS). After the National Environmental Policy Act (NEPA) process has been completed, a decision is made about whether to proceed with the action.

The methodology is aimed at assessing:

- Fire risk rating for an area
- Sensitivity of resources in an area
- Whether to use flares in a location
- What operating procedures to implement

The following sections describe the process in detail.

E.1 INITIAL ASSESSMENT OF FIRE RISK

The initial assessment has six main steps: (1) defining the parameters of the proposed flare use, (2) characterizing the environment of the proposed location for flare use, (3) identifying sensitive resources in the area, (4) reviewing fire history for the area, (5) using this information to assess potential fire risk, and (6) making appropriate adjustments to the proposal as a result of the assessment. Since much of the data used in the initial assessment is geographic, a series of mapped overlays will be prepared. **Table E-1** lists the type of information that could be mapped. Use of Geographic Information System (GIS) or computer aided design (CAD), if available, will greatly facilitate this process.

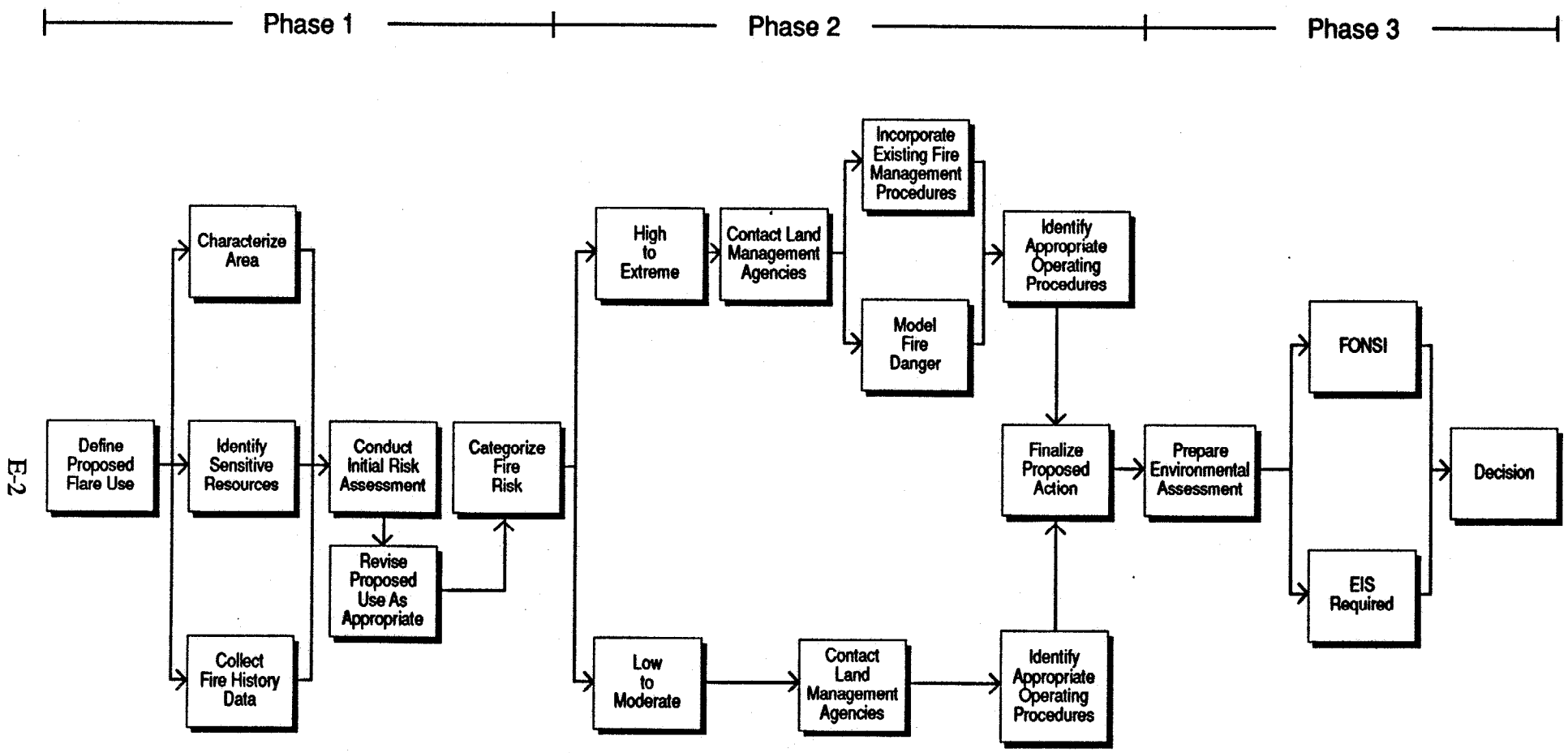


Figure E-1. Fire Risk Assessment Methodology

Table E-1. Possible Map Overlays for Initial Fire Risk Assessment

Land ownership and general uses
Special use areas (e.g., parks, monuments, wilderness areas, national forests)
Sensitive land uses
Plant community - vegetation
Terrain
Sensitive habitats
Migratory routes
Sole-source aquifers/well-head projection areas
Prime and unique farmland
Important historic and cultural resources
Areas of outstanding visual quality
Scenic highways and vistas
Location of fire occurrences
Generalized fire hazard ratings
Fire management zones
Fire stations, fire departments

The initial assessment is designed to give the proponent a general understanding of the prevailing fire situation in an area. As such, it does not include all factors that are considered in detailed predictive fire risk modeling. It is for this reason that more detailed analysis is recommended in the second phase, if warranted as a result of the initial risk assessment.

E.1.1 Definition of the Proposal

The definition of the proposal involves identifying proposed airspace(s) and flare use activities, including the amount and types of flares to be dispensed, proposed release altitudes, and time of use. The proposal should clarify whether flares will be used only occasionally (such as for an exercise, a few consecutive months) or regularly (daily, one week every month), and whether flares will be used during the day and/or night. The proposal should be reviewed to ensure that the proposed flare use area is adequate for operation and training needs and easily distinguishable to pilots during training.

The land area underlying the airspace proposed for flare releases needs to be accurately defined and mapped. Navigational section charts and U.S. Geologic Survey (USGS) topographic maps (1:250,000 or 1:100,000 series) would be appropriate base maps. The area may coincide with an existing airspace unit (such as a Restricted Area or MOA), or it may be defined in terms of target locations or range boundaries.

E.1.2 Characterization of the Area

The purpose of this step in the initial assessment is to identify attributes that contribute in a significant manner to the risk of a fire spreading, if it starts, including land ownership/use, climate, terrain, and vegetation. Land ownership is identified so that data on existing fire history and management procedures can be obtained. If, for example, lands underlying proposed flare use airspace are managed by a federal or state agency, fire assessment and management capabilities may be in place that can be used for the risk assessment.

Land Ownership and Use

Information on land ownership or management authority in areas underlying proposed flare use airspace can be identified through USGS maps (particularly the 100,000 series Land Status maps which cover most of the western Continental United States) or State Land Offices. These sources should delineate areas owned and managed by federal agencies (such as National Forests, National Parks, and Wilderness Areas), public lands administered by BLM, tribal lands, and, to some extent, state-owned lands, particularly state forests, parks, or special management areas. Areas that are not easily identified are most likely owned by state or local governments or private entities. For rural and remote areas, general land use descriptions of forest, rangeland, or agricultural use are sufficient for initial assessments. Reports published by regional Councils of Governments may be useful for identifying land uses.

Climate

Local climatological data for selected cities in the vicinity of the proposed flare use area can be obtained from the Department of Commerce or the local National Weather Service office. Data summarizing monthly average and extreme temperatures, precipitation, and wind speed should be collected for an initial assessment.

Terrain

Terrain affects vegetation type, water runoff, and fire spread behavior. Mapping general terrain using elevation bands and indicating the location of major ridges and valleys (water channels) is sufficient for an initial assessment.

Vegetation

USGS maps provide general locations of forests and wetland and marshy areas. This information may need to be augmented and refined with other map sources (such as State Atlas), field surveys, or aerial photographs to identify areas of cropland, plantation forest, open rangeland, or forest types that may not be evident from maps. The appropriate state department of agriculture can assist in identifying predominant crop types and general areas. The state forestry department or natural resource agency can assist in identifying natural vegetation associations.

E.1.3 Sensitive Resources

The primary resources that can be affected by fire include biological resources, such as critical or sensitive habitat, particularly for threatened or endangered species; physical resources, including air, soil, and water; land uses, such as forestry, agriculture, recreation, and protected areas; cultural resources; and areas that are valued for their outstanding visual quality. **Table E-2** lists potential fire-sensitive resources and sources of information about those resources. Sensitive resources should be identified within the proposed flare training area and located on overlay maps. A brief description of sensitive resource topics follows.

Biological Resources

Changes in plant community (both the species composition and structure) after a fire can mean a loss of wildlife habitat and significant plant communities. Habitats supporting sensitive and protected species are particularly vulnerable to changes resulting from fire. The geographic location of sensitive habitats for threatened and endangered plants and animal species are usually available from the state fish and wildlife (or game and fish) or natural resources departments or from the state Natural Heritage program. Other important locations include migratory routes for birds and mammals, wintering areas, nesting areas, and lambing areas for sensitive species. The federal land management agencies and the National Park Service also have biologists who can be consulted and who have documents with this information for their resource areas. If there are seasonal variations, these should be noted. Plant and animal species that are not well adapted to surviving fire should be identified. A trained biologist can identify which habitats are most vulnerable to the size of fires that are typical for the area. Aquatic species and their habitat should be identified if they are particularly sensitive to temporary and small changes in water temperature or may be affected by sedimentation due to fire-induced erosion.

Physical Resources

Physical and chemical changes in water quality can result from siltation or alterations in the timing or volume of peak flows as a result of burned areas in a watershed. For an initial assessment, the location of federally designated sole-source aquifers should be identified and mapped, and any special local air quality regulations should be identified.

Land Use

Special use areas should be identified and mapped using USGS maps, road atlases, and information directly from federal and state agencies. These would include national and state parks and monuments, Wilderness Areas, National Wildlife Refuges, Areas of Critical Environmental Concern, Wilderness Study Areas, Wild and Scenic Rivers, national and state recreation areas, National Forests, state forests, state wildlife management areas, and coastal management zones. Other sensitive land uses could include population centers and industrial complexes in remote areas, prime and unique farmland, and petroleum extraction sites or refineries. On DOD-owned land, the fire manager and security office can identify assets that are

Table E-2. Fire Sensitive Resources

Resource Category	Sensitive Resources	Sources of Information
Biological Resources	Sensitive and protected habitat Threatened, endangered, proposed, and candidate species Critical habitat Migration corridors Sensitive plants Breeding areas Riparian areas Biodiversity	DOD land Base or range Environmental Office, Natural Resource Management Plan, EAs and EISs for previous activities Other Federal and State Agencies BLM District Office, USFS, State Department of Natural Resources, State Fish and Wildlife or Game and Fish Department, infrared photographs, Resource Management Plans, vegetation management plans, University specialists
Physical Resources	Prevention of Significant Deterioration Class 1 Areas Water resources (streams, lakes) subject to sedimentation Sole-source aquifer and well-head protection areas	State Water Engineer, State Environment Department or Natural Resources Department, Environmental Protection Agency, USGS maps
Cultural Resources	Important historic and archaeological sites and monuments	State Historic Preservation Office, road atlas/gazetteer, land manager (e.g., BLM, USFS, National Park Service), USGS maps
Visual Resources	Scenic routes and highways Scenic overlooks Wilderness Areas BLM Visual Resource Management Class I and II areas U.S. Forest Service Preservation and Retention areas Historic site	Road atlases, DeLorme atlas and gazetteer (or equivalent), State Highway/Transportation Department, BLM District Office, U.S. Forest Service District Office, State Historic Preservation Office

Table E-2. Fire Sensitive Resources (cont.)

Resource Category	Sensitive Resources	Sources of Information
Land Use	Wilderness Areas Wilderness Study Areas Areas of Critical Environmental Concern Coastal Management Zone Wild and Scenic Rivers National and State Recreation Areas National and State Parks or Monuments National and State Forests National and State Wildlife Refuges State Wildlife Management Areas Prime and unique farmland Populated areas Commercial forest areas Petroleum extraction sites and refineries Mining sites	USGS maps, BLM, USFS, National Park Service, State Department of Natural Resources (or equivalent), State Forest Department/Commission, state or agency Geographic Information System database, State Parks and Recreation Department, State Department of Agriculture, county agricultural department, U.S. Department of Agriculture, U.S. Soil Conservation Service, DeLorme atlas and gazetteer (or equivalent)

BLM = Bureau of Land Management
DOD = Department of Defense
EA = Environmental Assessment
EIS = Environmental Impact Statement
USFS = U.S. Forest Service
USGS = U.S. Geologic Survey

particularly sensitive to fire. The natural resources manager can identify areas that require special management protection.

Cultural Resources

Some cultural resources, especially extant historic structures such as wooden buildings or mine equipment, are vulnerable to fire. Important archaeological, sacred, and historic sites, parks, and monuments should be identified through the State Historic Preservation Office.

For DOD lands, sensitive natural and cultural resources should be identified through the installation environmental management office. Existing plans and studies, such as natural resources plans or cultural resource surveys, that have been performed in the general location of the proposed flare use area should provide information about sensitive biological or cultural resources, including management objectives.

Visual Resources

Visual resources include areas specifically valued for their outstanding visual quality that would be significantly changed by fire. Areas to include in the initial assessment are scenic routes and highways, scenic overlooks, BLM Visual Resource Management Class I areas, and USFS Preservation areas.

E.1.4 Fire History

Fire history data for a proposed flare use area can assist in formulating reasonable alternatives for fire prevention and suppression. Fire history data include information on fire occurrences and fire management capabilities. Land managers for most federal and state lands have fire management plans that outline management goals and objectives, suppression allocations, and interagency agreements for suppression. These plans are based on information about resource types, uses, and values in the management area and the agency's ability and priorities in responding to fires. **Table E-3** lists potential sources of information relevant to fire hazard assessment.

Fire Occurrence Data

All federal land management agencies (USFS, BLM, National Park Service) and state agencies with responsibility for fire suppression collect data on fire starts. These data are collected in a standardized format and tracked by the interagency fire occurrence database, overseen by the National Interagency Fire Center and managed by the BLM. Fire occurrence data for twelve states (Alaska, Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Wyoming, and Washington) are compiled in the NIFC database. Databases for other states can be identified through the NIFC in Boise, Idaho. The databases usually include information on number of acres burned, causes, and the range and frequency of fire sizes. Fires occurring on private land may not be recorded by these agencies unless they drew on suppression resources beyond local services. For DOD-owned areas, fire occurrence data and history can be obtained from the installation fire department or range manager.

Table E-3. Fire History - Sources of Information

Category	Source of Information
Fire Occurrence Data	NIFC in Boise, Idaho; BLM District Office; USFS District Office; State Forest Manager; State Forestry Commission; State Department of Agriculture (Fire Management); other federal agencies (e.g., Bureau of Indian Affairs, National Park Service); County Fire Departments
Vegetation	USGS maps; field survey; state atlases; State Department of Agriculture; State Forestry Department, federal agency district office (e.g., BLM, USFS); Bailey R.G., *Description of the Ecoregions of the United States*
Fire Hazard Ratings	USDA Ft. Collins Computer Center, Fort Collins, Colorado; National Weather Service local office; State Department of Agriculture; State Forestry Commission
Climate/Weather	Department of Commerce; National Weather Service local office, NOAA Regional Climate Center

BLM = Bureau of Land Management
NIFC = National Interagency Fire Center
NOAA = National Oceanic and Atmospheric Administration
USDA = U.S. Department of Agriculture
USGS = U.S. Geologic Survey

Where possible, data for a ten year period should be collected. The data may be entered and retrieved in a variety of ways, depending on the organizational system (e.g., by county, by coordinates, or by administrative district). Useful information to extract from the data may include:

- Total number of fires by year and total acres burned by year.
- Total number of fires and acres burned by month (to identify seasonal fire patterns).
- Average size of fires by year and by month (to determine when fires are likely to spread).
- Number of fires by size, year, and season (to determine whether the majority of fires burn out within a small area or spread to large areas).

BLM uses the following size categories, which can be adopted for this assessment: less than 0.25 acre; 0.26 to 9 acres; 10 to 99 acres; 100 to 299 acres; 300 to 999 acres; 1,000 to 4,999 acres; and 5,000 acres and over.

The proposed flare use area may not cover exactly the same area as the fire history data set; therefore, individual fire occurrences should be mapped. If possible, different parameters and

patterns (such as cause, size, annual fluctuations) should be plotted in geographic context. If available, a GIS system can make mapping this level of detail practical. The data should be reviewed for patterns or trends, such as concentrations of fires around geographic areas (such as mountainous areas, population centers, or recreation areas), seasons, or vegetation types (such as forested areas).

Federal agencies use nine fire cause categories: lightning, camp fire, smoking, fire use, incendiary, equipment use, railroads, children, and miscellaneous. Flare use and other military activities are not specifically addressed in these categories, and those fires are generally tracked as incendiary or miscellaneous. The incendiary category also includes legal and illegal fireworks. When analyzing data in areas where flares are already used, discussions with state or federal agency fire investigators, fire marshals, or fire management officers should assist in determining if flares are known to have been a source of ignition in the past.

If the proposed flare use area is mostly over private land, there may be no record of fires in the area, and it may be necessary to extrapolate from available information. For example, if there is a pattern of fire occurrence on forested land within an area for which data is recorded, it may be assumed that areas with similar plant communities and terrain will have a similar fire history. Alternatively, county fire departments can be contacted for records of fires in the area. If the proposed flare use area includes several counties, patterns may be determined from a sample of county records.

The fire occurrence data should be compared to the climatological data, to see if there are correlations between monthly precipitation, wind speed, or temperature, or between historic weather conditions and annual fire occurrence.

Fire Danger Rating

Fire danger for any given area is determined using the National Fire Danger Rating System. NFDRS ratings are established by fire weather meteorologists at local National Weather Service offices using predictive modeling based on broad vegetation patterns, daily and historic weather conditions, and historic fire occurrence data at different locations. The resulting fire hazard rating is distributed to requesting agencies. The five fire hazard ratings used in the NFDRS are low, moderate, high, very high, and extreme.

NFDRS has parcelized the entire country into "fuel type" areas based on vegetative characteristics (i.e., the propensity for certain vegetation types to burn). NFDRS utilizes 20 standard fuel type models. Fuel type determines which of 20 possible fuel models is used for the area. NFDRS calculates fire risk on a daily basis using daily weather observation data. Weather data used in the calculation include temperature, humidity, cloud cover, haziness, wind direction and speed, lightning, and fuel moisture. The NFDRS rating system has limitations because the information on fuel (vegetation) conditions tends to be very general.

Records of fire danger ratings are archived at the USDA Fort Collins Computer Center in Fort Collins, Colorado and can be retrieved in machine-readable form for a modest fee through

remote computer link or from local National Weather Service offices. These data can be examined for a typical range of fire ratings for a location. Again, historical data will permit a more comprehensive assessment of seasonal variations. Both worst-case ratings and a range of typical ratings in an area should be ascertained. An overlay of the worst prevailing fire danger ratings should be made. Annotations can indicate seasons or months when ratings are typically higher or lower.

Fire danger ratings are also assigned by land managers or agencies with responsibility for fire suppression and can be obtained from these agencies (e.g., BLM, state forestry department). Agencies can "fine tune" fire ratings to reflect risk of unsuppressed fires spreading beyond a certain size.

Fire Management Zones

BLM typically classifies areas of similar vegetation and fire risk into Fire Management Zones (FMZs). These zones are subdivided into areas with similar fire management objectives (based on resource sensitivity) ranging from "let burn" areas to areas where every fire start is suppressed. The FMZs are designated according to historic fire frequency and size, resource values, and NFDRS. Typically, the management objective is to limit fires to a certain size (e.g., below 100 acres). If FMZs are available for a proposed flare use area (or a portion of the area), they can be adopted for the initial assessment.

Fire Management Capabilities

Current fire suppression responsibilities and capabilities in the area should be identified. Any constraints on fire management, such as ownership patterns, geography, lack of road access, limited personnel and equipment, absence of cooperative agreements, and available water sources, should also be identified. Federal and state land managers and local county fire marshals will have information about fire suppression capabilities in an area.

E.1.5 Initial Risk Assessment

The mapped data on environmental conditions, sensitive resources, and fire history are used to make an initial fire risk assessment for the proposed flare use area. The area should be divided up as appropriate to reflect different conditions. For example, the fire risk may not be uniform throughout the area, and locations where there are particularly sensitive resources or where vegetation types are particularly conducive to fire spread (e.g., grasses) should be identified. This may result in some portions of the proposed flare use area being identified as having relatively low risk and other portions having a relatively high risk.

In assigning risk, consideration should be given to all three types of information collected about the area. Vegetation and climate data help identify areas where fires are likely to spread because of the type of vegetation, low humidity, slope, high wind speed, and low precipitation. Areas that might otherwise be considered of low risk should be assessed more conservatively if sensitive resources are present. Areas that have experienced a large number of fires in the past, or where

past fires have spread to burn large acreages, should be identified as higher risk. If possible, fire management specialists should be consulted in making the initial assessment.

E.1.6 Adjustments to the Proposal

Based on the initial risk assessment, it may be appropriate to consider adjustments to the proposed action to reduce the risk. For example, if there is a high risk location at the edge of the proposed flare use area, the boundary of the area may be redefined to avoid this location. If the high risk segment is in the center, in isolated pockets, or cuts across the training area, avoiding it may not be possible. Similarly, portions of the proposed flare use area that contain sensitive resources may be "carved out" to avoid potential impact. The proponent may also decide to restrict flare use to high altitudes (e.g., above 8,000 feet AGL) in order to reduce the overall risk of fire. Considering these limitations, a decision should be made whether to further consider the proposal.

E.2 DETAILED EVALUATION

The purpose of this phase of the process is to evaluate areas identified as having potential for high to extreme fire risk in more detail, in order to determine whether to proceed with the proposal. This phase includes three main steps: (1) categorizing risk level, (2) contacting agencies, and (3) collecting detailed information on high risk areas, either by incorporating existing fire management procedures or through fire danger modeling.

E.2.1 Categorize Risk

Once a flare use proposal has been adjusted and refined based on the initial risk assessment, the proposed flare use area, divided into subareas if appropriate, is placed in one of two fire risk categories: low to moderate risk or high to extreme risk. If the fire risk is not uniform throughout the proposed area, portions that have high to extreme risk should be identified and subject to detailed analysis. Areas that may have moderate risk based on vegetation, climate, terrain, and fire history should be treated as high risk if they contain highly sensitive resources. Seasonal variations should also be considered in assigning risk category. If an area has a potential for high risk during certain times of year or under certain weather conditions, that area should be placed in the high to extreme risk category, unless the proposed action includes a provision to suspend flare use during those periods.

If it is determined that part or all of the proposed flare use area has low or moderate risk, it may be sufficient to indicate that the proponent would notify any fire managers in the area of the proposed activities and include them in the review of the EA. A suitable procedure to include as part of the proposed action would be a written agreement between the proponent and area fire managers that identifies minimum release altitudes, a DOD point of contact for reporting any fires or concerns, and provisions for annual review of the agreement. If the area includes any sensitive resources (e.g., sensitive wetland habitat), even if it is at low risk for fire, the managers or caretakers (e.g., state department of fish and wildlife) should be included. If the area includes

privately owned lands with moderate fire risk, coordination between local (county) fire departments should be included.

Another appropriate procedure to include in low to moderate risk areas would be to adopt any local land management agency's fire management procedures. For example, the proponent could agree to contact the agency regularly to obtain fire danger ratings and suspend flare use during periods when fire risk is elevated. Fires are known to occur in times when the hazard rating is moderate, and if there is significant lightning activity, for example, fire suppression capabilities may be taxed. Therefore, there may be times when fire danger is rated moderate that flare use should be reduced or suspended.

E.2.2 Agency Contacts

For areas with potential high to extreme risks, more detailed evaluation is needed, and appropriate agencies should be included in the evaluation. This will help streamline the NEPA process by ensuring that agency concerns are incorporated in the development of the proposed action. Agencies can assist in identifying sensitive resources and fire management objectives.

Some areas may have an existing Fire Management Action Plan in effect, which outlines fire management goals, suppression allocations, and interagency agreements for fire management. Fire managers for these areas probably use predictive fire behavior modeling in order to anticipate conditions under which fires would exceed fire size objectives. If available, existing plans should be used to help identify procedures for flare use. These could include avoidance of areas with designated fire hazard ratings, altitude restrictions, fire suppression support, or fire surveillance support.

For areas where no existing fire management planning is available, it may be beneficial to use fire behavior modeling (such as BEHAVE) at selected high risk and sensitive locations to estimate fire sizes under a range of hypothetical conditions. Fire size is a useful measure of risk because it is related to the potential for environmental damage. If modeling indicates that fires could spread beyond a few acres, the risk of damage from a flare-caused fire is relatively high. Discussion with agencies or local fire managers can help identify what fire size thresholds to apply (considering sensitivity and suppression capabilities).

Modeling can also identify when certain procedures for flare use should be implemented. For example, BEHAVE modeling can be used to determine fire spotting distances, which can be used to locate manned observation towers or develop strategies for aerial fire spotting. A description of the BEHAVE model and its use is provided below.

Predictive Fire Modeling Using BEHAVE

The BEHAVE fire behavior prediction and fuel modeling system is a set of interactive computer programs that can be adapted to a variety of specific fire management needs (Andrews 1986). This system is made up of two subsystems: FUEL, the fuel model subsystem, and BURN, the fire behavior prediction subsystem. **Figure E-2** illustrates the components that comprise

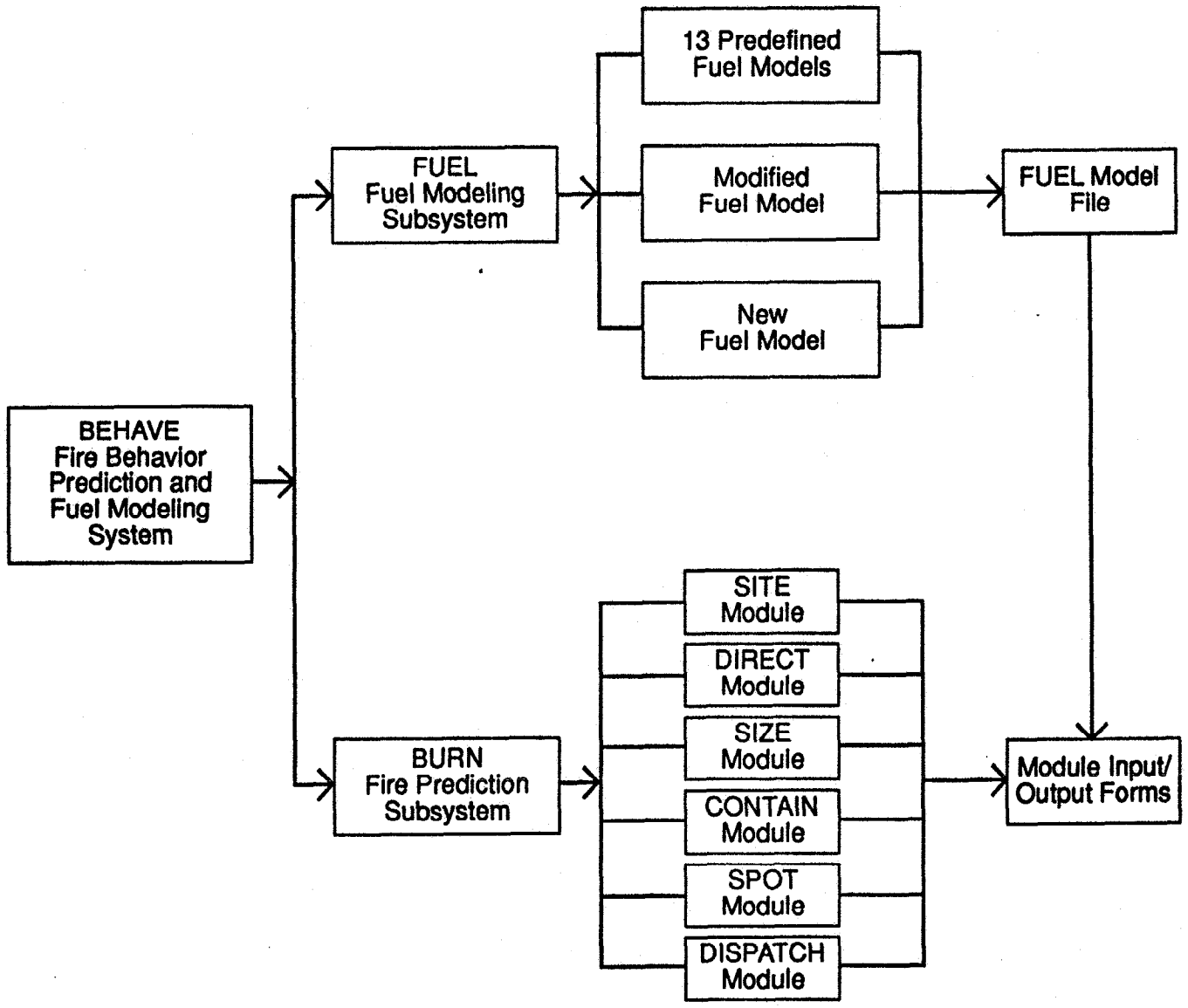


Figure E-2. Components of the BEHAVE Fire Prediction and Fuel Modeling System

BEHAVE. Within the FUEL subsystem, there are 13 models based on different vegetation conditions. Within BURN, there are six modules tailored for specific inputs and outputs. For example, DIRECT is used to identify the rate of spread and fire intensity for each fuel type identified in a study area. The fire behavior depends on several input factors including fuel model, slope, and wind speed. Information on the fire line intensity, flame length, and spread rate can also be obtained through the BEHAVE model.

The 13 standard fuel models available in the BEHAVE FUEL subsystem are called Northern Forest Fire Laboratory fuel models or fire behavior models. The first step in the modeling is to select the appropriate fuel model(s) for the study area. The following criteria are used to select the appropriate model for each vegetation type in a study area (adapted from Rothermal 1983):

- Determine the general vegetation type, (e.g., grass, shrubs, timber, litter, or slash).
- Estimate which vegetation type is most likely to spread the fire.
- Determine the general depth and compactness of the fuel.
- Determine which fuel classes are present and estimate their influence on fire behavior.
- Using these observations, proceed through the fuel model key and description in the BEHAVE instructions.

The selected fuel model(s) is held in a file which works in conjunction with the BURN subsystem. **Table E-4** provides a selection of example fuel models. BEHAVE also provides the options of modifying the standard models for an application or developing a new model.

Selecting which BURN module to use depends on the objectives of the modeling effort. **Figure E-2** lists the modules available. The CONTAIN, SPOT, and DISPATCH modules are used primarily in planning detection and suppression activities. SITE, DIRECT, and SIZE are useful in predicting fire behavior to assess risks. SITE and DIRECT are for predicting spread rate and intensity for site-specific and general conditions, respectively. SIZE calculates the expected area and perimeter of a fire that started from a point source. This module can be used to assess whether a fire started by a flare is likely to spread to a large area. Under low risk conditions, even if a fire starts, it is likely to burn itself out without damaging a large area. The BEHAVE model output tends to be conservative in estimating fire size because it does not incorporate breaks in fuel continuity (e.g., cleared area, roads, fire breaks) that limit fire size.

The BURN module selected determines what input data are needed. Each module has data input forms to complete. Typical data needs could include:

- Time and location (month, day, time of day, latitude, state).
- Fuel model (fuel model number(s), percent cover of each model).
- Fuel moisture (1 hour fuel moisture percent, 10 hour fuel moisture percent, 100 hour fuel moisture percent, live herbaceous moisture percent, live woody moisture percent).

- Slope, elevation, aspect (if known or applicable).
- Timber overstory description (crown closure percentage, foliage present or absent, shade tolerant or intolerant, dominant tree type, average tree height, ratio of crown height to tree height, ratio of crown height to crown diameter).
- Burn time weather (temperature, relative humidity, 20 foot wind speed, direction of wind vector from uphill, exposure of fuels to winds, cloud cover, haziness).
- Historic weather and moisture conditions.

Table E-4. Sample of Available Fuel Models and Corresponding Vegetative Types Used in the BEHAVE Fire Model System

Fuel Model Number	Typical Fuel Complex	Vegetation Types Within Study Area
1	Short grass (1 foot height)	Cheatgrass grasslands; well utilized crested wheatgrass plantings; low sagebrush communities
3	Tall grass (2.5 foot height)	Bluebunch wheatgrass grasslands; tall cheatgrass (especially in the canyons); crested wheatgrass planting
5	Brush (2 foot height)	Big sagebrush
6	Dormant brush, hardwood slash	Big sagebrush, mountain mahogany glades, mixed juniper/mountain mahogany

Adapted from Andrews 1986.

The model contains default values for parameters that are not specified.

Input data on weather can be obtained from regional climate centers operated by NOAA. There are six regional climate centers in the U.S. These centers receive fire weather data daily from the NIFC, which collects the data from RAWS and manual weather stations throughout the country. A description of the data categories collected as RAWS sites is provided in **Table E-5**.

Once input parameters have been inserted, the module is run, and a series of outputs are provided. Outputs vary depending on the BURN subsystem module selected. For example, the SITE module output includes rate of spread, heat per unit area, fireline intensity for each fuel type identified in a study area, flame length, reaction intensity, effective wind speed, and direction of maximum wind speed. Some of these outputs have specific applications for fire managers during fire suppression events. Other modules identify fire spotting distance, area and perimeter growth of fires, scorch height, and tree mortality.

Table E-5. Description of Categories Used in RAWS Data Forms

Data Category	Data Description
Date/Time	Read in Greenwich Mean Time. Data line is read from the left as year, month, day, hour, and minutes past the hour. When the hour is listed as 00, the time is midnight.
Accumulated Precipitation	Measured in inches. Sites not reset on a regular basis. When reset, they are reset to .02. If no difference in the reading is shown, no precipitation was received. A difference in number reflects precipitation. A change from 2.4 to 2.9 indicates .5 inches of precipitation. A change from 2.4 to 1.4 indicates the site was reset to .02, and then 1.2 inches of precipitation was measured.
Wind Speed	Measured in miles per hour. Not a standard category at USFS RAWS sites.
Wind Direction	Measured in degrees. The average direction blowing over a 10 minute interval every hour. The time recorded is consistently the 10 minute interval prior to data transmittal. Transmittal time varies from site to site.
Air Temperature	Recorded air temperature in degrees Fahrenheit.
Fuel Temperature	Measured in degrees Fahrenheit. Taken to simulate the temperature of wood or sticks. A broom handle device with a thermometer inside is hung from the site. Indicates cloudiness or sunniness depending on whether it is greater or less than the air temperature.
Relative Humidity	Given as a percent.
Barometric Pressure	Measured in inches. Not included for USFS or BLM RAWS sites.
Gust Direction	Directional measurement in degrees for the highest instantaneous gust (not an average). When the wind is strong there is less difference between the direction of the average wind and gust wind. Not a standard category in USFS RAWS sites.
Maximum Gust Speed	Measured in miles per hour. Equal to or greater than the average wind speed. Not a standard category in USFS RAWS sites.

E.3 NEPA COMPLIANCE

The last phase of the fire risk assessment process is completing the documentation required for NEPA compliance. This begins with finalization of the proposed action and incorporating appropriate use restrictions and operational procedures, identified during the assessment process. Next, an EA is prepared. The EA will result in either a FONSI or, if significant impact could result, a Notice of Intent to prepare an EIS. After the NEPA process has been completed, a final decision can be made concerning the proposed flare use.