CHAPTER 4

SITE HAZARD ANALYSIS

4.1 INTRODUCTION

Safety analyses evaluate hazards that could potentially impact immediate workers, collocated workers, the public, and the environment. These evaluations typically focus on the mechanisms that could potentially initiate an uncontrolled release of radioactive and hazardous chemical materials. This chapter contains the following information:

- An overview of the methodology used in the safety analyses contained in the Rocky Flats Environmental Technology Site Safety Analysis Report (Site SAR), Section 4.2.

- Identification of hazards on a site wide basis, Section 4.3. This section does not include hazards specific to an individual facility. It does include hazards which are common to several facilities.

- Summaries of facility classification and major hazards for all facilities on the Rocky Flats Environmental Technology Site (RFETS), Section 4.4.

- An assessment of the interaction potential between facilities, Section 4.5.

- An evaluation of the potential impact to the site from commercial facilities located in the proximity of the site, Section 4.6.

4.2 SAFETY ANALYSIS METHODOLOGY

RFETS consists of buildings and structures with various hazard classifications, which include nuclear hazard Category 2 and 3, radiological, non-nuclear moderate and low hazards, and industrial facilities. DOE documents, DOE Order 5480.23 (DOE, 1992a), DOE-EM-STD-5502-94 (DOE, 1994a), DOE-STD-1027-92 (DOE, 1992b) and DOE Order 5481.1B (DOE, 1987), define these classification. The hazard classification is based on the quantity of hazardous material present in the facility and determines the level of analysis necessary in an authorization basis. One aspect of the Site SAR is to provide the authorization basis for nuclear hazard Category 3 facilities, with the exception of the 904 Pad. The safety analyses for the Category 3 facilities included in the Site SAR are in Appendices G, H, and I. The authorization basis for the 904 Pad is combined with the 750 Pad in a Final Safety Analysis Report (FSAR). Auditable safety analyses, as facility safety analyses (FSAs), for radiological, non-nuclear, and industrial facilities are collected in Volume II of the Site SAR.

The appendices and the FSAs contain a brief description of the facility as to location, physical features, and important processes and activities. The hazard analyses presented in these safety analyses are graded based on the complexity of the facility, the quantities of hazardous materials present in the facility, the energy sources available to disperse the hazardous materials, and the dispersibility of the material. The hazard identification uses a standardized checklist of typical hazard types found in industry, which have the potential to impact the immediate and collocated workers, the public, and the environment, as well as provide an initiator for the release of hazardous materials. The hazard identification provides the basis for scenario development and calculations of frequency, consequences, and risk. The methodology used for frequency, consequence, and risk determinations is presented in the Safety Analysis and Risk Assessment Handbook (SARAH) (RFETS, 1997).

4.3 SITE-WIDE HAZARD IDENTIFICATION

The site-wide hazard analysis uses a comprehensive checklist to identify hazards common to the site. The following paragraphs describe each hazard, provides the criteria for inclusion, and lists the hazards falling into that hazard type for the site. Each table describes pertinent information concerning the form, packaging, and locations of the hazards, and identifies features to prevent accidents and mitigative consequences of an accident involving the hazard. The specific hazards identified below for the hazard types are considered site-wide hazard and are not associated with a specific facility unless noted. If an individual facility or operation also has this type of hazard, it will be identified in the hazard descriptions in the appropriate safety analysis, e.g., FSAR, BIO, Basis for Operation (BFO), FSA, or other type of auditable safety analysis. Hazards specific to facilities with their own safety analysis are not included in the following tables.

4.3.1 High Voltage

Electrical energy sources with more than 600-volt (V) potential, including AC (alternating current) electrical distribution systems from site power.

Table 4-1. Site High Energy Hazard Description

Hazard/ Energy Source	Description	Preventive & Mitigative Features	Remarks
13.8-kV power distribution lines and 115-kV transmission lines	Exposed and underground throughout site constructed per ANSI C2.	- Overhead lines isolated by height - Underground lines isolated by burial - Procedures, training, protective equipment for maintenance - Fuses and breakers, switch out capability	Standard industrial hazard. 115-kV systems operated and maintained by PSCo.
Transformers and switchgear	Located throughout the site.		Standard industrial hazard.

4.3.2 Explosives

Explosives are designated in 49 Code of Federal Regulations (CFR) 173.50 - .114. This category is not for potentially explosive gases or chemicals that should be noted under Section 4.3.8, Flammable Gases and Liquids, and Section 4.3.16, Toxic and Hazardous Chemicals. This category is specifically for explosive devices or the chemicals that are being prepared or used in explosive devises (blasting caps, squibs, dynamite, etc.). Halon fire suppression systems generally have squibs.

The squibs for Halon fire suppression systems are covered by the appropriate building specific safety analysis. Explosives, such as ammunition, pyrotechnics, explosives, utilized by the protective force are identified in the risk assessment for their operations.

4.3.3 Cryogenic Systems

This category is used to identify substances or systems that could cause bodily injury on contact (lower than -100°F). Liquefied gases are usually cryogens.

Table 4-2. Site Cryogenic Systems Hazard Description

Hazard/ Energy Source	Description	Preventive & Mitigative Features	Remarks
Liquid nitrogen storage tanks	Several liquid nitrogen storage tanks are located on the site, outside the building served by them.	- Double-walled design - Standard design, procedures, PPE, isolation valves	Standard industrial hazard, therefore, no additional evaluation will be performed. Individual locations will be evaluated with the associated facility if applicable.
Nitrogen production	Equipment casings, piping, vessels located in and adjacent to Building 223.	- Area fenced, not normally occupied, remotely monitored, 2-hour operator response time - Liquid nitrogen reserve automatically engaged if production is interrupted - Insulation	Standard industrial hazard. See the Industrial Gas section in Chapter 3.

4.3.4 Inert and Low-oxygen Atmospheres

This includes gloveboxes or work areas where inert atmospheres are used. This indicates the potential for an asphyxiation hazard, especially if related to an inadequate ventilation hazard as described in Section 4.3.17.

Table 4-3. Site Inert and Low-oxygen Atmospheres Hazard Description

Hazard/ Energy Source	Description	Preventive & Mitigative Features	Remarks
Basins	Several concrete basins, covered and uncovered at various locations.	- Confined space entry program	Standard industrial hazard.
Electrical manholes	45, below-grade concrete manholes for underground power located throughout site.	- Confined space entry program	Standard industrial hazard.
Fuel tank pit	One, concrete basin with raised-pattern floor plate covers for generator fuel tank located south of Building 827.	- Confined space entry program	Standard industrial hazard.
Lift stations	Two, below-grade concrete vaults located northwest of Building 771, south of Building 881.	- Confined space entry program - Ventilation	Standard industrial hazard.
Manholes	Many, below-grade manholes with access hatches located throughout site. Consists of concrete shell with steel covers.	- Confined space entry program - Accesses covered	Standard industrial hazard.
Tanks	Many large tanks located throughout site. Includes water tanks, acid tanks, process waste tanks, and distillate tanks.	- Confined space entry program - Accesses sealed - No need to enter tanks on a regular basis	Standard industrial hazard.
Transformer tanks	Nine, 115-kV to 13.8-kV primary transformer casings with inert blanket. Steel shells. Located at all primary substations.	- Confined space entry program - Accesses sealed - Oil filled - Not normally entered	Standard industrial hazard.
Valve vaults	20, below-grade concrete vaults with access hatches located throughout plant.	- Confined space entry program - Forced ventilation and testing prior to entry	Standard industrial hazard.
Valve and heater vaults	Four, below-grade covered pits for valves and a pipeline heater. Located inside and outside B869.	- Confined space entry program - Training - Personal Protective Equipment (PPE) - Buddy system	The vaults are not used and would be entered only in unusual circumstances. Standard industrial hazard.

4.3.5 Direct Radiation Sources

These are sources that produce ionizing radiation at a known level and include X-ray machines, accelerators, and sealed sources.

Sealed radioactive sources represent a special case regarding the inclusion or exclusion of the sealed source in the radiological inventory of a facility. Sealed radioactive sources that are engineered to pass the special form testing specified by the Department of Transportation (DOT) in 49 CFR 173.469 or testing specified by ANSI (American National Standards Institute) N43.6, *Sealed Radioactive Sources Categorization*, may be excluded from summation of a facility's radioactive inventory. However, there must be documentation that the source or prototypes of the source have passed the tests specified by DOT and ANSI and are therefore "qualified".

The source control program at RFETS is regulated under 10 CFR 835.1201, Subpart M, and complies with DOE Notice 441.1, *Radiological Protection for DOE Activities*. The DOE notice is implemented at the site by the Radiological Protection Program and the Radiological Controls Manual. Sealed sources are identified and evaluated in the individual facility evaluations.

Table 4-4. Site Direct Radiation Sources Hazard Description

Hazard/ Energy Source	**Description**	**Preventive & Mitigative Features**	**Remarks**
X-ray equipment	Several commercial X-ray machines located at medical (Bldg 122), in the mail room (Bldg 460), shipping and receiving (Bldg 130), and the PACS.	- Commercially available equipment of standard design	Standard industrial hazard, therefore, no additional evaluation will be performed.

4.3.6 Radioactive Materials

This includes radioactive materials that are located on the site. Sealed sources (Section 4.3.5) and nontransferable contamination (Section 4.3.26) are not included.

Table 4-5. Site Radioactive Materials Hazard Description

Hazard/ Energy Source	Description	Preventive & Mitigative Features	Remarks
Metals, oxides, residues, etc. containing radioactive material	Packages and containers stored and transferred throughout the site.	- Containers and packaging - Radiation Protection Program - Transportation Manual	- Storage is covered in the appropriate authorization basis - Transfer evaluated in Chapter 8
Low-level waste (LLW)	Drums, crates, half-crates, etc., stored throughout site. Contains <100 nCi/g activity.	- Containers and packaging - Radiation Protection Program - Individual drums can not exceed TQs	- Primarily contains surface contamination. - Potential to exceed 40 CFR 302 RQs for some radionuclides
Low-level mixed waste (LLMW)	Drums, crates, half-crates, etc., stored throughout site of materials meeting the hazardous waste criteria and the low-level waste criteria.	- Containers and packaging - Radiation Protection Program - RCRA program	- Potential to exceed 40 CFR 302 RQs for some radionuclides and chemicals. - See the RCRA Units safety evaluation in Appendix I.
Transuranic waste (TRU)	Waste containing >100 nCi/g activity. Stored in drums or approved metal containers at several locations on site.	- Can only be stored in drums or other approved containers - Radiation Protection Program	- Individual drums can exceed TQs
TRU mixed waste (TRM)	Materials meeting the hazardous waste criteria and the TRU waste criteria.	- Containers and packaging - Radiation Protection Program - RCRA program	- Individual drums can exceed TQs
Process wastewater	Aqueous process waste containing up to 13,500 pCi per liter alpha.	- Confined - Tested - Radiation Protection Program - SPCC Program - PPE - Training required for operators	- Potential to exceed 40 CFR 302 RQs for some radionuclides. - See Process Waste Transfer System FSA.

4.3.7 High Noise Levels

Areas with noise sources equal or greater than 85 decibels (db) or areas marked for hearing personal protective equipment are included in this category. Noise levels are monitored in all likely or suspected site areas in accordance with the Health and Safety Practices manual. Employee hearing is monitored by occupational health to identify potential noise-induced hearing changes. Hearing protection is provided to employees. High noise areas have controlled access.

4.3.8 Flammable Gases and Liquids

Gases or low vapor pressure liquids that have a flashpoint less than 100°F, National Fire Protection Association (NFPA) diamond flammable value of 3 or 4, or are noted in the 40 CFR 68 (CFR, 1993a) flammable substance. Natural gas is included in this category. Various solvents (usually present in small quantities) are also included here. This category also includes areas where airborne dusts could present a flammable source.

Table 4-6. Site Flammable Gases and Liquids Hazard Description

Hazard/ Energy Source	Description	Preventive & Mitigative Features	Remarks
Gas cylinders	Cylinders of compressed gas containing various flammable substances and mixture contained in DOT cylinders.	- Restrained - Pressure regulator - Cylinders capped when not in use - Inspected - Procedures for transport and storage	Standard industrial hazard.
Hydrogen	Hydrogen gas generated by charging wet-cell batteries released to buildings. Located in emergency generator and switchgear buildings.	- Some electrical fittings are explosion-proof; buildings are ventilated.	Hydrogen readily dissipates. Standard industrial hazard.
Natural gas distribution	Natural gas transmission and distribution piping is throughout the site. Natural gas consists mostly of methane. Contained in steel piping, systems per ASME and NFPA.	- Venting - Odorant - Isolation capability - Cutoff capability to facilities	Standard industrial hazard.
Potential sewer gas	Primarily methane and hydrogen sulfide evolving from decomposition. Sewer pipes and manholes throughout plant.	- Isolated from human contact and ignition sources. - Low concentrations	Standard industrial hazard See the Sanitary Sewer description in Chapter 3.
Propane	- Two propane tank farms P750 and P904, each with eight steel tanks (1,000-gal capacity each tank) - Many individual tanks located throughout the site. Steel tanks, varying in capacity.	- NFPA and ASME conformance - Protective barriers - Pressure relief - Procedures - Inspections - Outside installations	Quantity exceeds 40 CFR 68 10,000-pound TPQ. See the Fuel Gas section in Chapter 3 and the hazard evaluation in Appendix D.

4.3.9 Compressed Gases

Compressed air used as a facility utility and standard compressed gas bottles are included here. Cylinders of many different chemicals and mixtures are located in various facilities throughout the site, including compressed carbon dioxide, nitrogen, air, helium, specialty gases, argon, oxygen, nitrous oxide, and refrigerants. Cylinders meet Department of Transportation (DOT) requirements, and are restrained and capped when not in use. Appropriate procedures are followed for transport and storage. See the facility authorization bases documents for compressed gases in the individual facilities.

4.3.10 High-Pressure and High-Temperature Systems

This category is used to note systems or processes that represent significant energy sources. The high-pressure systems have significant overlap with Section 4.3.9 but also include high-pressure fluid systems. High-pressure/temperature systems are capable of producing burns, starting fires, causing undesired chemical reactions, or producing hazardous vapors. Hot surface hazards are included in this item.

Table 4-7. Site High-Pressure and High-Temperature Hazard Description

Hazard/ Energy Source	Description	Preventive & Mitigative Features	Remarks
Steam plant and distribution piping	Superheated and saturated steam and condensate, 125- and 140-psi systems. Carbon steel piping throughout site.	- ASME design and construction - Pressure relief at steam plant - Insulation - Training - Procedures	Standard industrial hazard. See the Steam and Condensate System evaluation in Appendix E.

4.3.11 Kinetic Energy (KE)

These energy sources include both rotating and linear motion moving masses. Failure of the controls used to direct kinetic energy toward an intended function represents a significant energy source that could initiate or propagate an accident scenario or sequence. Rapid destruction of mechanical systems represent shrapnel sources that could fail confinement systems. At RFETS, vehicular traffic in the areas and around facilities represents a significant KE hazard.

Table 4-8. Site Kinetic Energy Hazard Description

Hazard/ Energy Source	Description	Preventive & Mitigative Features	Remarks
Vehicular traffic	Movement of equipment and vehicles. All areas.	- Barriers, markings, and signage - Licensing - Regulation - Enforcement	Standard industrial hazard.

4.3.12 Potential Energy (PE)

These energy sources include systems with stored chemical (large battery banks), mechanical, or electrical energy (large capacitor banks). Large masses at heights referred to as mass, gravity, and height (MGH) hazards are included here. In the hazards list used for the Site SAR, many potential energy hazards have been assigned a specific category (high voltage, explosives, flammable gases, compressed gases, working at heights, etc.).

Table 4-9. Site Potential Energy Hazard Description

Hazard/ Energy Source	Description	Preventive & Mitigative Features	Remarks
Elevated tank	One, steel tank, 155-ft in height, 300,000-gal water located at Bldg. 124.	- Structural support - Controlled access	Standard industrial hazard.
Transmission and distribution systems	Overhead distribution lines for electrical power, steam, natural gas located throughout the site.	- Structural support	Standard industrial hazard.

4.3.13 Non-ionizing Radiation

These energy sources include microwave generators, induction ovens, and electric arcs (welding arcs and electron beams). Microwave ovens are excluded. Lasers are included in Section 4.3.22.

Table 4-10. Site Non-ionizing Radiation Hazard Description

Hazard/ Energy Source	Description	Preventive & Mitigative Features	Remarks
Electromagnetic communications waves	Radio and microwave frequencies. All areas.	- Low-power radio waves, microwave beams directed through unoccupied spaces.	Standard industrial hazard.
Electromagnetic fields	High-voltage AC produces significant electromagnetic fields. Most significantly near 115-kV lines and equipment.	- Isolation by height along transmission lines and fences around9 substations.	Standard industrial hazard.

4.3.14 Magnetic Fields

This category includes magnetic fields large enough to produce unwanted strong electrical currents or large enough to affect safety-related instrumentation.

Table 4-11. Site Magnetic Fields Hazard Description

Hazard/ Energy Source	Description	Preventive & Mitigative Features	Remarks
Electrically induced magnetic fields	Electrical current induces magnetic fields. High-current conductors, busses, switchgear, particularly at substations.	- Isolated areas, not normally occupied.	Not shown to produce adverse health effects. Standard industrial hazard.

4.3.15 Chemical Exposures

The hazards associated with general chemicals and materials are covered in this item. The chemical tracking database and facility walkdowns are used to identify the chemicals present in a facility. The intent of the chemical exposure hazards list is to identify chemicals in the facility and disposition them for further analysis. There are several categories of material that may contain hazardous components; however, they are used in the form obtained from the manufacturer

Toxic and hazardous chemicals are not included in this item (see Section 4.3.16).

Table 4-12. Site Chemical Exposure Hazard Description

Hazard/ Energy Source	Description	Preventive & Mitigative Features	Remarks
General industrial chemicals	Lubricants, water treatment products, lab chemicals, refrigerants, paints, coolant (propylene glycol), and maintenance products stored in drums, buckets, bottles, cans, etc. (primarily manufacturers' packaging) located throughout the site.	- Procedures - Identification and warning labels - Ventilation - Packaging - HAZCOM Program - Chemical Management Program.	Standard industrial hazard. Materials with significant amounts of hazardous components are evaluated with the facility where they are found.
Paints, epoxies and thinners	The amount of hazardous material varies by manufacturers and the quantities required to reach a threshold quantity is large in comparison to the inventories present on the site.	- Procedures - Identification and warning labels - Ventilation - Packaging - HAZCOM Program - Chemical Management Program	Standard industrial hazard.
Chemicals in laboratory quantities	These chemicals are not specifically identified because the small quantities make further analysis unnecessary.	- Procedures - Identification and warning labels - Ventilation - Packaging - HAZCOM Program - Chemical Management Program.	Standard industrial hazard.
Mineral oil	Thousands of gallons of non-PCB oil used as dielectric fluid and coolant in transformers and oil breakers. Located primarily at substations.	- Not hazardous - Exposure limited - Packaging - HAZCOM Program	Standard industrial hazard.
Possible residual hydrofluoric acid	Possible residual hydrofluoric acid in piping, pumps, tanks in Bldg 714.	- Procedures - Warning signs - HAZCOM Program - Building 714 door locked and tagged out	Standard industrial hazard. Quantities of residuals less than RQs, TQs, or TPQs.
Non-hazardous or non-toxic chemicals	Could be present in large quantities	- Not hazardous	Standard industrial hazard.

4.3.16 Toxic and Hazardous Chemicals

This item identifies chemicals considered to be toxic or hazardous. A chemical is considered hazardous if it meets at least one of the following criteria:

- The chemical is Resource Conservation Recovery Act (RCRA) listed,
- The chemical has a reportable quantity (RQ) according to 40 CFR 302,
- The chemical has a threshold quantity (TQ) according to 29 CFR 1910 or 40 CFR 68,
- The chemical has a threshold planning quantity (TPQ) according to 40 CFR 355, or

- The chemical has an Emergency Preparedness Screen Threshold (EPST) (RFETS, 1995a).

Regulatory threshold quantities and RCRA designation are provided in Appendix D of the SARAH (RFETS, 1997). Chemicals with reportable quantities are included in the hazardous material category based on the concern associated with a release to the environment. EPST values represent the minimum quantity of a chemical that would result in a ground level centerline concentration (using stability Class D weather conditions) greater than or equal to the ERPG-2 value at a downwind distance of 100 meters as a result of an unmitigated spill or release. Chemicals identified with an EPST are those that warrant consideration in RFETS Emergency Preparedness Hazard Assessments (RFETS, 1995a).

Wastes with RCRA constituents are identified as RCRA controlled substances. These wastes can be present in satellite collection areas, 90-day storage areas, or RCRA permitted storage units. Actual quantities of the hazardous material may not be known; however, credit is taken for the controls placed on storage of these material by the RCRA permit. Inventories in satellite and 90-day areas are not considered in hazard identification and assessment due to the limited quantity which may be collected and the limited storage time. Material stored in these areas must meet the RCRA requirements in order to be transferred to a RCRA storage unit.

Table 4-13. Site Toxic and Hazardous Chemicals Hazard Description

Hazard/ Energy Source	Description	Preventive & Mitigative Features	Remarks
Asbestos (CAS # 1332-21-4)	Insulation and building materials used in various locations throughout the site.	- Plant policy for safe handling, 1-62200-HSP-9.09	Has the potential to exceed the 1-lb RQ. No TQ or TPQ.
Beryllium (CAS # 7440-41-7)	Beryllium contamination at various locations throughout the site.	- Plant policy for beryllium protection 1-15310-HSP-13.04	Has the potential to exceed the 10-lb RQ. No TQ or TPQ. RCRA controlled substance.
Creosote preservative (CAS # 8001-58-9)	Timbers used for utility poles and buss support structures throughout the site are impregnated with an estimated 120-lb creosote per pole.	- Retained in timber unless fire promotes release - Poles are separated - Replaced by non-creosote poles when necessary	Exceeds 40 CFR 302 1-pound RQ, no TQ or TPQ. RCRA listed substance.
PCB	Contamination in transformers and wastes	- Containers and packaging - TSCA program	All PCB transformers have been drained, however, residual contamination may be present. Waste drums containing PCBs may be stored until disposal is achieved.
Hazardous materials in equipment	Equipment such as barometers can contain hazardous materials, e.g., mercury.	- Integral with equipment - Workers not exposed during normal usage of equipment	Standard industrial hazard
Lead	Lead bricks are used as shielding and lead is found in some batteries.	- Integral with equipment - Non-dispersible form - Handling procedures	
Hazardous waste	Drums, crates, half-crates, etc., stored throughout site containing wastes with hazardous constituents identified by RCRA.	- Containers and packaging - RCRA program - Excess chemicals are packaged to prevent spillage and handling is minimized.	- Potential exists to exceed RQ levels of some chemicals; however, historically levels are extremely low. - See the RCRA Units safety analysis in Appendix I.

4.3.17 Inadequate Ventilation

Areas or rooms susceptible to low or inadequate ventilation where flammable gases, hazardous vapors, or asphyxiants may accumulate are noted. These areas usually have markings or alarms (for low oxygen or presence of the hazardous vapors). For asphyxiants, areas with the potential for less than 18 percent oxygen are noted. For flammables, areas where the lower flammability limit are noted. For general ventilation, areas with less than six air changes per hour are noted.

Table 4-14. Site Inadequate Ventilation Hazard Description

Hazard/ Energy Source	Description	Preventive & Mitigative Features	Remarks
Storage shed	Odor in lubricant storage shed, Bldg T707S indicates possible need for ventilation.	- Materials are combustible, not flammable - Building is not normally occupied	Standard industrial hazard.
Manholes, etc	See Section 4.3.4.		

4.3.18 Material Handling

This category is intended to highlight handling operations that involve continuous handling of materials. Activities that involve routine handling are identified to allow an assessment of the frequency that accidents involving hazardous materials could occur. For environmental restoration projects, this item identifies the handling operations associated with remediation as identified in the work plans.

4.3.19 Ambient Temperature Extremes

This item includes rooms or areas with temperatures that exceed 90°F. Such conditions may lead to improper chemical storage or may lead to degradation of human responses to abnormal conditions. Outdoor activities and activities in unheated or non-cooled facilities can fall into this category.

4.3.20 Working at Heights

This hazard represents a human life safety threat as well as a particular type of mass, gravity, or height hazard (see Section 4.3.12). This hazard applies to routine working at heights as indicated by the presence of fixed ladders or stairs and equipment used to access heights such as hysters, high lifts, scissor jack scaffolds, "cherry-pickers," etc.

Table 4-15. Site Working at Heights Hazard Description

Hazard/ Energy Source	Description	Preventive & Mitigative Features	Remarks
Elevated tank	Elevated water tank 155-ft in height with ladders and walks. Tank 215A, north of Building 124.	- Steel shell, six tubular steel cross-braced legs - Cages and railings, access controls, training and procedures, approved work plans - Access currently prohibited because railing does not meet all Occupational Safety and Health Administration (OSHA) requirements	Standard industrial hazard. Tank was not seismically designed, 100-mph wind.
Maintenance and construction	Can involve elevated work on distribution lines electrical lines, antennas and support structures located throughout the site.	- Training and procedures, approved work plans, safety equipment. - Qualified service personnel, safety equipment, procedures, work control program.	Standard industrial hazard.

4.3.21 Pesticide Use

Pesticides are an environmental hazard and could be a significant hazard for the environmental projects and other work performed in the buffer zone. Pesticides are considered to be a standard industrial hazard.

4.3.22 Lasers

Lasers are a specific type of non-ionizing radiation (see Section 4.3.13). All lasers are identified, including commercially available Class I and Class II lasers per American National Standards Institute (ANSI) Z136.1. Class II and Class IV lasers (or custom lasers) are assessed in detail with respect to beam enclosures and interlocks used as controls.

4.3.23 Inadequate Illumination

Areas where human response to abnormal conditions could be degraded by inadequate illumination or where abnormal events could be initiated by improper human actions caused by poor illumination are noted.

4.3.24 Biohazards

Biohazards include pollens, viruses, bacteria, algae, or other organic material that could degrade the "healthy building" aspects of a facility or area. Biohazards are usually marked with the distinctive biohazard symbol. Blood and blood products, and bodily fluids (such as bioanalysis samples) are considered biohazards.

Table 4-16. Site Biohazards Hazard Description

Hazard/ Energy Source	Description	Preventive & Mitigative Features	Remarks
Medical wastes	Various medical samples in Bldg 122.	- Procedures - Training - Disinfectants	Typical medical hazard.
Sewage	Sanitary sewage may contain parasites and pathogens. In pipes and manholes located throughout plant.	- Isolated from human contact - Treated before being released to environment	Standard industrial hazard.

4.3.25 Unmarked Materials

Chemicals and other materials in unmarked containers fall into this category. These items are identified in the individual hazard assessments.

4.3.26 Other Hazards

This item includes other hazards or concerns that do not fit in a specific hazard category. This category includes areas with high combustible loads, areas with contamination, or areas particularly susceptible to natural phenomenon (including local flooding) events. The information pertaining to other hazards are identified in the individual hazard assessments.

4.4 FACILITY SUMMARIES

Facilities at RFETS are classified as nuclear hazard Category 2, and 3, non-nuclear moderate and low hazard, radiological, and industrial facilities. Since various RFETS facilities are in different stages of decontamination, deactivation, decommissioning, and demolishment, hazard classifications may change over a short period of time. The facility classifications summarized below represent the most current information at the time of the current revision of the Site SAR. As hazards in facilities change or facilities are remediated, the classification changes. Table EX-3 provides a history of facilities classification changes since the initial issue of the Site SAR.

The facilities summarized below are documented in detail in facility specific authorization basis documents, with the exception of industrial facilities, which has one authorization basis document for all facilities. All nuclear hazard Category 2 facilities and one nuclear hazard

Category 3 facility (the 904 Pad) have stand alone FSAR, BIO or BFO documents. The following sections provide summaries from facilities authorization bases documents. Information on the latest revision of the safety analysis document and other authorization basis documents can be found on the Authorization Basis Document List (ABDL) available on the Site Intranet. These documents will not be referenced here.

4.4.1 Nuclear Hazard Category 2 Facilities

RFETS has several nuclear hazard Category 2 facilities which have stand-alone authorization basis documents. This hazard category is determined using the criteria and radionuclide inventory thresholds in DOE-STD-1027-92 (DOE, 1992b). The nuclear hazard Category 2 facilities at RFETS have a MAR greater than 450 grams ^{239}Pu, if there is a potential for a criticality, or over 900 grams of ^{239}Pu, if a criticality is not a concern. Other isotopes are present in site facilities as well, but ^{239}Pu is the dominant isotope in a majority of the facilities. An activity overview and hazard summary is presented below for each nuclear hazard Category 2 facility.

<u>Building 371/374</u>

Buildings 371/374 are one large structure for plutonium recovery and waste treatment and support functions such as maintenance, utilities, and chemical preparation. The building is a reinforced concrete structure with four levels. Major operational areas of the building include special nuclear material (SNM) storage, residue storage, waste storage, thermal stabilization and repackaging of SNM, caustic waste treatment, liquid waste treatment, laboratories, shipping and receiving, and utilities. Significant hazards associated with Building 371/374 operations are spread of radioactive contamination; dispersion of radioactive aerosols, noxious fumes, and vapors; fires; and inadvertent nuclear criticalities. Fire scenarios, particularly those which can not credit the HEPA filters, and any scenarios occurring on the receiving docks bound the risk for this facility due to the significant consequences for unfiltered releases.

<u>Building 440</u>

Building 440, located outside the Protected Area (PA), is a low-level (LLW) and transuranic (TRU) waste storage, staging, and repackaging facility. Building 440 is constructed of metal sandwich-type panels for exterior walls with concrete masonry and gypsum board interior walls. Only the waste repackaging area has a ventilation system with filtration. Releases occurring elsewhere in the building would be considered unmitigated. The most significant accident scenario (i.e., the accident with the highest consequences to workers and public) is an aircraft crash followed by a fire.

Building 559

Building 559 is the Plutonium Analytical Laboratory and is located within the PA. Building 559 is a poured in-place reinforced concrete column structure with non-load bearing reinforced and non-reinforced concrete block walls. The laboratory facilities perform analytical analyses of samples received from on-site activities. The total fissile material inventory is limited to 7 kilograms and the facility is classified as nuclear hazard Category 2. A solution criticality is considered credible in Building 559; however, the operations at RFETS have changed in such a way that the frequency of having enough material in an area for criticality to be a likely concern has been reduced. Fires are considered the most likely accident scenario, followed closely by spills. Explosions would have a higher consequence; however, they are less frequent.

Building 569

Building 569, located in the PA, stores and assays containers of waste, including filled waste crates and transuranic, transuranic-mixed, low level, low level mixed, residue and residue-mixed waste drums. The non-destructive waste assay uses a passive-active crate or drum counter, a low specific activity counter, and/or a real-time radiography unit. Containers, received from throughout the site for assay, are staged/stored in the building, a RCRA permitted storage unit. Following assay, the containers are stored in the building or sent to other facilities. No processing of fissile materials or opening of containers is allowed in the building. It is anticipated that Building 569 will continue as a waste assay and storage facility throughout the environmental restoration phases for all buildings at the site. Building 569 is classified as a nuclear hazard Category 2 facility based on the anticipated inventory of radionuclides.

The risk dominant accident scenario to the public is a hydrogen explosion in a 55-gallon drum. The frequency of this event has been reduced to extremely unlikely by implementing a program to assure drums received in the building have undamaged drum lid vents and that the vents are not plugged. The consequence to the public in the event of a hydrogen explosion is moderate if the drum involved is a residue drum with maximum loading (1,100 gram plutonium equivalent). The consequences can be reduced by controlling the quantity of material at risk in the drum. The risk dominant accident scenario to RFETS workers is a small fire inside the building involving three TRU/TRM waste drums. Other risk dominant accident scenarios identified for Building 569 are a large lofted fire inside the building and an earthquake caused spill.

Building 664

The mission of Building 664 consists of interim storage, real time radiography, non-destructive assay, shipping/receiving, staging and loading pre-package waste containers for off-site shipment. It is a pre-engineered metal building located outside the PA. Waste is stored in DOT-approved shipping containers, drums and crates, and the waste package meets shipping requirements prior to being stored in Building 664. Building 664 may contain TRU, TRU-mixed, low-level and low-level mixed waste. Recently, the storage of POCs was approved for Building 664.

The safety analysis for Building 664 takes no credit for mitigating systems. The dominant accident scenarios are a drum fire, SAND box puncture, and an earthquake spill. These three scenarios exceed the dose threshold for the collocated worker. However, it was concluded that the risk is acceptable based on several conservatisms assumed in the analysis. An aircraft crash is the only accident scenario with the potential to impact POCs. Based upon the amount of material at risk from POCs that could be released in the most severe accidents, potential consequences are considered "moderate."

Building 707

Building 707 is a former plutonium manufacturing facility. Some of the activities being performed or planned include salt stabilization, classified shapes and dry combustible repackaging, ash stabilization, and oxide stabilization. Building 707 is a two story concrete building with a single story section on the east side. The first floor is divided into eight compartments referred to as modules. The modules are designed to inhibit the spread of radioactive contamination or fire. Two of the modules, J and K, are in an area of the building that has been seismically hardened. Modules A, D, E, F, and J have activities on-going or planned. The other modules are idle or are going through the decontamination and decommissioning process. Events involving fires result in the most significant consequences.

750 Pad

The 750 Pad is a paved pad on which multiple tent structures have been constructed for weather protection. The 750 Pad is located within the PA fence and is used for storage of low-level and low-level mixed waste, hazardous chemical waste forms and for specific operations performed in *Perma-Con* enclosures. In addition, TRU and TRU-mixed waste is stored inside pipe overpack containers (POCs) in Tents 2 and 12. The only TRU and TRU-M wastes that current packaged in POCs are residues and residue-derived wastes. The storage of POCs increases the anticipated inventory of radionuclides, resulting in a hazard classification of Category 2 nuclear facility.

The amount of material at risk from POCs that could be released in the most severe accidents do not yield a consequence higher than "moderate." The largest postulated release of LLW/LLMW results from an earthquake with a subsequent propane fire. For TRU/TRU-M, the largest release is from an aircraft crash with a subsequent fuel pool fire involving POCs.

Building 771

Building 771 is a former plutonium processing facility. Building 771 is a two-story building with multiple one-story additions located within the PA. Activities presently performed or planned in Building 771 are focused on waste management, special nuclear material management, and decontamination and decommissioning. The risk reduction efforts in Building 771 have significantly reduced the amount of radiological materials in the facility. For example, all the tanks containing radioactive liquids have been drained and the liquid has been transferred or process appropriately. An earthquake causing a criticality constitute the major risks for Building 771.

Building 774

Building 774 is a liquid waste treatment facility with the current mission of treating low-level and some TRU wastes on a small scale or limited throughput basis. Building 774 is a multi-story building located within the PA. The building is constructed primarily of reinforced concrete and has concrete block and metal panels-on-steel framing. Three processes are either currently in operation or are planned for operation: first-stage carrier precipitation, second-stage carrier precipitation, and miscellaneous aqueous waste handling and solidification. A large room fire in Room 210 is the bounding accident for Building 774.

Building 776/777

Activities presently performed in Building 776/777 are related to waste management, stabilization, or decontamination. Building 776/777 has exterior walls of structural steel covered with transite and interior walls of concrete block or steel with transite. The original structure has been modified several times and there are some poured concrete vaults. Building 776/777 is located within the PA and has been used for special production and research functions. The risk dominant accident scenarios include natural phenomena (i.e., earthquake, heavy snow), external events (aircraft crash), and various fire scenarios. The risk associated with these accident scenarios could not be reduced to a Risk Class III or IV.

Building 886 Complex

The Building 886 Complex has been decontaminated and decommissioned (2002) and no longer exists.

CHG-15

Building 906

Building 906 is a pre-engineered metal building located outside the PA which stores low-level and low-level mixed waste. Waste in Building 906 can be stored in plywood crates or drums. Anticipated events included spills, punctures, and drops related to material handling. The most significant consequences are associated with a fire especially if the building contains a large number of crates.

Building 991

Building 991 is a partially buried, one-story structure with a partial basement that is connected by tunnels to underground Vaults 996, 997, and 999, and Room 300. The building originally housed the Product Warehousing operations and the Final Quality Acceptance and Certification offices. The current mission of Building 991 and its associated underground tunnels and vaults includes the warehousing functions of receiving, staging, storing, and shipping Special Nuclear Materials, and transuranic and low-level wastes. The facility also contains metallography laboratories, a non-destructive testing department, and operations involving the maintenance and repair of site-wide alarm systems.

Of the twelve scenarios analyzed, seven initially resulted in a Risk Class I or II to either the public or workers. These included fires, spills, punctures, explosions, and natural phenomena (earthquake). Of the accident scenarios evaluated, none resulted in a public dose exceeding 5 rem. The highest collocated worker dose was 390 rem for an *extremely unlikely* Type B shipping container puncture event. Following an explanation of the analysis conservatism, the risk class for these scenarios could be lowered to Risk Class III or IV.

4.4.2 Nuclear Hazard Category 3 Facilities

CHG-18

Nuclear hazard Category 3 facilities have stand-alone authorization basis documents or are included in Volume I of the Site SAR. The authorization bases for Building 881, and the RCRA Units are provided in the Site SAR, Volume I. There is an approved FSAR for the 904 Pad that is included with the 750 Pad FSAR. Using the criteria contained in DOE-STD-1027-92, a nuclear hazard Category 3 facility contains more than 8.4 grams but less than 900 grams of ^{239}Pu. The nuclear hazard Category 3 facilities are discussed below with an activity overview and hazard summary.

Building 666

CHG-18

Building 666 was used to store Toxic Substance Control Act (TSCA) waste prior to ultimate disposal. TSCA wastes at RFETS has contained asbestos and/or PCBs and could be straight TSCA wastes, wastes contaminated with TSCA materials, or TSCA wastes contaminated with radionuclides. The facility received, stored, handled, inspected, and shipped these wastes prior to its demolition in 2002.

Building 881

Building 881 is a multi-purpose building with a significant amount of active laboratory work. Building 881 is a two-story and basement concrete with steel frame building built into a hillside and is mostly below grade. The building housed about 40 organizations with functions ranging from administrative support to laboratory services and development support. Building 881 is a nuclear hazard Category 3 facility due to the potential amount of material releasable from the waste stored in the building and the estimated amount of plutonium holdup in the ventilation system and an abandoned scrubber. The most significant event for this building from a consequence stand point is an earthquake or other scenario involving breaching the ventilation system since that is the location of the most radioactive material. For additional information, refer to Appendix H in Volume I of this Site SAR.

904 Pad

The 904 Pad is paved pad on which multiple tent structures have been constructed for weather protection. The 904 Pad, along with Tent 7 on the 902 Pad, are also known as RCRA Unit 15B and are located outside the PA. The pads are used for storage of low-level and low-level mixed waste, hazardous chemical waste forms and for specific operations performed in *Perma-Con* enclosures. The 904 Pad and 902 Pad are considered hazard Category 3 nuclear facilities. The largest postulated release of LLW/LLMW results from an earthquake with a subsequent propane fire.

Resource Conservation and Recovery Act (RCRA) Storage Units

There are several RCRA Storage Units permitted for storage and management of low-level, low-level mixed and hazardous waste. The units covered by Appendix I in Volume I of this Site SAR are Units 1, 10, 13, 15A, 18.03, 18.04, and 24. These areas store containerized waste in cargo containers or buildings. All the units included in the RCRA Storage Unit safety evaluation are permitted for low-level and/or low-level mixed waste, and if full to its permitted capacity with maximally loaded low-level waste containers, the inventories exceed the nuclear hazard Category 3 threshold. The accident of concern is an aircraft crash with subsequent fire.

4.4.3 Radiological Facilities

The authorization basis for radiological facilities is provided by the Site SAR. A FSA is included in Volume II for each radiological facility. A radiological facility has a MAR more than the 40 CFR 302 threshold of 0.01 Ci for ^{239}Pu and 0.1 Ci for depleted uranium (assumed to be ^{238}U), but less than the DOE-STD-1027-92 threshold of 0.52 Ci (8.4 grams) of ^{239}Pu or 4.2 Ci (13 metric tonnes) of depleted uranium. These facilities have the potential to cause minor on-site and negligible off-site impacts.

Building 126

Building 126 is a one-story concrete slab-on-grade building which stores sealed sources. Many of the sources are no longer in use and are stored in pits or wells that provide shielding for direct radiation from the sources. Certified sealed sources may be excluded from the facility inventory (DOE, 1992b); however, the sources in Building 126 can not be excluded due to lack of or expiration of certification. Therefore, the facility is classified as radiological.

Building 444 Complex

The current mission of the Building 444 Complex (Buildings 444, 445, 447, 448, and associated support buildings) is storage for scrap and components made of depleted uranium and beryllium, graphite stock and molds, and management of low-level radioactive, hazardous, and polychlorinated biphenyl (PCB)-contaminated wastes. Due to the non-dispersible form of the depleted uranium, the facility is classified as radiological.

Building 790

Building 790 is a one-story concrete structure located in the PA. The facility is specifically designed for radiometric calibration and characterization of the thermoluminescent and radiation detection devices used at RFETS. The building consists of three irradiation cells, instrument calibration support area, control room, and office area.

To accomplish the calibrations, the facility stores and uses radionuclides in both normal and special form sealed sources. Due to the form and radiation levels of the radioactive material in the building, this facility is classified as radiological. The most significant potential consequence in this facility is direct radiation and the radioactive material content of sources not qualifying for exclusion from the facility inventory.

Building T886D

CHG-15

Building T886D is a Modular Analytical Laboratory located west of the 904 pad. The laboratory is operated by Thermo NUtech and will perform laboratory analyses previously performed in Buildings 123 and 881. Operation of the modular laboratory allows the operations of the laboratories in Buildings 123 and 881 to be terminated in support of facility decommissioning. The laboratory will perform radiological analysis of various sample matrices. Activities include the receipt, preparation, analysis, and disposal of the samples. Radiological and chemical hazards are present in the facility. The Modular Analytical Laboratory is classified as a radiological facility based on the controlled quantities of potentially releasable radiation. The operations in Building T886D are evaluated in the *Safety Analysis for Modular Laboratory, Building 886D* (RMRS, 1997).

Buildings 903A/B, 966

The Decontamination Facilities consist of Buildings 903A/B and 966. These facilities are used to decontaminate equipment which has been used in environmental remediation work. Since the areas where this equipment has been used potentially contain radionuclides, the potential exists for these facilities to have radioactively contaminated materials. Therefore, the Decontamination Facilities are conservatively classified as radiological. Screening for radionuclides which has been performed over a two year period has not yet identified significant levels of radioactivity.

Building 231, Tanks 231 A and B (Process Waste Transfer System)

Process Waste Transfer System is classified as radiological based the quantity of radioactive material that may be present and on the lack of dispersibility of radioactive material potentially contained within the system. This system is designated as RCRA Unit 40 and is comprised of underground lines, valve vaults, pumphouses, tanks, tanker trucks, and portable tanks.

903 Pad, Environmental Restoration Projects

Environmental Restoration (ER) projects were evaluated for their *static* condition, only. An ER project is in a *static* condition when all activities currently being performed are considered non-intrusive so no potential exists for dispersing the contaminants. Any intrusive activities performed to accomplish remediation are analyzed on a case-by-case basis prior to performing the activities. These analyses may be hazard assessments, auditable safety analyses, or safety analysis reports depending upon the specific ER site. Any specific controls required for an intrusive activity are developed based upon the case-by-case analysis. All work performed at environmental sites must be accomplished under the auspices of applicable regulations such as RCRA and CERCLA. Also, health and safety plans must be developed and approved prior to performance of any work.

Environmental Restoration (ER) projects in their *static* condition were evaluated generically by discussing the top 20 ER projects as originally documented in the Rocky Flats Cleanup Agreement. Hazard classification for each ER project, in accordance with DOE-EM-STD-5502-94, was not performed. The top 20 provide a good representative sample of the wide variety of entities requiring environmental remediation at RFETS. Also, a generic evaluation focused on the top 20 provides an adequate authorization basis for other currently identified RFETS ER sites while in their *static* state because sites not in the top 20 are expected to contain contaminants considered less hazardous than the top 20 ER sites.

In addition, to addressing ER projects generically, the hazard classification for the 903 Pad and Lip Area, Operable Unit 2, was addressed because it had been preliminarily classified as a nuclear Hazard Category 3 facility based solely on projected amounts of radioactive materials in the area. However, when an ER site is in its static condition, there is minimal potential to release contamination in a large enough amount to impact the collocated worker or public. Soil contamination, whether under an asphalt cap or not, is considered unreleasable from an accident consequence perspective when no initiators or energy sources are available. In other words, it is inconceivable that a release from the 903 Pad could occur in an amount approaching the nuclear Hazard Category 3 thresholds. Therefore, based on identifying a lack of initiators and energy sources for a release of radioactive materials during *static* condition, the 903 Pad area is classified as a radiological facility in accordance with DOE-EM-STD-5502-94.

4.4.4 Non-nuclear Moderate Hazard Facilities

The facilities on-site which have been classified as non-nuclear moderate hazard have no radioactive materials, have only sealed sources, or have radioactive materials below the 40 CFR 302 thresholds. The hazards presented by these facilities are related to chemicals handled in the facility and the quantity stored is over the TPQ or TQ listed in 40 CFR 355, 29 CFR 1910, or 40 CFR 68. The potential consequences from a release are toxicological in nature, and have the potential of having major on-site impacts on people or the environment, but only minor off-site impacts. Toxicological impacts are calculated using ALOHA software (Reynolds, 1992) and comparing the results to the appropriate ERPG value.

<u>P750 and P904 (Fuel Gas System)</u>

The Fuel Gas System includes the natural gas distribution system, the Public Service of Colorado and KN Energy natural gas transmission pipelines, the natural gas meter and pressure-reducing station, two propane tank farms (P750 and P904) and the out-of-service propane mixing facility. This system has been classified as moderate hazard based on the potential consequences to the public from releases of propane.

4.4.5 Non-nuclear Low Hazard Facilities

Facilities at the site with hazardous material inventories greater than the RQs contained in 40 CFR 302 were evaluated to determine the consequences of material releases. Facilities with minor on-site and negligible off-site impacts on people and the environment are classified as non-nuclear low hazard. Toxicological consequences from releases at these facilities are limited to the immediate worker with minor environmental impacts. Environmental releases in quantities greater than the RQ are reportable under Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The Site SAR, including the individual FSAs in Volume II, documents the authorization basis for low hazard facilities.

<u>Building 125</u>

Building 125 is a one-story pre-engineered steel-framed building with a 6-inch slab-on-grade foundation. The building has an inventory of mercury that has the potential to result in minor on-site consequences. However, the inventory is over the RQ contained in 40 CFR 302 which means there are may be environmental concerns and reporting requirements associated with an outdoor spill.

Buildings 129 and 928 (Domestic Cold Water System)

The Domestic Cold Water System is comprised of Buildings 124, 129, 206, 216, 928, 215A, 215B, and 215C. All the buildings are industrial facilities with the exception of Buildings 129 and 928, which are classified as low due to the quantity of 65% calcium hypochlorite in tablet form.

Building 443 (Steam and Condensate System)

The Steam and Condensate System consists of Buildings 443, 211, 240, and 710. All the facilities are classified as industrial with the exception of Building 443. Building 443 contains sulfuric acid, sodium hydroxide, mercury and cyclohexylamine which were evaluated in the hazard assessment. Building 443 is a low hazard facility based on the potential consequences of a release of these hazardous materials. The remainder of the facilities are classified as industrial.

Building 891, T900A/B

Building 891 along with T900A, T900B, and several water storage, chemical storage, and process tanks comprises the Consolidated Waste Treatment Facility. The processes performed in the facility use various chemicals including hydrochloric and sulfuric acid and hydrogen peroxide. The amounts of hydrochloric and sulfuric acid are in excess of the RQ from 40 CFR 302 and the amount of hydrogen peroxide exceeds the designated TPQ. No significant dispersion would occur in a spill involving the sulfuric acid solutions because of the high boiling point and low vapor pressure. Therefore, the facility is classified as non-nuclear low hazard because such a release would present only minor onsite and negligible offsite impacts.

4.4.6 Industrial Facilities

The industrial facilities are those facilities on-site which provide general site support. Also, included are former production facilities when hazardous materials have been removed in preparation for decontamination and decommissioning. The activities performed in these facilities covers a wide range including administrative buildings, storage areas, carpentry and maintenance shops. Not all facilities designated as industrial are buildings. The industrial facility classification was also assigned to other site structures and components such as tanks, towers, roads, and electrical substations. The characteristic which all these facilities have in common is they contain no radiological or non-radiological hazardous materials over 40 CFR 302 RQs. Administrative controls of the Chemical Management and Radiological Control Programs are invoked to maintain the facility classification.

4.5 FACILITY INTERACTIONS

The intent of this section is to identify on a sitewide basis potential physical interactions between facilities, such that an event in one facility results in a release of hazardous materials from another facility. The events of interest focus on fires and explosions because these may contain enough energy to breach a confinement in a neighboring facility resulting in a release of hazardous materials, radiological and/or non-radiological. The originating facilities for fires and explosions are natural gas lines and propane tanks. Other impacts to RFETS facilities, such as (a) damage without the release of hazardous materials or (b) suspended operations, are not considered. Consideration of the consequences associated with facility interaction provides a comprehensive evaluation of the sitewide safety envelope, which is based upon accidental exposures to hazardous materials impacting the site workers, public, and environment.

4.5.1 Introduction

As discussed in Chapters 2 and 3, RFETS consists of approximately 470 identified and numbered facilities located in the center 2,520 acres of a 6,550-acre parcel of land. These facilities include (a) major buildings for stabilization operations, radioactive waste management, closure operations, sitewide utility systems, and sitewide administrative support, (b) appurtenances to major buildings, (c) support buildings for utility equipment, (d) trailers, typically used as office space, (e) structures such as stacks and cooling towers, (f) above- and below-ground storage tanks, (g) distribution piping and ducting, and (h) storage sheds, tents, pads, and areas. With respect to the hazardous materials existing on the site, facilities provide protection from the elements, management control, primary confinement, and/or secondary confinement. Typically, these facilities passively co-exist and provide safe conditions for RFETS workers. However, potential facility accidents may impact neighboring facilities because of the compactness of the site and close proximity of two or more facilities.

The purpose of identifying facility interactions is to ensure a comprehensive evaluation of the sitewide safety envelope, which is based upon accidental exposures to hazardous materials impacting the RFETS workers, public, and environment. The safety envelope does not account for standard industrial accidents and economic impacts, such as fire, lost operations, and destruction of a facility, not involving the release of hazardous materials. These impacts are considered typical in all industries and are not considered in the overall site safety envelope. The facility interaction evaluation concludes that only fires and explosions have the potential to physically breach confinements associated with neighboring facilities.

4.5.2 Accident Screening

The spectrum of safety analysis accidents encompasses three major accident classifications: natural phenomena, external events, and operational accidents. Natural phenomena are considered "Acts of God" and external events refer to accidents initiated off site. Operational accidents occur within the site boundary and thus are the focus of facility interactions. Operational accidents comprise four accident types: spills, fires, explosions, nuclear criticality (RFETS, 1997).

Indirect impact on a facility relates to the inability of facility personnel to maintain control of the confinement of hazardous materials. This may result if an accident in a neighboring facility (a) incapacitates personnel or (b) requires sheltering or evacuation. A release of any significant amount of hazardous material from a facility at RFETS has the potential to indirectly impact neighboring facilities depending upon several factors, such as amount and location of the release and the wind direction. Indirect impacts on facilities are evaluated in authorization basis documents using the representative consequences associated with the collocated worker and the maximum off-site individual (MOI). Therefore, indirect impacts are not considered in determining "interactions of interest."

Direct impact physically compromises a facility's hazardous materials confinement capabilities. Physical compromise requires an accident to have enough energy to breach building confinements and/or primary confinements, such as tanks, pipes, ducting, bottles, drums, and waste boxes. Therefore, operational accidents (i. e., spills, fires, explosions, and nuclear criticalities) are evaluated to determine if they could physically compromise neighboring facilities.

Spills

Spills of hazardous materials do not have sufficient energy to directly impact neighboring facilities. However, spread of a spill may indirectly impact a neighboring facility if facilities are connected or the spill involves a significant quantity of hazardous materials. Spills of hazardous materials are not considered "interactions of interest" because, typically, a spill in one facility does not have the energy to directly cause an accident (spill, fire, explosion, or nuclear criticality) in a neighboring facility.

Fire

Many potential fire initiators exists at RFETS. Fire has the potential to breach some of the confinements of neighboring facilities because it can propagate if fuel or sufficient combustibles are available. Therefore, fires are considered "interactions of interest."

Explosion

At RFETS, explosions with the potential to affect neighboring facilities are limited to explosions of propane and natural gas. Overpressurization may occur with other hazardous materials; however, the energy associated with such overpressurization is not sufficient to breach the facility in which it occurs and thus would not breach a neighboring facility. Explosion impact on neighboring facilities depends upon the magnitude of the explosion and the distance between neighboring facilities and the explosion source. Also, an explosion may generate missiles that may directly impact a neighboring facility. Therefore, explosions are considered an "interaction of interest."

Nuclear Criticality

Nuclear criticalities are very energetic; however, most of the energy is in the form of thermal energy that heats objects and/or substances surrounding the occurrence. The thermal energy may boil water or melt metal. Only a small portion of the total energy released during a nuclear criticality has the potential to breach structural components such as a building wall. Penetrating radiation (neutrons and gamma rays) released during a criticality is not expected to affect structural components of adjacent facilities. Nuclear criticality occurrences require specific quantities and configurations of fissile materials. Based upon the operations at RFETS, fissile materials, which have the potential to be involved in a criticality, are located inside major buildings in vessels, bottles, and/or vaults except during transfer to another major building. Thus, if an inadvertent nuclear criticality event occurs structural damage to a neighboring facility is not expected.

4.5.3 Hazards Assessment

Section 4.3 presents a hazards identification for the site based upon a checklist of 26 typical hazards found in the nuclear industry as well as other industries. Many of the hazards on the checklist are routine occupational hazards that only impact the immediate worker and can not initiate any "interactions of interest." Therefore, examination of these routine occupational hazards is not required for the facility interaction evaluation. As identified in Section 4.5.2, hazards important in the facility interaction evaluation are the ones with the potential to initiate fires and/or explosions.

4.5.3.1 Fires

Hazards existing at RFETS facilities that have the potential to initiate fires generally fall into one of the following categories.

- Radioactive Materials (pyrophoric reactions)
- Electrical Hazards
- Flammable Substances
- High-Pressure and High-Temperature Systems
- Toxic and Hazardous Chemicals (exothermic reactions)

Several factors are required for a fire initiated in one facility to propagate to neighboring facilities and to reach sufficient magnitude to breach confinements of neighboring facilities. Propagation requires factors such as the availability of a sufficient amount of combustibles between site facilities or an extremely short distance between site facilities that would support flame jumping associated with low combustible load fires. Factors that assist in preventing propagation include, but are not limited to, (a) on-site terrain has a relatively low combustible loading, (b) existence of fire breaks, such as parking lots, roadways and walkways between facilities, (c) availability of fire suppression capability in the originating facility, and/or (d) response by the RFETS Fire Department. For a fire to reach a sufficient magnitude to breach a neighboring facility depends upon the (a) construction of the originating and neighboring facilities and (b) availability of a significant amount of combustibles between the two facilities. For example, a fire occurring in a major building with two-hour fire walls would have to reach a magnitude to burn through these walls and then spread to a neighboring facility. If the neighboring facility also had two-hour fire walls, the fire magnitude would have to be maintained until these walls were breached.

Evaluating these factors for the various types of site facilities and on-site terrain, several conclusions may be derived that eliminate the need to analyze fire interactions for most site facilities.

- Parking lots, roadways, and walkways are quite efficient fire breaks and reduce the potential for fire propagation. Therefore, a fire interaction between site facilities separated by parking lots, roadways, and walkways is highly unlikely, given a fire has occurred in a facility.

- Vegetation within the industrial area provides very little combustible loading for fire propagation. A fire interaction occurring between site facilities separated by large open spaces is unlikely, given a fire has occurred in a facility.

- For fires occurring inside facilities that provide additional confinement capabilities for hazardous materials, automatic fire suppression and/or the quick response time of the RFETS Fire Department provides a highly reliable fire suppression capability to control fires prior to propagation from the final confinement of the originating facility.

- Fire-rated outer walls of buildings provide extremely reliable protection for the hazardous materials in the building. Propagation of a fire out of or into a facility through fire walls is highly unlikely, given a fire has occurred in a facility.

Fire interactions between facilities that fit into one or more of the above descriptions are extremely unlikely. Two types of facilities exist at RFETS between which fire interactions are significant: (1) interconnected facilities with either or both containing hazardous materials and (2) facilities providing no additional confinement capability for their hazardous materials. Interconnected facilities are facilities that are connected by such entities as tunnels and ducting (typically ventilation) and/or have a common wall or barrier(s). Fires occurring in a facility with an interconnected neighboring facility have the potential to impact the interconnected neighboring facility.

Facilities that provide no additional confinement capability for the hazardous materials include (a) piping, ducting, and tanks containing hazardous materials and (b) building docks and storage sheds, tents, pads, and areas containing primary confinements such as drums and/or wooden crates. These facilities function as either (a) primary confinement or (b) protection from the elements and/or management control of primary confinements. Piping, ducting, and tanks provide primary confinement for hazardous materials. For facilities, such as storage sheds, tents, pads, or areas, the function is protection from the elements and/or management control of primary confinements (e. g., drums and crates) and the facility does not provide any additional confinement for the hazardous materials. Therefore, to release hazardous materials from these facilities a fire only needs to breach one confinement (i. e., drum and/or crate). These types of facilities generally are not equipped with automatic fire suppression and the required magnitude of a fire is not as great as what is needed to breach a major building. Therefore, fires occurring in facilities located close to facilities that provide no additional confinement capability could potentially impact the hazardous materials. The extent of the impact depends on the combustible loading availability to propagate the fire, Fire Department response, and potential fire breaks.

4.5.3.2 Explosions

At RFETS, only two hazardous materials are recognized as able to initiate explosions with a magnitude that could breach confinements of neighboring facilities: natural gas and propane. Therefore, the site natural gas distribution lines and propane tanks are considered the originating facilities for the potential explosion interactions. Distribution lines for natural gas and propane located inside facilities are analyzed as an integral part of the facility. These two systems are also described in Chapter 3 with the associated hazard assessment in Appendix D of Volume I of this Site SAR.

The evaluated explosion interactions are either related to peak overpressure or impulse (pressure duration function) impinging upon the surfaces of neighboring facilities. The amount of overpressure or impulse needed to structurally damage a facility is dependent upon the construction of the facility (e. g., a significant amount of overpressure is required to breach a concrete wall and very little is needed to breach a corrugated metal facility). The overpressure from an explosion is greatest at the originating point and diminishes as it dissipates in the surrounding vicinity. An overpressure of 1.0 psi is typically used as a threshold level for evaluating a facility's capability to maintain its integrity in the event of an explosion. Above 1.0 psi the following are expected: (a) partial demolition of houses to the point of uninhabitableness; (b) failure and buckling of corrugated metal panels; (c) blown in housing wood panels; and (d) slight to serious skin lacerations from flying glass and other missiles (RFETS, 1997). Using a 1.0 psi overpressure to evaluate facility interactions at RFETS is extremely conservative for the major buildings constructed of reinforced concrete; however, it is realistic for metal buildings, ducting and piping, and confinements, such as drums and crates.

Potential Site Explosion Scenarios

Four fundamentally different release/explosion scenarios associated with propane or natural gas were identified as being possible at the site (RFETS, 1998).

1. Propane Vapor Cloud Explosion (Deflagration): In this scenario, propane spills from a catastrophic rupture in the side of a storage tank. The propane forms a homogeneous stoichiometric cloud among nearby objects such as vehicles, storage drums, or waste crates. The cloud is ignited causing a vapor cloud explosion (VCE). The surrounding objects obstruct the flame travel causing significant overpressures in the vicinity.

2. Propane Vapor Jet Explosion (Detonation): In this scenario, propane is released in a turbulent jet from a stuck-open relief valve. A plume forms outside the propane tank and is ignited.

3. Natural Gas Vapor Jet Explosion: In this scenario, a natural gas distribution line attached to the outer wall of a building breaks releasing natural gas in a turbulent jet. A plume forms along the building and is ignited.

4. Boiling Liquid, Expanding Vapor Explosion (BLEVE): In this scenario, a flame impinges on a propane storage tank, heats the contents, and weakens the steel tank wall until it fails.

Vapor Cloud Explosions

VCEs result from a release of flammable material in the atmosphere, a subsequent dispersion phase, and, after some delay, an ignition of the vapor cloud, followed by a high-speed propagating flame generating the blast. The occurrence of a VCE with damaging overpressure is a function of obstructions in the area of the storage tank, e.g., crates in the vicinity of a propane tank will contribute to an overpressure that could impact material or facilities in the area. The required flame acceleration is only possible under the following three conditions (AIChE, 1994). These conditions could exist at the site so the location of each propane tank is evaluated.

- The presence of outdoor obstacles, for example, congestion due to pipe racks, weather canopies, tanks, process columns, and multilevel process structures.

- A high-momentum release causing turbulence, for example, an explosively dispersed cloud or jet release.

- Combinations of high-momentum releases and congestion.

Boiling Liquid, Expanding Vapor Explosions

A BLEVE is defined as a catastrophic failure of a container into two or more pieces at a moment in time when the contained liquid is at a temperature well above its boiling point at normal atmospheric pressure (NFPA, 1993). BLEVEs are rare and damaging; but are most damaging when the boiling liquid is also flammable, as in the case of propane. The thermodynamic mechanism for large blast wave overpressures as a result of a tank failure is related to the state of the liquid in the tank when the internal pressure suddenly becomes atmospheric from an elevated saturated moisture pressure and temperature. At this point, the transition from liquid to superheated vapor is explosively rapid, and can lead to blast waves with peak overpressures as high as those arising from a detonation. This condition leads to an explosive rate of boiling, which, when coupled with ignition of the vapor, can result in large fireballs with solid fragments propelled at high velocities.

BLEVEs occur when an energy source (typically a fire) heats a pressurized tank causing the liquid in the tank to boil and pressurizes the tank to the point of failure. The heating time will vary based upon several factors such as, but not limited to, amount of propane in the tank, temperature of the fire, and location of the fire. Fire prevention around propane tanks is extremely important and so several preventative measures are utilized.

At RFETS, the low combustible loading of the vegetation and the mounting of the propane tanks on concrete or asphalt slabs eliminates the threat of a vegetation fire impinging on a propane tank. Stacking combustibles by propane tanks is prohibited by administrative control programs. The tanks are all protected from vehicle collision by Jersey bouncers and/or structural steel barriers. Therefore, the only BLEVE scenario postulated is interfacing with a propane delivery tanker. It is postulated that a turbulent jet from the propane delivery tanker is ignited and the resultant flame impinges on a site propane tank long enough to result in a BLEVE. Therefore, this interaction is initiated by a transportation issue and will not be discussed in this section.

Facility Interaction Evaluation of Propane Tanks

To identify the neighboring facilities to propane tanks, the site was inspected to determine the location of the propane tanks. The immediate vicinities surrounding the fourteen tank locations were inspected to determine the likelihood that the conditions required to generate damaging overpressures exist or have the potential of existing. The location of the 14 tanks and a summary of the findings of the walkdowns are listed in Table 4-23. More detailed information is available in CALC-RFP-98.055-RDC (RFETS, 1998).

Table 4-17. Propane Tank Facility Interaction Evaluations

Tank ID	Location	Capacity (gallons)	Evaluation
A4 Pond #1 & #2	East of A4 Pond Tents	1,000 & 1,179	The area is free of obstructions so no significant overpressure conditions are expected.
372A	West of Building 372A	500	Vehicles in the parking lot could cause significant overpressure conditions potentially affecting Building 372A. Building 372A is classified as an industrial facility and so no release of hazardous materials is expected.
549	West of Building 549	1000	No blockages to flame travel are in the area; therefore, no significant overpressure conditions are expected.
750 #1 - #8	East of 750 Pad	8 @ 1,000 each	Propane tank farm consists of eight 1000 gallon tanks connected to a common manifold. No significant obstructions are in the vicinity; so, overpressure conditions and subsequent release of hazardous materials are not expected. The distance to Building 991 is far enough that it is not possible for a propane vapor cloud to be flammable at the surface of Building 991.
760A	West of Trailer T760A	1,000	Vehicles in the parking lot could cause overpressure conditions potentially affecting trailer T760A and Building 762A. Both are classified as industrial facilities and so no release of hazardous materials is expected.
762A	West of Building 762A	1,000	Vehicles in the parking lot could cause overpressure conditions potentially affecting Buildings 709, 763, 764, 765, and 865, and propane tank 760A.
771B	Southwest of Trailer 771B	500	Storage boxes in the vicinity could cause overpressure conditions that may impact office trailers and plywood storage boxes in the vicinity.
771G	Southeast of Trailer 771G	1000	Negligible overpressure conditions are expected.
792A	West of Building 792A	1,000	Vehicles in the parking area could cause overpressure conditions that may impact trailers T771A and B.
T891G	West of Trailer 891G	250	Office trailers in the vicinity may experience small overpressure conditions but no release of hazardous materials is expected.
903	West of Building 903	250	No significant flame front obstacles exist in the area, so overpressure conditions are not expected.
904 #1 - #8	South of 904 Pad	8 @ 1,000 each	Pallets of drums stored in the area could provide sufficient blockage to lead to dangerous overpressure conditions in a VCE due to a southward drift of a vapor leak from one of the Pad 904 tanks. Building 906 and material stored in the area could be affected.

Facility Interaction Evaluation of Natural Gas Distribution System

Natural gas is distributed across the site in piping located 12 to 20 feet overhead, except for the underground sections crossing the protected area boundary. Inspection of the system indicates that, generally, no areas exist with sufficient obstacles to flame front travel to allow damaging overpressures to be generated in a VCE originating from a breach in the piping. The only possible source with damaging consequences would result from a large leak in a line within a few feet of a building. Such a leak could result in a high momentum turbulent gas jet having a region of gas/air mixture existing close to the building within the upper and lower flammability limits.

In this scenario, a natural gas line attached to a building breaks and is subsequently ignited. The explosion burns the gas in the plume, and if the ignition source remains within the area of the plume, it would re-ignite, essentially repeating the event. Since the explosion event occurs over a short duration, the impulse load on the building should be evaluated to determine the potential damage. The worse case explosion occurs when the plume is oriented perpendicular to the building wall (RFETS, 1998). For this worse case scenario, the explosion calculation indicates a small value of impulse load, for which negligible damage to concrete and masonry walls is expected (RFETS, 1998). However, all facilities with attached natural gas distribution lines should evaluate the interface between the wall and its attached distribution lines based upon specific facility structural information.

4.5.4 Facility Interaction Conclusions

As stated above, facility interactions focus on an accident in one facility causing the release of hazardous materials in a neighboring facility. Thus, "interactions of interest" require significant energy to breach major structures, such as the plutonium stabilization facilities. Accident types were screened to determine the types possessing significant energy. It was concluded the "interactions of interest" are limited to explosions involving propane and natural gas.

This analysis concludes that postulated propane VCEs result in significant overpressure conditions if the propane tank is located near a parking lot containing a large number of parked vehicles. These propane tanks include 372A located near PACS #2, 760A and 762A located by PACS #1, and 792A by PACS #3. Other tanks of concern are 771B and 904 Tank Farm, which are located in the vicinity of storage of boxes and 55-gallon drums. Release of hazardous materials is possible if propane tank 771B or any tank at the 904 Tank Farm experiences a VCE.

The analysis of the natural gas interface indicates that any RFETS building with attached natural gas distribution piping should analyze for the overpressure condition that results from a breach in the piping. It is expected that damage to concrete and masonry walls would be negligible.

4.6 NEARBY FACILITIES

The purpose of this section of the Site SAR is to evaluate the potential that an accident at a nearby facility could adversely affect operations in the industrial area of the site and lead to a release of hazardous materials. The scope of this section is limited to nearby facilities within approximately a five-mile radius of the site industrial area. General operations at nearby facilities include a cement plant, a drilling and blasting operation, an explosives storage area, a natural gas storage area, an airport and industrial parks.

4.6.1 Facility Description and Activity Characterization

This section provides a brief description of some of the significant nearby facilities as well as a general discussion of the types of businesses located in industrial areas close to the site. The relative location of the nearby facilities to the site is provided and shown in Figure 4-11.

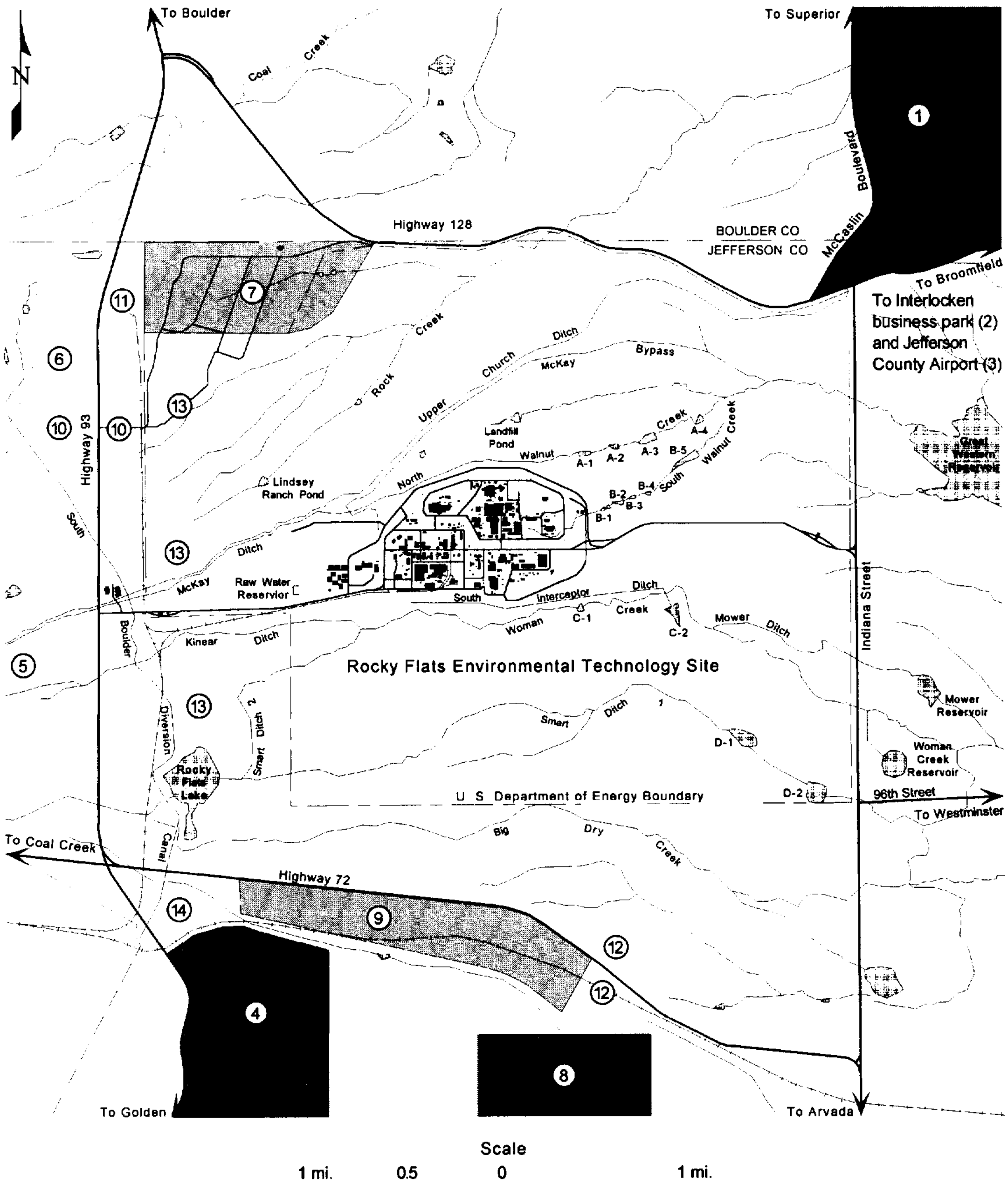
4.6.1.1 A & A Enterprises and Western Aggregates, Inc.

A & A Enterprises, located approximately two miles northwest of the site industrial area, conducts drilling and blasting operations. A & A Enterprises is permitted by the Federal Bureau of Alcohol, Tobacco, and Firearms (ATF) to store explosives. It currently complies with the Inhabited Building, Public Transportation Route, and Passenger Railway restrictions pertaining to the amount of explosives that can be stored on the premises as defined in NFPA 495 (NFPA, 1992a) and 29 CFR 1910.109 (CFR, 1994b).

Western Aggregates, Inc., processes aggregates to produce cement. This facility is located approximately two miles northwest of the site industrial area, next to A & A Enterprises.

4.6.1.2 Yenter Company, Inc. and AllWaste Explosive Services

Located two miles southwest of the site industrial area, just east and south of the intersection of State Highways 93 and 72, are the offices of Yenter Company and AllWaste Explosive Services. Yenter Company does drilling, blasting, and rock stabilization and AllWaste Explosive Services does hazardous and non-hazardous waste transportation and disposal, and explosive and chemical remediation. Explosives are only stored at the site and currently this storage complies with all applicable explosive storage regulations. The companies, together, have been permitted by the ATF and the Colorado Department of Labor to store approximately 40,000-pounds of explosives.



1	Rock Creek residential development	8	Public Service Natural Gas Storage Area (Leyden Mine)
2	Interlocken business park, golf course, and hotel	9	Industrial Park
3	Jefferson County Airport	10	Rocky Flats Lounge, Sawmill
4	BFI Waste Systems landfill	11	Western Aggregates, A&A Enterprises
5	Jefferson County Open Space	12	Unmarked storage tank, business storage areas
6	Mining by Western Aggregates	13	Clay pits
7	National Renewable Energy Laboratory, Wind Site	14	Yenter Company and AllWaste Explosives Services

Figure 4-1. Relative Location of Nearby Facilities to RFETS

4.6.1.3 Public Service of Colorado's Natural Gas Storage Area

Public Service of Colorado (PSCo) currently uses the Leyden Mine, a former underground lignite coal mine, as a natural gas storage facility. The mine shafts are located approximately 2½-miles south of the southern border of the site. The facility has the capability to store up to three BCF (billion cubic feet) of natural gas at 250 psig. The facility includes a series of production wells, used for injection and collection of natural gas, on the surface of the mine. The closest well heads are approximately two miles from the site industrial area. The storage area also consists of monitor wells used for observation and water wells to pump water to the surface from the mine.

4.6.1.4 Industrial Facilities

The largest industrial complex in the vicinity of the site is the Jefferson County (Jeffco) Airport and Industrial Park. This area is located approximately five miles east and slightly north of the site industrial area. Operations of the tenants at the Jeffco Airport and Industrial Park include office areas, manufacturing, a hydraulic repair garage, an aviation technician training facility, an aviation and fire coordination center, and research facilities.

Another industrial park complex is located approximately two miles southeast of the site industrial area, accessible by State Highway 72. Operations in this complex include steel and iron working facilities, manufacturing facilities, office areas, and a solar testing facility. An unmarked storage tank is located within this complex. Other businesses located along State Highway 72 between this industrial complex and Indiana Street include office areas, storage areas (boats, recreational vehicles, and miscellaneous storage), a small-tank propane-filling operation and an oil storage area. An unmarked storage tank is located across State Highway 72 from these businesses. These businesses are located approximately 2¼ miles from the site industrial area.

4.6.1.5 Other Facilities and Operations

There are several other facilities in the general vicinity of the RFETS that are not in the categories discussed above. A landfill site operated by BFI (Browning Ferris Industries) Waste Systems is located approximately 2¼ miles southwest of the site industrial area. The National Wind Technology Center, which conducts wind research and is operated by the National Renewable Energy Laboratory, is located approximately 1½ miles north of the site industrial area. The land occupied by the Wind Site was formerly part of the Buffer Zone. A housing development site, Rock Creek, is located approximately 2¼ miles north of the site industrial area. A sawmill operation and a restaurant are located approximately two miles northwest of the site industrial area. Three clay pits are located approximately 1½ miles west of the site industrial area (east of Highway 93). Two of the pits are now on site property although the rights to work these pits remains with the former owners. The Ball Corporation's Colorado Office Center is located approximately five miles east of the site industrial area and south of Jeffco Airport.

Some public facilities in the general vicinity of the site include Witt Elementary School and the Standley Lake Recreation Area. Witt Elementary School is located approximately five miles east of the site industrial area and the Standley Lake Recreation Area is located approximately 5¾ miles southeast of the site industrial area.

4.6.2 Hazard Assessment

Two potential hazards associated with nearby facilities that could adversely impact operations at the site industrial area by leading to a release of hazardous materials were identified. These potential hazards are (a) an explosion and subsequent fire from stored explosive substances, and (b) an explosion or fire from flammable gases or liquids. An explosion can potentially create an overpressure condition that could damage site industrial area facilities, which in turn could lead to a release of stored hazardous materials. This aspect of an explosion is analyzed in the following sections. The fire hazard is the potential initiation of a range fire that impacts the site. Range fires, from all initiating events, are addressed in Volume I, Chapter 5, of the Site SAR.

4.6.2.1 Explosion from Stored Explosive Substances

An explosion from stored explosive substances can be initiated in numerous ways that do not originate from the site but from a facility storing explosives. Two nearby facilities, A & A Enterprises (located approximately two miles northwest of the site industrial area) and AllWaste Explosive Services (located approximately two miles south of the site industrial area), are currently permitted to store explosive substances. To determine the amount of risk to the site industrial area facilities from an explosion involving stored explosive substances, two factors are of primary concern: (a) the quantity of explosives involved, and (b) the distance between the explosion and the site industrial area. NFPA 495 provides the formula (Equation 1) used to determine the quantity and distance requirements (NFPA, 1992a).

$S = KW^{1/3}$ where: (1)

S = distance (feet)
K = risk factor
W = net explosive weight (pounds of explosives)

The following assumptions were used in the data presented in Table 4-18.

- A K-factor of 50 is used because this provides a distance based upon a potential blast overpressure of 0.90 - 1.2 psi (0.06 - 0.08 bars). This is a very conservative estimate of the risk factor.

- From NFPA 921 (NFPA, 1992b), Table 13-12.3.1, the potential effects of a blast overpressure of 0.9 to 1.2 psi (0.06 to 0.08 bars) are:
  - shattering glass windows (0.5 to 1.0 psi)
  - shattering corrugated asbestos siding (1.0 to 2.0 psi)
  - buckling and connection failure for steel or aluminum paneling (1.0 to 2.0 psi)

- minor damage similar to that resulting from a high wind (1.0 psi) for wood frame buildings

- Mass detonation of the stored explosives occurs. Mass detonation implies simultaneous detonation or explosion of the total or substantial amount of a quantity of explosive material, caused by the explosion of a unit or part of the explosive material.

- The worst effect to the site industrial area from a nearby facility explosion will occur due to the blast pressure wave effect. In accordance with NFPA 921, the effects of explosions can be observed in four major ways: (a) blast pressure wave effect, (b) shrapnel effect, (c) thermal effect, and (d) seismic effect. The blast pressure wave effect is considered to be primarily responsible for the damage and injuries associated with explosions. The blast pressure wave effect normally occurs in two distinct phases: positive and negative. The positive pressure phase normally results in the greatest damage and injuries.

- High explosive materials are being stored in the storage location. High explosive materials are characterized by a very high rate of reaction, high pressure development, and the presence of a detonation wave.

The only distances not calculated using the above formula and risk factor are when a net explosive weight of 40,000 or 300,000 pounds is assumed. The distances for 40,000 and 300,000 pounds is extracted from Table 6-4 (b) in NFPA 495 assuming an unbarricaded storage area.

To store explosive substances, a facility must be permitted and comply with the federal requirements contained in NFPA 495 and 29 CFR 1910.109. These include maintaining the proper distance from inhabited buildings, public highways, and passenger railways and constructing an approved storage location (magazine) depending upon the class of explosives.

The inhabited building constraint, which requires that explosives cannot be stored in a quantity or location that would endanger an inhabited building, is the most restrictive. An inhabited building is any building or structure regularly used, in whole or in part, as a place of human habitation. These include houses, churches, schools, railroad stations, stores, and any other structures where people are accustomed to assembling. The passenger railway and public highway restrictions require that proper separation be maintained between an explosive storage area and any railway that carries passengers for hire or any public street, public alley, or public road that has a traffic volume greater than 3,000 vehicles/day. A third constraint is the public highway distance that must be adhered to where the traffic volume on a public street, alley or road is less than 3,000 vehicles/day.

Currently, two facilities within approximately two miles of the site industrial area are permitted to store explosives. These are A & A Enterprises and AllWaste Explosive Services. The quantity/distance restrictions applied to A & A Enterprises are based on the facility's proximity to State Highway 93 (the nearest Public Highway) and the cement plant offices (the closest inhabited building). The quantity/distance restrictions applied to AllWaste are based on the facility's proximity to State Highways 72 and 93 (the nearest Public Highways) and the railroad that is located just north of the facility. It is therefore concluded that it would be physically impossible to create a 0.90 to 1.2 psi overpressure condition at any of the site industrial area facilities due to an explosion from an accident at a nearby facility. Furthermore, there is little concern in the future of an accident involving explosives leading to an overpressure condition at the site industrial area because the inhabited building, public highway, and passenger railway constraints will be applied when an explosives storage magazine is permitted. Thus, there is no risk to site industrial area facilities from an accident involving explosives at a nearby facility.

Table 4-18. Quantity/Distance Calculations for 0.90 - 1.2 psi Blast Overpressure.

Net Explosive Weight (lb)*	Distance (feet)	Distance (miles)
40,000	2000	0.38
300,000	2275	0.43
1,000,000	5000	0.95
1,500,000	5724	1.08
2,000,000	6300	1.19
2,500,000	6786	1.29
3,000,000	7212	1.37
3,500,000	7592	1.44
4,000,000	7937	1.50
4,500,000	8255	1.56
5,000,000	8550	1.62
5,500,000	8826	1.67
6,000,000	9086	1.72
6,500,000	9332	1.77
7,000,000	9565	1.81
7,500,000	9788	1.85
8,000,000	10,000	1.89
8,500,000	10,205	1.93
9,000,000	10,401	1.97
9,500,000	10,590	2.01
10,000,000	10,773	2.04

* NFPA 495 indicates that storage in excess of 300,000 pounds of explosive materials in one magazine is generally not required for commercial enterprises.

4.6.2.2 Explosion from Flammable Gases or Liquids

An explosion from flammable gases or liquids was evaluated for the effect on the site industrial area. The main area of concern is the Leyden Mine that PSCo uses to store natural gas. A safety analysis concerning the storage of natural gas in the Leyden Mine was performed in 1995 (RFETS, 1996e). Three potential hazards to the site were identified: (1) a natural gas leak from the Leyden Mine that migrates underground, enters a site industrial area structure, and creates a flammable atmosphere in the facility; (2) a surface gas leak or fire at the Leyden Mine and its potential to effect the site industrial area; and (3) the effect on the site industrial area due to an underground natural gas explosion at the Leyden Mine.

The Leyden Mine has not had a net loss of natural gas that has not been accounted for during its 35 years of operation. This implies that natural gas is not being vented from the Leyden Mine, either to the surface or toward the site. Due to the lack of continuity of the lithologic units that make up the Laramie formation, the chance of any underground migration of natural gas from the Leyden Mine to the site industrial area is remote. Further, any disruption of the strata by faulting makes a continuous flow path even more unlikely. A leak to the surface has a much greater probability of occurring than a horizontal transmission of the gas to the site industrial area. Based on the data available, it is believed that no natural gas from the Leyden Mine can reach the site industrial area facilities.

The largest risk of a natural gas explosion exists at the wellheads when the mine is at its maximum working pressure. Calculations show that the maximum area of surface concentrations of natural gas capable of combustion will be limited to a radius of 500 feet from the well. Calculations were also performed to determine the overpressure of a shock wave occurring as a result of the rapid ignition of the plume. Based on the amount of natural gas, 50,000 cubic feet, within the combustible limits in the plume generated at a broken wellhead, the radius for a peak incident pressure of one psig was determined to be 360 feet from the wellhead. The closest surface facility at the site is located a distance of more than 10,000 feet from the northernmost well at the Leyden Mine. Therefore, there is no impact on the site industrial area structures from a surface explosion at the Leyden Mine.

The Leyden Mine Analysis concluded that no underground explosion is currently possible at the Leyden Mine because the mine is completely filled with natural gas and does not contain any air or oxygen. Natural gas is only combustible in the range of 5 to 15 volume percent natural gas/air. If it were possible to introduce air into the mine, the only scenario that could lead to the burning of natural gas would be at atmospheric pressure. Naturally occurring gas from the Laramie formation could produce the same results even if PSCO had not chosen this mine as a storage facility. Experiments have been conducted to show that the total mine pressure from a totally contained system could not reach even one-half of the current working pressure of the mine. As a result, it is not possible to cause damage to the structural integrity of the mine or the site industrial area from an underground natural gas explosion.

4.6.3 Nearby Facility Conclusion

Based upon the calculations performed, and the constraints placed upon explosive storage locations by Federal and State law and NFPA standards, it is concluded that there is no risk to site industrial area facility operations from an accident involving explosive substances at a nearby facility. Furthermore, the Leyden Mine Analysis documents the evaluation performed on the PSCO Leyden Mine natural gas storage facility with respect to possible risks to the site industrial area. This evaluation indicates that there is no risk to the site industrial area from any of the postulated accident scenarios.

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CHAPTER 5

NATURAL PHENOMENA AND EXTERNAL EVENTS

CONTENTS

FIGURES

TABLES

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CHAPTER 5

NATURAL PHENOMENA AND EXTERNAL EVENTS

5.1 INTRODUCTION

DOE Order 5480.28[a], *Natural Phenomena Hazards Mitigation*, requires DOE facilities to protect against exposure to hazardous materials during and after the occurrences of natural phenomena hazards. To support this goal, natural phenomena events are evaluated to determine their impact to the Rocky Flats Environmental Technology Site (RFETS) and their potential to initiate a release of hazardous materials from a facility. A natural phenomena hazard, as defined by DOE Order 5480.28, is an act of nature which poses a threat or danger to workers, the public, or to the environment by potential damage to structures. These acts of nature include earthquake, wind, hurricane, tornado, flood, precipitation, tsunami, volcanic eruption, lightning strike, or extreme cold or heat. Based on the location and geography common to RFETS, some natural phenomena events are not considered credible for this location. These are identified as follows:

- Hurricane: Hurricanes are associated with coastal areas of the continent. The mid-continental location of RFETS make the potential for a hurricane at the site impossible.

- Tsunami: Tsunamis are ocean waves generated as the result of an underwater disturbance such as an earthquake, landslide, or volcanic eruption. The mid-continental location of RFETS make the potential for a tsunami at the site impossible.

- Volcanic eruption: No active volcanos or inactive remnants of volcanos are present in the vicinity of RFETS.

- Extreme cold or heat: The high and low temperatures associated with the Colorado climate in the area of RFETS are not severe enough to cause potential significant damage to structures.

The following sections discuss natural phenomena which are of concern at the RFETS. These sections include potential impacts to the site, history of the phenomenon or event in the Rocky Flats region, and site-specific evaluation parameters. Evaluation parameters address the conditions that must be present for the natural phenomenon to occur. Occurrence probabilities and hazard curves are presented where appropriate. The natural phenomena addressed in this chapter include earthquake, high wind and tornado, heavy rain, heavy snow, and lightning.

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a. DOE Order 5480.28, *Natural Phenomena Hazards Mitigation*, has been replaced with DOE Order 420.1, *Facility Safety*; however, at this time the new order has not been made part of the Kaiser-Hill contract. The new order will become effective for RFETS at the time the contract is amended.

In addition to natural phenomena events, this chapter addresses external events (i.e., external man-made phenomena) which could impact the site as potential accident initiators. External events include explosions from natural gas lines, accident from nearby transportation activities, aircraft crashes, adjacent facility events and range fires. Sabotage and terrorism are not considered per DOE Order 5480.23. The external events addressed in this chapter include the potential for an aircraft crash to breach a facility, and for a range fires to impact facilities in the vicinity of the buffer zone. The sections addressing these events include events characteristics associated with the event in relation to the site and the probably of the event occurring. More extensive analysis of the following external events are also presented in the Site SAR:

- Natural gas explosions: The impact of natural gas and propane fuel supplies to facilities on the site are addressed in the Fuel Gas System Facility Safety Analysis (FSA) in Volume II of the Site SAR.

- Adjacent facility events: Facilities in the vicinity of the RFETS and their potential affects on site are addressed in Chapter 4, Section 4.6, Nearby Facilities, of Volume I of the Site SAR. The interaction of one site facility with another facility on the site are addressed in Chapter 4, Section 4.5, Facility Interactions, of Volume I of the Site SAR.

- Transportation activities: Both on-site and off-site transportation accidents and their affects on the site are evaluated in Chapter 8, Transportation Safety Analysis, of Volume I of the Site SAR.

5.2 EARTHQUAKE

5.2.1 Introduction

This section provides a general discussion of characteristics and annual recurrence frequencies of earthquakes that could affect RFETS and provides a common basis to judge earthquake risks for each facility. Planning for site emergency response can be prioritized using this basis to minimize site earthquake risk.

Earthquakes represent a special class of events that have two specific aspects that make them unique from all other natural phenomena: (a) no preliminary warnings occur before a seismic event and (b) they impact every facility simultaneously. The concern associated with this type of event is that emergency response must be prioritized and not every facility will receive immediate support. Therefore, structural collapses, hazardous material releases, fires, and other actions that may occur in low priority facilities may not be addressed because resources are directed to high priority facilities.

5.2.2 History

The site is located in a low seismic activity area. Figure 5-1 provides a compilation of recorded seismic event locations and magnitudes in Colorado (REI, 1994). Several seismic studies have been performed to develop a seismic hazard relating the annual probability of recurrence to ground motion at the site. The most recent of these studies (REI, 1994) was used to arrive at a basis for recommending a seismic hazard curve for use in site accident analysis.

The historical records of earthquakes that have occurred in Colorado were investigated (REI, 1994). A specific study was conducted on the 1882 Colorado earthquake because it represents the largest seismic event recorded in Colorado history. Since there were no seismographs installed at the time, historical accounts were used to estimate the most probable magnitude and location of the earthquake. The location of the 1882 earthquake estimated to be most probably located in the northern front range. The magnitude was estimated to be between 4.6 and 7.1 with a most likely value of 6.4 (REI, 1994).

The current seismic hazard analysis for the site (REI, 1994) presents the layout of geological features near the site and describes the nearest capable faults. Figure 5-2 mapped geologic features in the general area of the site. Not all faults shown on this figure are associated with past tectonic events. However, there are several potentially capable faults near the site. The Walnut Creek fault traverses the east side of the site and has about a 3 km length. The Rock Creek fault is near the north boundary of the site traveling northeast and has about a 4 km length. The Valmont fault is about 11 km north of the site and runs north-northeast with about a 4 km length. The Golden-Boulder segment of the Front Range fault system is about 4 km west of the site and runs north-northwest about 55 km. The Rocky Mountain Arsenal (RMA)/Derby source is located about 16 km east of the site running southeast with about a 22 km length. These faults were studied in the seismic hazard analysis (REI, 1994) for seismic capability, estimated magnitude capacity, closest distance to the site, and estimated recurrence from the slip rate. All of these factors were probabilistically weighted in a logic tree analysis to arrive at the probabilistic seismic hazard for the site.

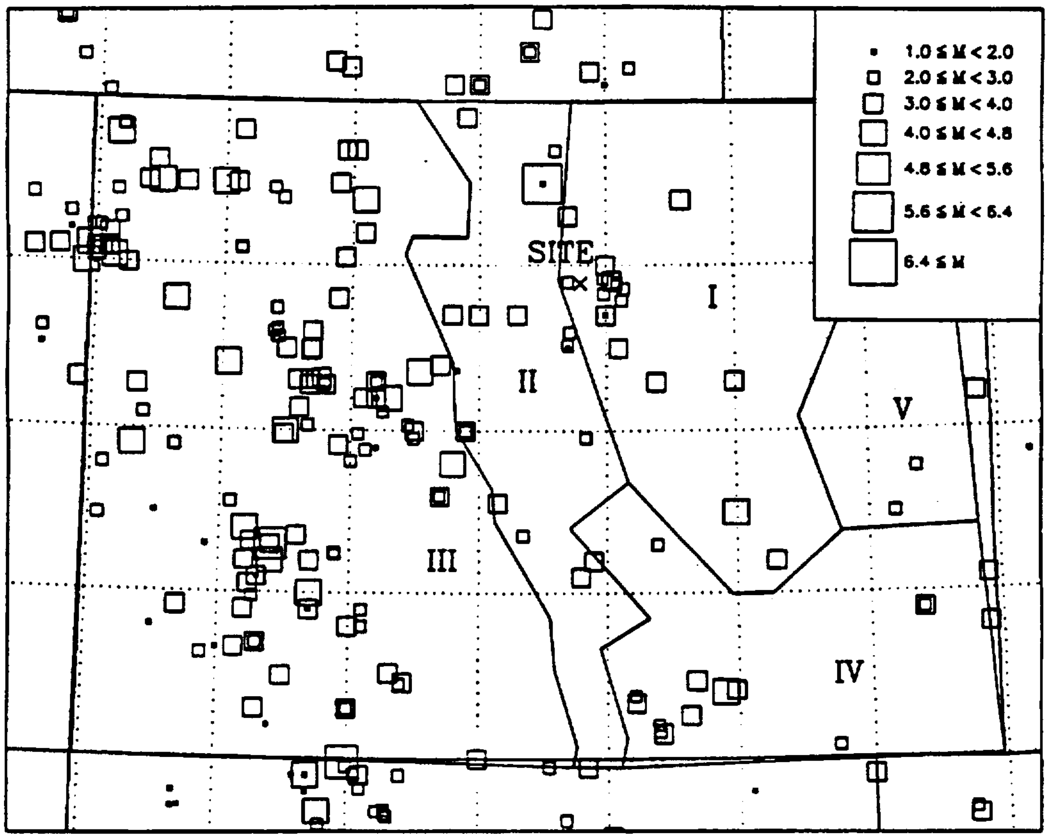

Figure 5-1. Colorado Earthquakes -1870 through May, 1993 (REI, 1994)

An additional review for Building 371 (Geomatrix, 1995a) studied capability of inferred faulting that runs generally northeast to southwest on site near that facility. Figure 5-3 illustrates the estimated locations of the inferred faults on the Rocky Flats site. This faulting is inferred from discontinuities in the underlying claystone at the site as determined by physical property measurements in wells and boreholes. Investigation of these faults was performed by construction of a trench to study the ~1 million year old alluvial deposits overlying the faults. The conclusion of the investigation was that these faults were not capable as defined by NRC criteria (i.e., no tectonic movement has occurred in the last 500,000 years). Therefore, these faults are categorized as non-capable.

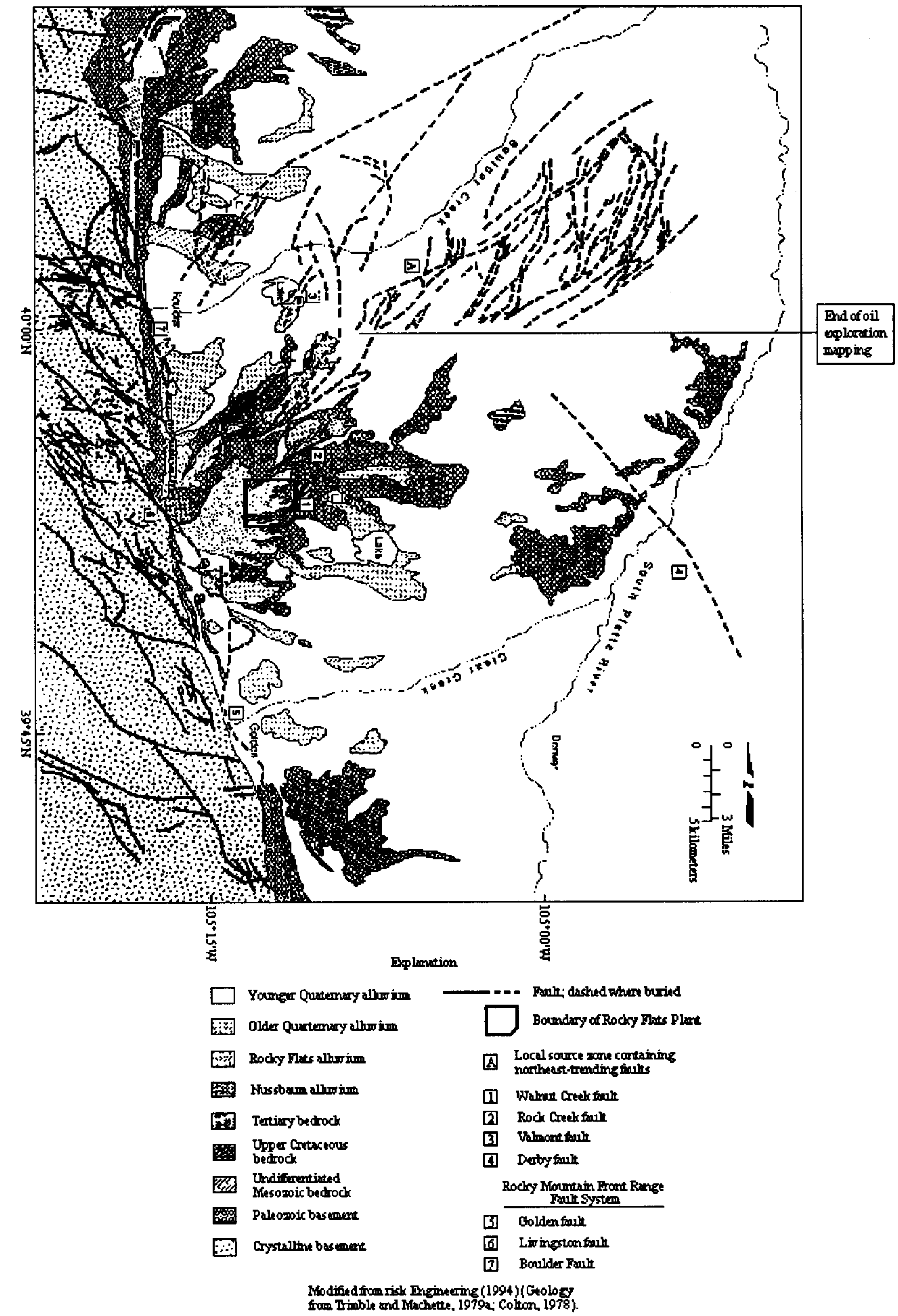

Figure 5-2. Mapped Fault Locations in the Vicinity of the Site (Geomatrix, 1995b)

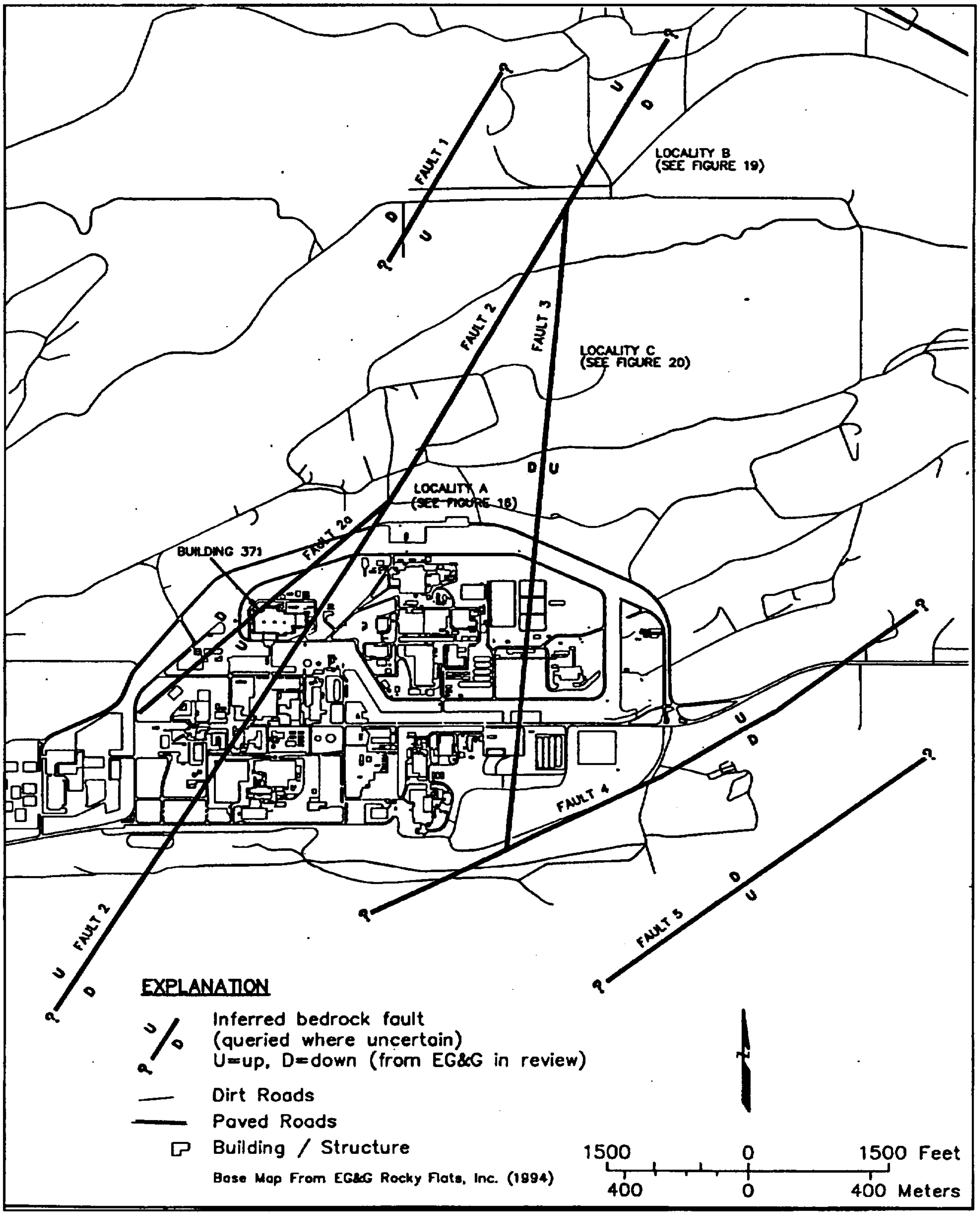

Figure 5-3. Inferred Fault Locations on the Site

5.2.3 Evaluation Parameters

Seismic Design Criteria

The current basis for seismic design at RFETS is derived from the following documents:

- *Seismic Hazard Analysis for Rocky Flats Plant (REI, 1994)*
- *Design Response Spectra for Rocky Flats Building 707 and 707A, WSRC-RP-97-4357 (Westinghouse – Savannah River Corporation, 1998)*
- *Deterministic Ground Motion Assessment for Building 371 Rocky Flats Environmental Technology Site, Colorado (Geomatrix, 1995b)*
- *Ground Motion Reconciliation and Consolidation for Evaluation Basis Earthquake Building 3 71, Rocky Flats Environmental Technology Site, (Geomatrix, 1995c)*
- *Uniform Building Code, International Conference of Building Officials, Whittier, California*

The Uniform Building Code separates the United States into five Zones according to seismic activity and intensity potential; Zone 0 being lowest intensity and least frequent, and Zone 4 being highest intensity and most frequent. The UBC lists central Colorado as a Seismic Zone 1 area. This code is used in combination with the Seismic Hazard Analysis for design of Performance Category (PC) -1 and -2 facilities on site. The UBC was used as the initial design basis for all facilities on site. For facilities with higher hazard potentials, a higher intensity event may be imposed upon their design as necessary to control the hazard to acceptable levels. Facility hazard levels are determined using *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports* (DOE, 1992a) which provides guidance to determine hazard classifications, used in DOE-STD-1021-93, *Natural Phenomena Hazards Performance Categorization Guidelines for Structures, Systems, and Components* (DOE, 1996a) to define Performance Categories.

The RMA/Derby source is the major contributor to site seismic hazard for probabilities of interest for PC-3 design. If the site had facilities requiring a PC-4 design, the Golden-Boulder portion of the Front Range fault zone has more significance due to its proximity to the site and potential for a large earthquake at a much lower probability of recurrence.

Defense Nuclear Facility Safety Board (DNFSB) Recommendation 94-3 made a request that information be developed on seismic resistance capabilities of the Building 371 complex. As part of the Implementation Plan to address DNFSB Recommendation 94-3, a study (Geomatrix, 1995b) was performed to reconcile the probabilistic seismic hazard analysis with a deterministic assessment performed to 10 CFR 100 Appendix A criteria. The results of that study showed that for a reactor facility designed as PC-4, the seismic hazard analysis and deterministic assessment would result in the same ground motion levels. A reconciliation and consolidation of site seismic issues was performed and documented (Geomatrix, 1995c). The reconciliation study served to validate the results of the Seismic Hazard Analysis. Once a facility has been characterized into a specific Performance Category, the recurrence probability is defined and the ground acceleration for bedrock can be derived from the hazard curve. The annual recurrence probability versus ground acceleration at bedrock is shown in Figure 5-4.

Hazard Curve

The Department of Energy (DOE) issued general evaluation guidance for natural phenomena and a seismic parameter study specific to major DOE sites throughout the nation. The document implements a series of related guidance documents listed below that cover all aspects of natural phenomena, how to evaluate them, and how to collect and report data using a formal standardized method. The site Seismic Hazard Analysis (REI, 1994) was performed in accordance with these standards.

- Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports (DOE, 1992a)
- *Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities* (DOE, 1996b)
- *Natural Phenomena Hazards Performance Categorization Guidelines for Structures, Systems, and Components* (DOE, 1996a)
- *Natural Phenomena Hazards Characterization Criteria* (DOE, 1996c)
- *Natural Phenomena Hazards Assessment Criteria* (DOE, 1996d)
- *Guidelines for Use of Probabilistic Seismic Hazard Curves at Department of Energy Sites* (DOE, 1996e)

Probability of Occurrence

The Seismic Hazard Analysis (REI, 1994) presents the calculated annual probability of occurrence versus ground motion level for several response frequencies. The results of the Seismic Hazard Analysis for peak ground acceleration are show on Figure 5-4. The acceleration values are for bedrock at approximately 100 feet below the surface and must be adjusted for the specific location of the facility to which they are applied. A structural engineer knowledgeable in soil-structure interaction and soil amplification analysis should make the determination of the ground motion at the surface to be applied to a specific structure.

The Seismic Hazard Analysis also addressed soil liquefaction and slope stability for the site. The conclusion was that these hazards are not a concern for ground motion levels at PC-3 or less.

5.2.4 Conclusion

Although the site is located in a low seismic activity zone, there still exists a potential for a moderate earthquake, which is considered an unlikely event. A moderate earthquake could cause significant damage to site facilities, particularly some of the older structures designed and constructed to the Uniform Building Code in effect at the time. An earthquake has the potential to initiate nuclear criticalities, fires, and spills, and is typically considered to result in a bounding spill scenario.

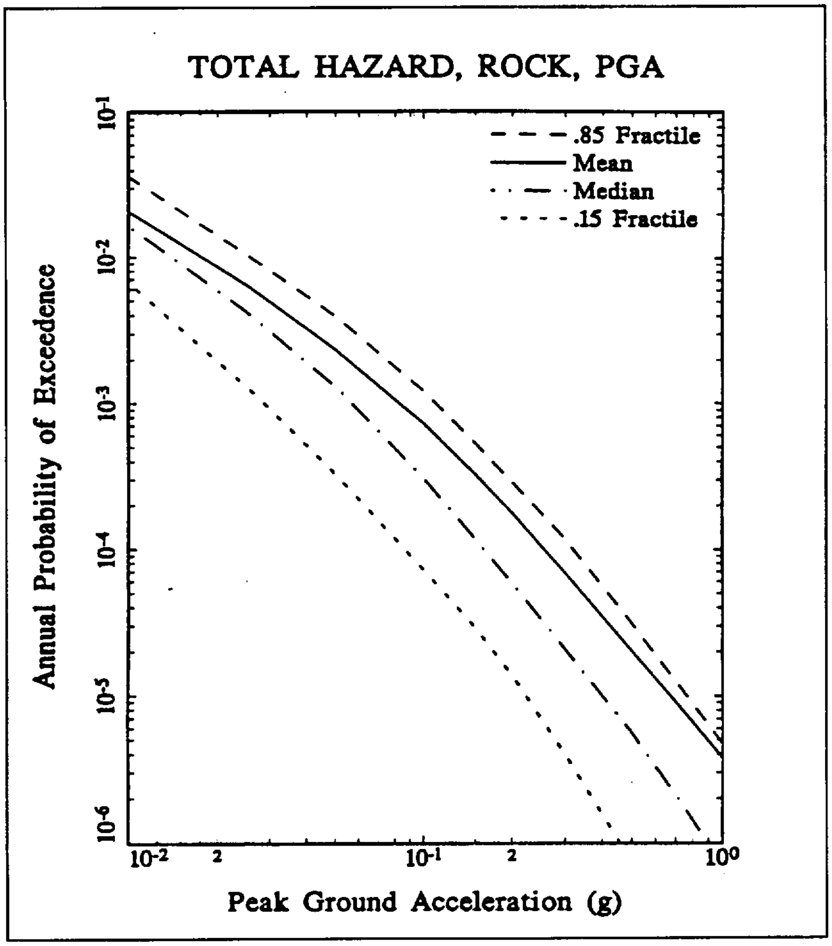

Figure 5-4. Hazard Curve for Seismic Events at the Site **(REI,** 1994)

5.2.5 References

DOE, 1992a — *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports,* DOE-STD-1027-92, U.S. Department of Energy, Washington, D.C., December 1992.

DOE, 1996a — *Natural Phenomena Hazards Performance Categorization Guidelines for Structures, Systems, and Components,* DOE-STD-1021-93, Change Notice 1, U.S. Department of Energy, Washington, D.C., January 1996.

DOE, 1996b — *Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities,* DOE-STD-1020-94, Change Notice 1, U.S. Department of Energy, Washington, D.C., January 1996.

DOE, 1996c — *Natural Phenomena Hazards Characterization Criteria,* DOE-STD-1022-94, Change Notice 1, U.S. Department of Energy, Washington, D.C., January 1996.

DOE, 1996d — *Natural Phenomena Hazards Assessment Criteria,* DOE-STD-1023-95, Change Notice 1, U.S. Department of Energy, Washington, D.C., January 1996.

DOE, 1996e — *Guidelines for Use of Probabilistic Seismic Hazard Curves at Department of Energy Sites,* DOE-STD-1024-92, Change Notice 1, U.S. Department of Energy, Washington, D.C., January 1996.

Geomatrix, 1995a — *Evaluation of the Capability of Inferred Faults in the Vicinity of Building 371 Rocky Flats Environmental Technology Site, Colorado,* Geomatrix Consultants, Inc., February 1995.

Geomatrix, 1995b — *Deterministic Ground Motion Assessment for Building 371 Rocky Flats Environmental Technology Site, Colorado,* Geomatrix Consultants, Inc., February 1995.

Geomatrix, 1995c — *Ground Motion Reconciliation and Consolidation for Evaluation Basis Earthquake Building 371, Rocky Flats Environmental Technology Site,* Geomatrix Consultants, Inc., February 1995.

REI, 1994 — *Seismic Hazard Analysis for Rocky Flats Plant,* Risk Engineering, Inc., 9217-C00-204, Revision 0, September 1994.

5.3 HIGH WINDS AND TORNADOES

5.3.1 Introduction

High-speed winds pose a major threat to the site, potentially damaging buildings and other structures in a variety of ways. Loose objects picked up by the wind can be turned into missiles that can penetrate a structure. The roof covering and siding material can be blown off of the building. Winds passing sharp corners of the building tend to separate from the building, causing an outward pressure. In general, the windward surfaces of the building experience an inward pressure and all other exterior surfaces experience an outward pressure. Likewise, the internal air pressure can rapidly change if air can pass into or out of a structure through openings, such as those caused by a wind-driven missile. If the opening is on the windward side of the building, the internal pressure increases, which reinforces the outward pressure of the outside air on the other surfaces. If the opening is on any other side of the building, the internal pressure decreases, which counteracts the outward pressure of the outside air. In any case, if the atmospheric pressure change (APC) exceeds the structural strength of the building, the building can suffer significant damage.

High-speed winds can be "straight," "tornado," or "hurricane." Straight winds are non-rotating winds that cover a wide area, typically many tens of miles across, and can reach speeds in excess of 100 mph (160 km/hr); they are generally associated with thunderstorms, mesocyclones, and, in the case of the site, Chinook winds. Tornadoes are violently rotating winds that are very localized, a few miles or less across, and can reach speeds in excess of 200 mph (320 km/hr); they can accompany severe weather events, such as thunderstorms and even hurricanes. Hurricanes are very large-scale rotating winds, typically hundreds of miles across; by definition, hurricane wind speeds are in excess of 73 mph (117 km/hr). Hurricanes are important to analyze at some Department of Energy (DOE) sites but not at Rocky Flats as they don't occur as far inland as the site. They are not considered further here. For any type of wind, whether straight or rotating, a building is small compared to the size of the area affected by the wind and the response of the building is the same. The main reason for making a distinction here is in the hazard curves, which show the wind speed as a function of the annual probability of exceedance of that wind speed.

Wind-speed data-gathering specifications for straight winds and tornadoes are given in DOE-STD-1022-94 (DOE, 1996) as:

Straight Wind: At least ten continuous years of annual extreme wind-speed data [such as peak gust or largest sustained wind (fastest-mile wind)][a] are needed to produce a statistically-significant wind-hazard curve. Data for wind-hazard curves shall be taken from anemometers located in flat, open terrain at an elevation of 10 meters (33 feet) above ground.

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a. Fastest-mile wind speed is the fastest speed of any "mile" of wind, as determined over a specified time period, such as one hour, one day, one month, or one year. In the RFRAG (RFETS, 1994), the largest sustained wind is equated to fastest-mile wind for the selected period. A peak gust, on the other hand, is the highest "instantaneous" wind speed recorded during the specified period.

Tornado Wind: For PC-1 and PC-2 facilities, tornado data need not be considered. For PC-3 and PC-4 facilities, tornado wind statistics shall be based on tornadoes within 310 miles (500 km) of the facility. The parameters of special importance are tornado track (latitude and longitude), intensity, length and width.

This section first discusses the conditions for the occurrence of these winds, reviews the history of past events, and then discusses the evaluation parameters. In particular, the subsections below provide curves of wind speed verses probability of exceedance for both straight winds and tornadoes and relate these wind speeds to performance categories.

5.3.2 Conditions for Occurrence and Site History

Straight Wind

The highest-speed straight winds at the site usually occur in the winter and are associated with Chinooks, the warm down-slope winds that accompany the jet stream. These high-speed winds typically last for many hours and occur at the site mainly in December, January, and February. High-speed straight winds can also occur in summer as part of thunderstorm activity, but historically they have not been as severe as the winter winds. These thunderstorm winds are most common in June, July, and August and are usually short-lived. One aspect of thunderstorm activity is the microburst, a sudden downdraft of air that, upon hitting the ground, spreads out in all directions, causing a burst of high-speed wind. Microbursts, which typically last only a few seconds at a given location, have been observed at the site. A microburst would affect only a portion of the site as microbursts typically measure only several hundred meters across. Although high-speed straight winds are not uncommon at the site, only minor damage has been sustained, such as broken car windows and torn tent fabric. The maximum straight-wind speed recorded at the site was a 127-mph gust that occurred January 17, 1982 (Hodgin, 1990).

Statistical studies of extreme wind conditions at the site have been performed by Fujita (1978), McDonald (1985), Coats and Murray (1985) and McDonald (1995). Fujita analyzed data from 1964 through 1976 (13 years) from an anemometer located 7.6 meters (25 feet) above ground level (AGL) [although the height had mistakenly been listed as 6.1 meters (20 feet)]. In particular, he analyzed the peak gust speeds for each month during this 13-year period. The largest of these gust speeds had registered incorrectly (Fujita did not know this) because the anemometer had "pegged" at 100 mph, which caused a bias in Fujita's results. One important result of Fujita's study was that the wind data from outlying sites, such as at the Denver airport, could not be used to infer maximum wind speeds at the site. McDonald (1985, a revision of a report he had originally issued in 1979 and first revised in 1983) analyzed data from 1954 through 1974 (21 years), a period that largely overlapped with the data Fujita analyzed. McDonald corrected for the erroneous peak gust speeds above 100 mph and used a statistical analysis of the yearly peak gust speeds. His analysis is based on the Type I Extreme Value Distribution (Gumbel distribution, also called the Fisher-Tippett Type I in McDonald's 1985 report). The peak gust speeds were first converted to fastest-mile wind speeds by dividing the peak gust speeds by 1.25, an empirical factor used by McDonald. His 1985 results, shown in Table 5-1, provide the expected fastest-mile wind speed as a function of frequency of occurrence, from 1.0E-1/yr to 1.0E-7/yr, corresponding to return periods of 10 years to 10 million years. Also shown are the upper and lower 95th percent confidence limits (95% CLs). Table 5-1 gives the results both in terms of fastest mile and peak gust.

Table 5-1. McDonald's (1985) Site Straight-Wind Analysis Results

Wind Data	Frequency of Occurrence (per year)						
	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}
Lower Limit Peak Gust (mph)	103	119	134	150	165	181	196
Expected Value Peak Gust (mph)	116	145	173	201	229	258	285
Upper Limit Peak Gust (mph)	130	171	211	253	293	334	374
Lower Limit Fastest-Mile (mph)	82	95	107	120	132	145	157
Expected Value Fastest-Mile (mph)	93	116	138	161	183	206	228
Upper Limit Fastest-Mile (mph)	104	137	169	202	234	267	299

Coats and Murray (1985), in UCRL-53526, *Natural Phenomena Hazards Modeling Project: Extreme Wind/Tornado Hazard Models for Department of Energy Sites*, reviewed these methods of analyzing straight-wind data and concluded that the McDonald straight-wind statistical methodology was preferred over that of Fujita. Coats and Murray utilized McDonald's method and performed calculations for the site and got essentially the same results. The results in Table 5-1 have been used in DOE-STD-1020-94 (DOE, 1994).

The latest report of McDonald (1995) is an update to his earlier work, incorporating more data but retaining the same analysis technique. The new work covers the original period (1954 through 1974) and adds 1990 through 1994, for a total of 26 years; the period 1975 through 1989 was excluded as the peak gust data were incomplete or missing. The results of this revised study are given in Table 5-2 and shown in Figure 5-5; the results for an exceedance probability of 1.0E-1/yr are not given in McDonald's report, so these have been extrapolated from the other results. The peak gusts shown are directly from the report and the fastest-mile winds are determined from peak-gust speeds using the equation given by Durst (1960), which McDonald (1995) uses:

$$V_{\text{fastest-mile}} = 0.958\ V_{\text{peak-gust}} - 11.34$$

This equation gives the same fastest-mile speed as the earlier method (of dividing the gust speeds by 1.25) for a gust of about 72 mph (or a fastest-mile speed of about 57 mph). For higher gust speeds, this equation gives fastest-mile speeds higher than the earlier method. Note that the results given in Table 5-2 are nearly the same as those of Table 5-1 for the "expected" fastest-mile wind speeds.

Table 5-2. McDonald's (1995) Site Straight-Wind Analysis Results

Wind Data	Frequency of Occurrence (per year)						
	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}
Lower Limit Peak Gust (mph)	100	114	128	142	156	170	182
Expected Value Peak Gust (mph)	111	134	157	180	203	226	247
Upper Limit Peak Gust (mph)	120	153	186	218	251	283	312
Lower Limit Fastest-Mile (mph)	84	98	111	125	138	152	163
Expected Value Fastest-Mile (mph)	95	117	139	161	183	205	225
Upper Limit Fastest-Mile (mph)	104	135	167	198	229	260	288

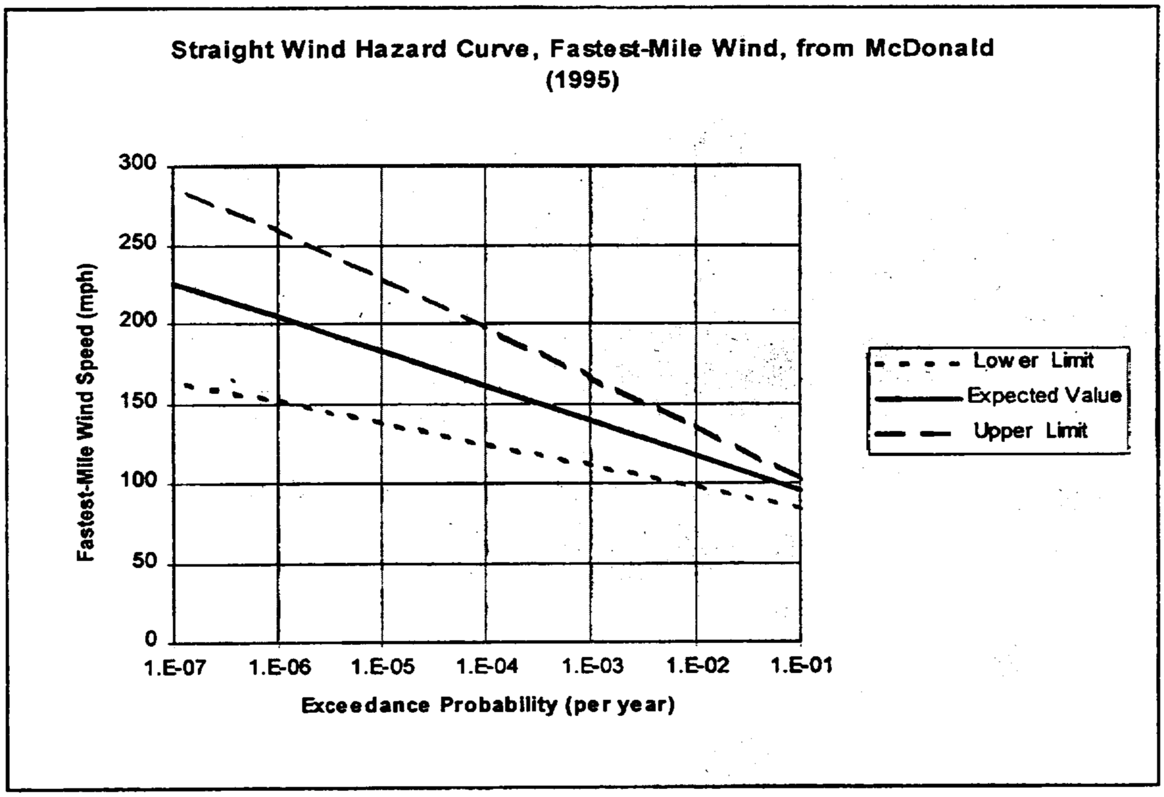

Figure 5-5. Wind Hazard Curves for Straight Fastest-Mile Winds, from McDonald (1995)

Tornadoes

Tornadoes occur nearly every summer in eastern Colorado, but they are very rare for locations as close to the mountains as RFETS. They are associated with thunderstorms and therefore occur primarily in the summer, although they can occur any time of the year. For locations near the site, tornadoes have occurred during every month except December, January, and February. However, a tornado has not occurred *at* the site during its 45-year history.

Statistical studies of tornado conditions at the site have been performed by Fujita (1978) and McDonald (1985), based on a common database. Coats and Murray (DOE, 1985) reviewed both methods and concluded that the method of Fujita was preferred. McDonald (1995) has updated his earlier analysis to include a larger database, this time based on data archived at the National Severe Storms Forecast Center (NSSFC) in Oklahoma City, OK; he used the same method as before.

Fujita (1978) used the DAPPLE (Damage Area Per Path Length) method for a circular area within 100 miles of the site, including all tornadoes known to have occurred in this area. The method derives statistics for weak, strong, and violent tornadoes and then combines them to derive the tornado hazard curve. Fujita's results are shown in Table 5-3. The results of McDonald (1995) are also shown in Table 5-3, for comparison. Because Coats and Murray (1985) recommend the Fujita method, the McDonald results will not be discussed further.

Table 5-3. Tornado Wind Speeds (mph) for the Site (Fujita's 1978 and McDonald's 1995)

Author	Data Type	Exceedance Probability (per year)			
		10^{-4}	10^{-5}	10^{-6}	10^{-7}
Fujita (1978)	Expected	51	110	158	204
	Lower	51	112	152	-
	Expected	77	145	201	253
McDonald (1995)	Upper	117	186	255	-

5.3.3 Evaluation Parameters

The "expected" hazard curves for straight wind and tornadoes are shown together in Figure 5-6. The intersection point of the two curves, which is off the chart for the site, is called the transition point. For wind-hazard analysis, the straight-wind hazard curve would be used for wind speeds up to the transition point and the tornado-hazard curve would be used for the higher speeds. The wind speed at the transition point also determines if other tornado effects (e.g., atmospheric pressure change, tornado-driven missiles) need to be considered. As can be seen for the site (Figure 5-6), the transition point is below an exceedance probability of 1E-7/yr. Damage from a small tornado (which are in the credible range) would be bounded by straight wind damage.

As mentioned above, damage to facilities can arise from both impact of the wind (pressure changes) and from airborne missiles driven by the wind. Coates and Murray (1985) relate the wind speed to the missile speed for a variety of missiles. This is shown in Table 5-4 and Figure 5-7. The four missiles considered by Coates and Murray are a timber plank (4"′12"′12', 139 lbs), a 3"-diameter standard steel pipe (10' long, 75.8 lbs), a utility pole (13.5" diameter, 35' long, 1,490 lbs), and an automobile (4,000 lbs). Obviously, heavier objects and objects with a smaller surface-area to volume ratio, have less speed in the wind.

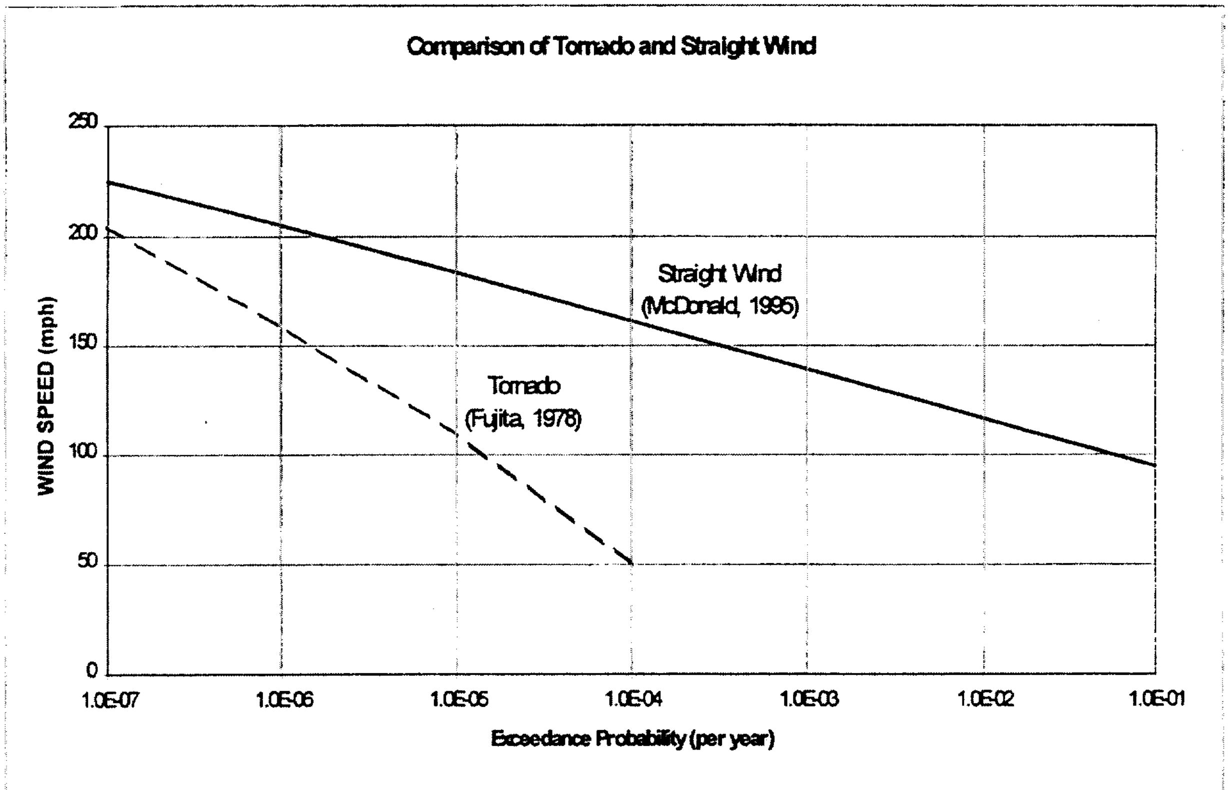

Figure 5-6. Combined Wind Hazard Curves for Straight Wind and Tornadoes

Table 5-4. Windborne Missile Velocities (mph)

DESIGN WIND SPEED (mph)	MISSILE TYPE			
	Timber Plank	**3" Pipe**	**Utility Pole**	**Automobile**
100	60	40	0	0
150	72	50	0	0
200	90	65	0	0
250	100	85	80	25
300	125	110	100	45
350	175	140	130	70

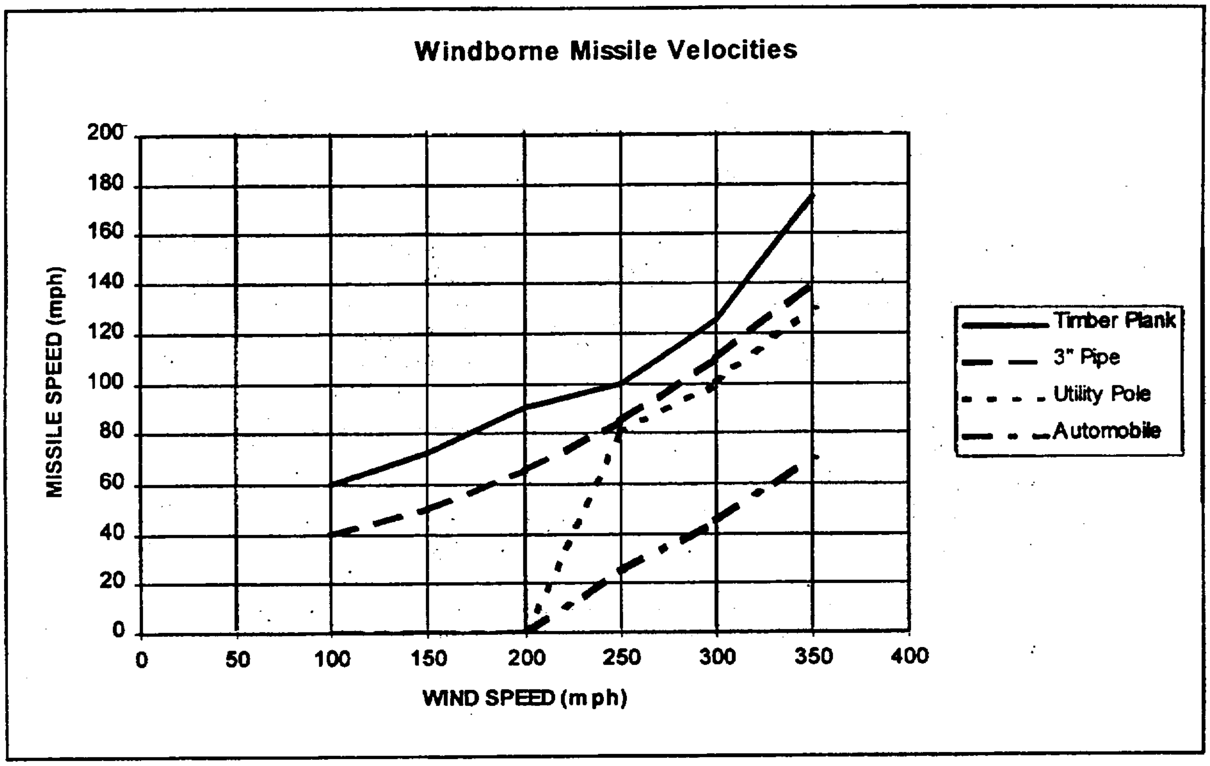

Figure 5-7. Missile Speed as a Function of Wind Speed

The performance categories (PCs) for facilities are related to the exceedance probabilities for the NPHs, as discussed earlier in this chapter. In the case of wind, the PCs are also related to the missile penetrations. These have been given in DOE-STD-1020-94 and are summarized in Table 5-5. In this table, the sustained (fastest-mile) wind speeds are those given that standard, rather than those from McDonald (1995) given above, because the two sets of wind speeds are nearly identical and it is proper to maintain consistency with DOE standards whenever possible. The relation between the Performance Categories and Exceedance Probability per year is shown in Figure 5-8. Note that the missile criteria in Table 5-5 (from DOE-STD-1020-94) do not match those given by Coats and Murray, quoted above in Table 5-4 and Figure 5-7. Those given in Table 5-5 take precedence.

5.3.4 Conclusion

Destructive tornadoes are considered *incredible* for the site. This is not to say that tornadoes cannot occur at the site, for they can. However, the credible tornadoes that could occur would be less damaging than the straight wind for the same exceedance probability. Thus, postulated accident scenarios initiated by tornadoes do not require a special evaluation in an accident analysis for the site. The most significant damage would be caused by straight winds, from pressure changes and airborne missiles. High-wind initiated accident scenarios are considered to result in spills and are evaluated as appropriate based upon the facilities performance category and construction criteria.

Table 5-5. Summary of Minimum Wind Design Criteria per DOE-STD-1020-94

	Performance Category	1	2	3	4
Wind	Annual Probability of Exceedance	2´10^{-2}	2x10^{-2}	1´10^{-3}	1´10^{-4}
Wind	Sustained Wind Speed	109 mph	109 mph	138 mph	161 mph
Wind	Missile Criteria	NA	NA	2´4 timber plank 15 lb @ 50 mph (horiz.); max. height 30 ft.	2´4 timber plank 15 lb @ 50 mph (horiz.); max. height 50 ft.
Tornado	Annual Probability of Exceedance	NA	NA	2´10^{-5}	2´10^{-6}
Tornado	Atmospheric Pressure Change	NA	NA	40 psf @ 20 psf/sec	125 psf @ 50 psf/sec
Tornado	Missile Criteria	NA	NA	2´4 timber plank 15 lb @ 100 mph (horiz.); max. height 150 ft.; 70 mph (vert.) 3-in.-dia. std. steel pipe, 75 lb @ 50 mph (horiz.); max. height 75 ft., 35 mph (vert.)	2´4 timber plank 15 lb @ 150 mph (horiz.); max. height 200 ft.; 100 mph (vert.) 3-in.-dia. std. steel pipe, 75 lb @ 75 mph (horiz.); max. height 100 ft.; 50 mph (vert.) 3,000-lb automobile @ 25 mph rolls and tumbles

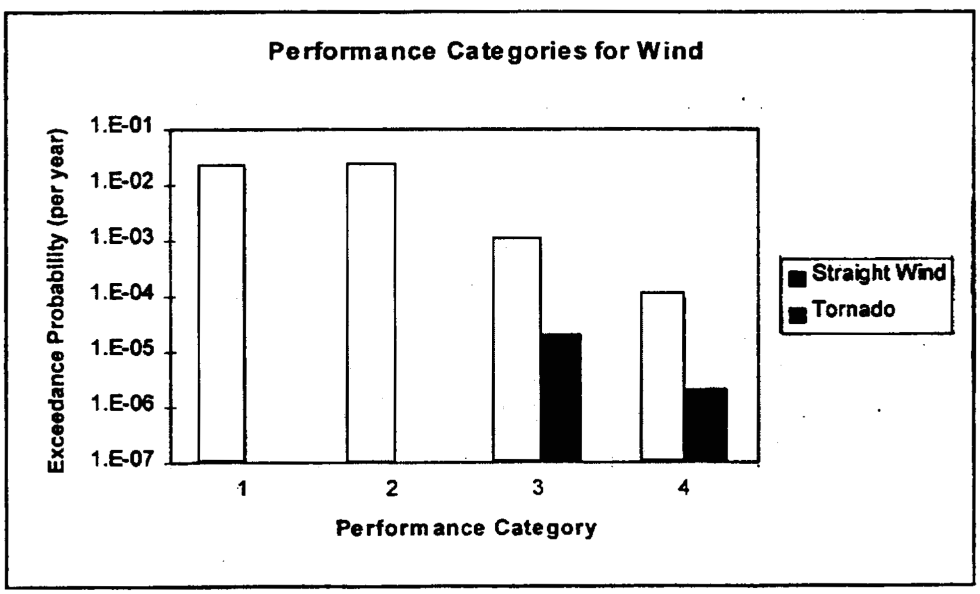

Figure 5-8. Performance Categories for Straight Winds and Tornadoes

5.3.5 References

DOE, 1994 *Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities,* DOE-STD-1020-94, U.S. Department of Energy, Washington, D.C., April 1994.

DOE, 1996 *Natural Phenomena Hazards Characterization Criteria,* DOE-STD-1022-94, Change Notice 1, U.S. Department of Energy, Washington, D.C., January 1996.

Hodgin, 1990 C. R. Hodgin, et al., *Wind Speed Analysis for Super Compactor Study*, EG&G Rocky Flats, Inc., Golden, CO, February 26, 1990.

RFETS, 1994 *Rocky Flats Risk Assessment Guide*, Revision 3, Safety Analysis, EG&G Rocky Flats, Inc., Golden, CO, September 30, 1994.

5.4 SIGNIFICANT PRECIPITATION EVENTS

5.4.1 Introduction

This chapter describes the history, meteorology, frequency, and consequences associated with Significant Precipitation Events. The historical sections address the past events in the region of RFETS and the impacts on the site from these events. The meteorological conditions and processes that lead to these events are described. Data from the site and from northern Jefferson County are used to prepare descriptive tables of precipitation statistics. These can be used to determine the probable frequency of occurrence or return period for a given magnitude of precipitation event.

Consequences of heavy precipitation may be the loss of human life and property, including damage to equipment and buildings as well as environmental damage caused by erosion and transport of soil and rock or transport of spilled materials. Section 5.4.2 describes some of the historical impacts to humans and property from heavy precipitation events. The following section describes additional impacts to buildings and equipment through excess roof loading due to heavy precipitation and ponding as well as impacts to the site from flooding. Site efforts to prevent erosion and sediment transport through best management practices and the potential for sediment transport through the ponds are summarized. The preventive measures to respond to spill events and on-site ponding of incidental waters are also included.

5.4.1.1 Regulatory Requirements

General Design Criteria, DOE Order 6430.1A (DOE, 1989), states: "*Storm water management systems shall be designed for not less than the 25-year, 6-hour storm*[a]. *The potential effects of larger storms (up to the 100-year, 6-hour storm) shall be considered.*" It also states that both storm sewers and open channels shall be sized to accommodate runoff from the 25-year, 6-hour storm. These facilities must be sized for a greater storm in locations where there is substantial risk to critical facilities and operations. Regarding street drainage, the DOE Order states: "*In locations where uninterrupted vehicular access is essential to critical operational activities, roadway cross sections shall be designed to convey runoff from the 25-year, 6-hour storm such that one driving lane (width of 12 feet) is free of flowing or standing water. Storm water management systems have sufficient capacity to ensure that runoff from the 100-year, 6-hour storm will not exceed a depth of approximately 10 inches at any point within the street right-of-way or extend more than 0.2 feet above the top of curb in urban areas.*" Additional regulatory considerations are specified in Chapter 2, Section 2.3.2.

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a. For the site, the 25-year, 6-hour storm is equivalent to about 2.4 inches of precipitation (Table 5-7).

5.4.2 Evaluation Parameters

5.4.2.1 Necessary Conditions

The conditions normally required for severe thunderstorm formation include (a) a warm, moist, unstable air mass, (b) a strong cold front to provide the needed lift, and (c) an airflow aloft that favors the formation of strong updrafts. In the United States, these conditions are most prevalent in the spring and early summer when warm, moist maritime tropical air from the Gulf of Mexico clashes with cold, dry continental air from polar Canada. At this time of year, there is a large temperature contrast between these two air masses, and cold fronts normally move rapidly, adding to the vertical acceleration of the displaced air. Also, because of the sharp temperature contrast, a steep pressure gradient exists aloft, generating a strong jet stream parallel to the front. Near the cold front, divergence in the upper-level jet stream favors upward flow and cloud formation. The formation of severe thunderstorms can be enhanced by the existence of a temperature inversion located a few kilometers above the earth's surface (Lutgens, 1986).

Not all severe thunderstorms occur along cold fronts. In some instances, a line of thunderstorms may form as much as 300 kilometers ahead of the cold front along a narrow belt called a "squall line". Some squall-line thunderstorms form when continental tropical air from the southwestern United States is pulled into a middle-latitude cyclone. The denser continental tropical air acts much like a cold front to forcefully displace the lighter maritime tropical air upward. On other occasions, squall lines are initiated by disturbances in the airflow aloft (Lutgens, 1986).

Once formed, a squall line helps propagate itself by aiding in the development of new cells downwind. This occurs as the downdrafts from the thunderstorm cells of the squall disturbance produce an advancing wedge of cold air. The leading edge of this advancing cold air is called a "gust front". Lifting of warm air along the gust front initiates the development of new cells ahead of the squall line. Thus, the squall-line disturbance generally moves ahead of and parallel to the cold front at speeds often exceeding that of the cold front (Lutgens, 1986).

5.4.2.2 Precipitation Frequency

The climate at the site is characterized by dry conditions -- low humidity and low precipitation. Annual average precipitation at the site is about 15 inches. The rainiest season at the site is the spring, during the month of May. The greatest amount of rainfall received in any one day at the site was 3.54 inches in May 1995. Forty percent of the site's total annual precipitation occurs during the spring months of March, April, and May. Colder periods of the spring season produce snow that is often interspersed with mild, sunny weather, which typically removes the snow cover. Heavy runoff sometimes occurs along the creeks that traverse the site, particularly during spring thaws and thunderstorms. Summer precipitation from scattered local thundershowers occurring during the months of June through August during the afternoon and evenings contributes about 30 percent of the annual total precipitation. Autumn, with more sunny days, has fewer thunderstorms. Precipitation for the months of September through November amounts to about 20 percent of the annual total. The months of December, January, and February are the coldest months and have the least precipitation. Most of the moisture falls as snow during this period, with the average total equaling 10 percent of the annual precipitation (RFETS, 1995a; Hershfield, 1961; and DOC, 1973).

Figure 5-9 shows annual precipitation for the years from 1953 through 1997; no precipitation data exist for the site for 1977 - 1983 and the data are incomplete for 1984 - 1985, so no data are plotted for these years. These data were taken from the Aerovironment (1995) report, supplemented with data provided by the site's Surface Water Group. This plot illustrates the fluctuation in annual precipitation at the site.

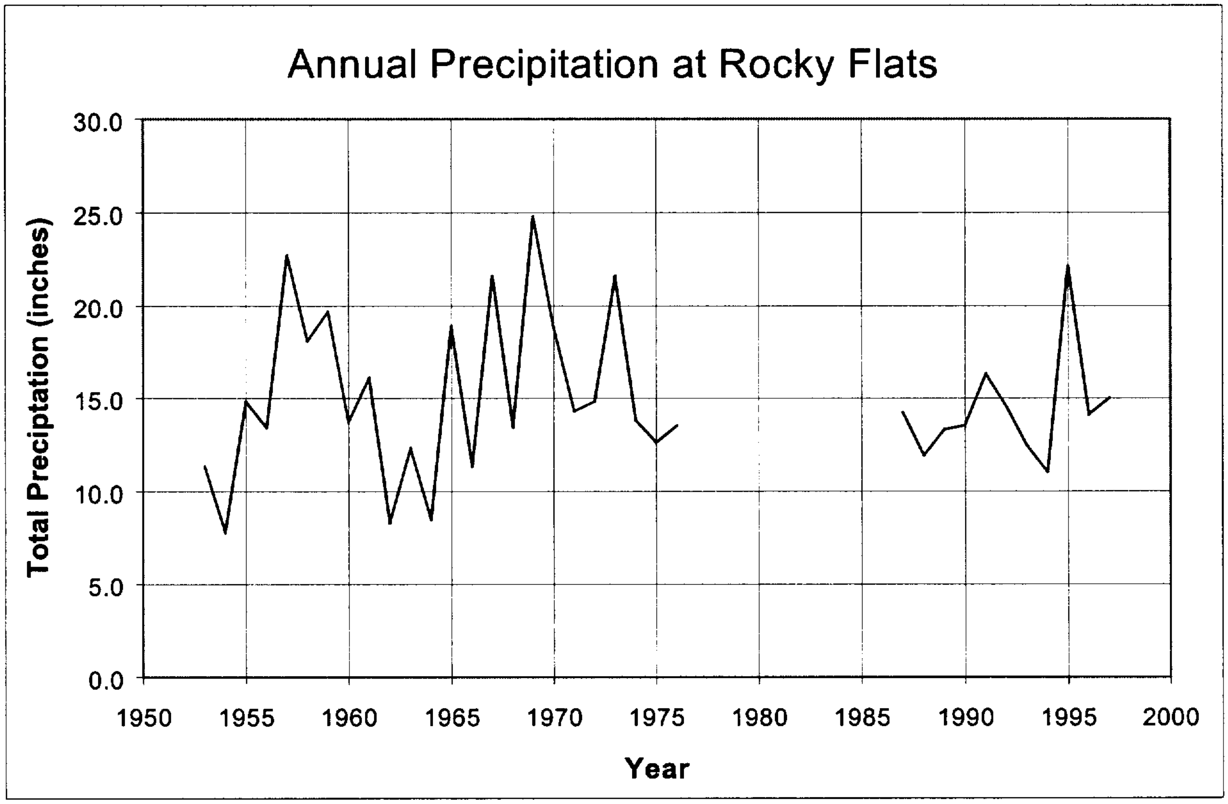

Figure 5-9. Site Annual Precipitation

Site monthly and annual precipitation means and medians are given in Table 5-6. Table 5-7 summarizes the return periods for the 1-hour, 2-hour, 3-hour, 6-hour, 12-hour, and 24-hour precipitation intervals as a function of return period (years). This table has been taken from Hershfield (1961). Data for the site from Aerovironment (1995) give smaller values than in this table, whereas the data from the NOAA Atlas for Colorado (DOC, 1973) give larger values. The Hershfild data have been chosen as that data represent a compromise between the Aerovironment and NOAA data sets and because the Hershfild data are the most complete. These data are representative of precipitation in northern Jefferson county over a many-year period. From this table it can be seen that 0.6 inch of precipitation can be expected during some 1-hour interval every year (on the average) and 4.1 inches can be expected during some 24-hour interval once every 100 years.

The amount of rain corresponding to the DOE Order 6430.1A (DOE, 1989) design limit for the 25-year, 6-hour storm is 2.4 inches and that for the 100-year, 6-hour storm is 3.1 inches.

Table 5-6. Site Monthly Precipitation Means and Medians

Statistic	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean Precipitation (in)	0.46	0.57	1.27	1.56	2.68	1.56	1.46	1.30	1.50	0.09	0.83	0.47	14.46
Median Precipitation (in)	0.31	0.54	0.94	1.25	2.07	1.17	1.26	1.22	1.26	0.53	0.82	0.37	13.51
For the years 1953-1977 and 1987-1993.													

Table 5-7. Precipitation for Various Return Periods and Time Intervals at the Site (in inches)

RETURN PERIOD (y)	TIME INTERVAL FOR PRECIPITATION					
	1-Hour	2-Hour	3-Hour	6-Hour	12-Hour	24-Hour
1	0.6	0.7	0.8	1	1.1	1.3
2	0.7	0.9	1.1	1.2	1.4	1.6
5	1.1	1.3	1.4	1.6	1.9	2.2
10	1.4	1.6	1.8	2	2.2	2.7
25	1.7	1.8	2.1	2.4	2.7	3.2
50	1.9	2.1	2.4	2.8	3.3	3.5
100	2.1	2.4	2.6	3.1	3.5	4.1

5.4.2.3 Precipitation Hazards

Impacts of heavy precipitation may endanger human life and property, including damage to equipment and buildings as well as environmental damage caused by erosion and transport of soil and rock or transport of spilled materials. The following section describes additional impacts to buildings and equipment through excess roof loading due to significant precipitation and ponding as well as impacts to the site from flooding. Site efforts to prevent erosion and sediment transport through best management practices and the potential for sediment transport through the ponds are described. The preventive measures to respond to spill events and on-site ponding of incidental waters are also discussed.

5.4.2.3.1 Rain Loads on Roofs

This section describes the effects of water depth and hydrostatic loading for short-period, extreme-precipitation events that pose an immediate threat to the structural design capacity of facility roofs. A generic, or non-building-specific, hazard curve is developed, based on amount of rainfall and/or ponding. Drainage system failure, resulting in a worst-case hydrostatic roof loading, is also discussed.

Roof drainage is designed to handle all the flow associated with intense, short-duration precipitation events. A very severe local storm or thunderstorm may produce a deluge of such intensity and duration that properly designed drainage provisions are temporarily overloaded. Temporary roof loads may be generated during such an intense storm. Such temporary loads are adequately covered in design when ponding loads and blocked drains are considered (ASCE, 1993).

Water may concentrate as ponds in undrained low areas of a roof. As additional water flows to such an area, the roof tends to deflect more, allowing a deeper pond to form. If the structure is not stiff enough to resist this progression, failure by localized overloading may result (ASCE, 1993).

Generally, roofs with a slope of 0.25 inch/foot (2.1 percent) or more are not susceptible to ponding instability from rain alone unless drain blockages allow deep ponds to form. Avoiding deep ponding if one drain becomes blocked is particularly important for flexible roof systems. The amount of ponding that would result from blockage of the primary drainage system should be determined and the roof designed to withstand the ponding load that would result plus an additional five pounds per square foot to account for the head needed to cause flow out of the secondary drainage system. Primary and secondary (overflow) roof drains are required as specified in DOE Order 6430.1A (DOE, 1989) or other local regulations. If parapet walls, cant strips, expansion joints, or other features create the potential for deep ponding in an area, it is often advisable to install in that area secondary (overflow) drainage provisions with separate drain lines to reduce the magnitude of the design load (ASCE, 1993).

The potential load on a building caused by Significant Precipitation can be calculated from the density of water (62.43 lb/ft^3) and the amount of rain. The total weight of water on a roof is dependent upon the average depth of water and the total area of the roof that is impacted. The structural design load, construction materials, and maintenance of the building are the factors that determine if the roof will be damaged by the amount/weight of the water.

5.4.2.3.2 Flooding

The Rocky Flats Plant Drainage and Flood Control Master Plan (DOE, 1992) (Master Plan) analyzed the effects of storm events (return periods between 2 and 100 years) at the site. To determine the flood hydrology characteristics of the site, the Master Plan utilized three models. Hydrographs for the plant were developed using the Colorado Urban Hydrograph Procedure. These hydrographs were then used to create a Stormwater Management Model. In order to further define the hydrology of the core area of the site, a HydroCAD model was developed to utilize the Stormwater Management Model output. In addition to these three models, the HEC-2 computer model was used to calculate flood elevations within selected drainage basins or areas. Several areas were found to be vulnerable to flooding during a 25-year storm event under present drainage conditions. A portion of this study examined the effect of large flood flows on the A- and B-series drainage ponds. For both the A- and B-series ponds, there was adequate capacity to contain the 25-year flood flow, but the 100-year flood flow filled all of the ponds and spilled out of terminal Ponds A-4 and B-5. Pond C-2 would contain the 10-year and 25-year flood flow, but the 100-year event would exceed its safe operating capacity. Although the ponds were originally designed to contain the 6-hour, 100-year flood, improvements to the Industrial Area, including increased paving, have increased runoff so that the 100-year flood would not be fully contained. In addition, because of the developed nature of the Industrial Area and its storm drainage system, very small precipitation events (less than 0.08 inch) are expected to show a runoff response.

The *Drain Repair and Improvement Plan Study* (EG&G, 1994) was written to address the most serious of the deficiencies in the stormwater drainage systems. The study provides recommendations for the correction of these deficiencies. Possible impacts from flood flows during high runoff storm events include floodwater inundation of facilities and equipment, loss of critical access to buildings and operational areas, scouring of contaminated sediments, and failure of detention or diversion structures. The *Drain Repair and Improvement Plan Study* focused on deficiencies associated with the three major drainage corridors of the site Industrial Area: North Walnut Creek drainage, South Walnut Creek drainage, and Central Avenue ditch. Analyses were also performed on the Woman Creek bypass structure and the Cottonwood Avenue drainage, which extends from the area of Buildings 444 and 460 to Central Avenue. Deficiencies and their associated impacts are described below.

Building 335

Building 335 is subject to flooding due to (a) lack of carrying capacity of the adjacent culvert and (b) the building's location in a low area of the drainage. Since the Master Plan was issued, the 24-inch line that carried flow under Sage Avenue was replaced by a 36-inch reinforced concrete pipe. However, the inlet to the 36-inch line is 70 percent blocked by sediment so that it does not provide adequate capacity to convey drainage without inundation of the area around Building 335 with a five-year storm. During a 100-year storm, the water surface would be approximately 3.2 feet above the building's finished floor elevation. With clean-pipe conditions, inundation would occur with a level slightly less than the 25-year storm. Since Building 335 is used for non-emergency fire equipment storage and is constructed of sheet-metal material that would not be damaged if subject to flooding, the existing flood risks may be acceptable.

Between Buildings 771 and 790

The area between Building 790 and Building 771 is subject to inundation because it is a flat low-lying area with inadequate conveyance capacity of adjacent storm sewers. Trailers T771D, T771E, T771J, T771K and neighboring cargo containers would be impacted. Because of security restrictions, the capacity of the 48-inch storm sewer is limited to slightly less than the 25-year storm event storm water ponds at the entrance of the culvert. The exact depth and elevation of ponding depend upon the flow rate and are, therefore, specific to each storm event. In general, the 25-year flooding would not exceed the finished floor elevation of the trailers or buildings, although shallow flooding could cause access problems and minor damage.

Building 991 and the B-1 Bypass

Building 991 is located in the lower portion of the Core Area watershed, which is situated in a natural drainage way and is affected by headwater conditions of adjacent culverts. Complex drainage conditions exist at this portion of the site. "Passive" detention of stormwater is currently provided at several culvert entrances above and below Building 991. Under current conditions, the first finished floor of Building 991 is above the ponded 500-year flood elevation, although the southeast stairwell accessing the basement and west storage bays are subject to flooding under 25-year flood conditions. Both the emergency generator and transformer are subject to flooding by the 10-year storm. If the storm sewers and culverts near Building 991 are not maintained and become fully silted, these facilities will be subject to even more frequent inundation (two-year).

Cottonwood Avenue Drainage/Buildings 444 and 460

The Cottonwood Avenue drainage path flows along the south side of Cottonwood Avenue north of Buildings 460 and 444. The entrance drive to a loading dock on the north side of Building 460 blocks this drainage path near the northwest corner of Building 460. Water that ponds west of Building 460 in excess of the storm sewer capacity is forced to drain via overland flow eastward along the south side of Building 460 and then northward on the east side of Building 460.

The five culverts along the drainage path are undersized. They are in poor maintenance condition and would convey only a small fraction of the runoff from the 25-year, 6-hour storm event. The earthen swale that forms the drainage path from Building 444 to the intersection of this drainage path with Central Avenue is inadequate to convey the flow from a two-year storm event. The local storm sewer located around Buildings 444 and 460 has the capacity to convey slightly less than the five-year storm event. Flooding along this drainage path, due to inadequately sized culverts and drainage swales, will not cause flooding to buildings during the 25-year, 6-hour storm event. During the 100-year, 6-hour storm event, flooding will occur along the west side of Building 444. Cottonwood Avenue (immediately west of Parking Area No. 444), Central Avenue (immediately north of Cottonwood Avenue), and the railroad tracks (immediately west of Parking Area 444) will be overtopped by floodwater.

An area of depression located between Buildings 444 and 460 is subject to inundation by both localized rainfall and stormwater overflow drainage around Building 460. An eight-inch berm prevents overflow for up to the 25-year event, but allows a flow of five cubic feet per second (cfs) into the depression area during the 100-year event. The storm sewer that drains the area bounded by the berm and Buildings 444 and 447 has the capacity to convey less than the two-year event before ponding will occur. For the 25-year and greater storm events, ponded water will be above the finished floor elevation of Building 444.

Central Avenue Drainage

The portion of the evaluated drainage area involves the south side of Central Avenue (extending from the Fifth Street Crossing on the west to the point of the drainage crossing under

CHG-15

Central Avenue approximately 700 feet east of where Building 886 use to stand). The primary drainage structure in this reach is an earthen channel interrupted by numerous crossing structures to access side streets and buildings adjacent to Central Avenue. Analysis shows the channel is generally capable of conveying the 10-year storm, but the culvert crossings are capable of conveying less than the two-year storm without overtopping. The capacity of the crossings limits the capacity of the drainage. This drainage segment was identified as deficient in the Master Plan with respect to maintaining access along the Central Avenue roadway at all times and causing inundation of facilities located to the south of the ditch. Buildings that are vulnerable to shallow flooding include the Building 442 electrical box and the 452 Trailer Complex (T452B, T452C, T452D, T452F, and T452G). Additional features that may be affected by floodwater include utility vaults (telephone, electrical, and steamline), sanitary sewer manholes, air-conditioning equipment, and electrical transformers.

CHG-15

Vicinity of the former Building 886

April/May 1995: Flooding occurred in the Filter Plenum 502, the Plenum Deluge Tank D-501, and the duct inside the underground tunnel. High water levels in the 828 pit (due to high ground water level from an extended period of heavy rain in April 1995) was the cause of flooding. Water in the 828 pit flowed through the vent line into the exhaust duct. A valve on the Building 828 pit vent line leading to the duct was supposed to be closed, however it partially opened, possibly by the water pressure in the vent line (RFETS, 1995b). Incoming water to the plenum stopped when the partially-opened valve was identified and closed. Water in the plenum and deluge tank was slightly contaminated with uranium, and was shipped to liquid waste operation for processing. The water was measured to contain a maximum of 4,500 picocuries per liter, or approximately 0.07 mg/l.

The high ground water from the above flooding incident also seeped into the Room 103 pit in Building 886; the highest water level in the pit was 2.5 inches. The pit was filled with Raschig rings up to a depth of 11 inches. The Criticality Safety Department determined that as long as the water level remains below five inches, no violation of the safety limits exists and no further action is needed. However, the Criticality Safety Department imposed a routine surveillance of the water level in the pit (Malinosky, 1995a, 1995b).

5.4.2.3.3 Storm Water

A National Pollutant Discharge Elimination System (NPDES) Storm Water Discharge Permit application was submitted for the site to the Environmental Protection Agency on September 29, 1992. (As of the end of October 1999, this permit has yet to be issued.) The Storm Water Discharge Permit application contained the following information: outfall location and receiving water; a description of improvements to the site that may affect the storm water discharges; a site drainage map; a narrative description of pollutant sources for each of the six outfalls; a certification that non-storm water discharges do not take place at any storm water outfall; a history of significant leaks and spills for the last three years; and chemical and physical discharge information. In addition, a (Draft) *Storm Water Pollution Prevention Plan* (RFETS, 1994), required by the permit, was prepared. The purpose of the (Draft) *Storm Water Pollution Prevention Plan* is to implement measures to minimize pollution associated with storm water runoff.

Site hydrologic and storm water quality characterizations are generated from in-stream gauging stations. The stream gauges are equipped with continuously recording flow meters and automatic water samplers that are programmed to sample storm events and pond discharge event flows whenever specified water flow levels are reached. More information concerning surface water monitoring is available in Chapter 2, Section 2.3.2.

5.4.2.3.4 Sediment Transport

The potential for sediment transport was investigated as part of the *Final Phase I RFI/RI Report Woman Creek Priority Drainage Operable Unit 5* (RFETS, 1996a). This report concluded that while the presence of contaminants in stream, seep, and pond sediments is likely a result of surface-water transport of contaminated surface soils to Woman Creek, cancer risk estimates are within the Environmental Protection Agency target risk range of 1E-06 to 1E-04 latent cancer fatalities per year. External irradiation due to exposure of uranium-238 in surface soil is the primary contributor to this estimate of cancer risk.

The potential for sediment transport was investigated as part of the *Final Phase I RFI/RI Report Walnut Creek Priority Drainage Operable Unit 6* (RFETS, 1996b). This report concluded that the presence of contaminants in pond sediments is a result of historical discharges to the ponds and runoff from site facilities to the North and South Walnut Creeks. Surface water modeling indicates that the chemical concentrations in pond sediments will not increase in the future from source loads in OU6, which are insignificant compared to existing pond sediment concentrations. Furthermore, little potential exists for contaminated pond sediment transport beyond the ponds themselves, even under extreme precipitation events. Because model simulation indicates that no net erosion occurs at any of the detention ponds, there is little likelihood for contaminated sediments to migrate out of the system past Indiana Street.

Erosion and sediment transport modeling is being done for the entire site to establish appropriate soil clean-up levels for closure under the Actinide Migration Evaluation project. Results of this study will be presented for present site conditions and future scenarios in two reports due in FY00.

5.4.2.3.5 Incidental Water

Water of unknown quality or origin that has ponded in natural or man-made depressions within the Industrial Area are called incidental waters. Incidental waters, typically those contained within a vault or pit, may originate from several sources including precipitation, surface water runoff, groundwater, utility water, process water, or wastewater. Precipitation and stormwater runoff can cause incidental waters to accumulate in excavations, pits, trenches, ditches, depressions, secondary containments, process waste valve vaults, electrical vaults, sumps, and manholes. Water accumulated in these locations is controlled, contained, analyzed, and treated or discharged according to procedures described in the *Control and Disposition of Incidental Waters* (RFETS, 1998b).

5.4.2.3.6 Spills

An internally reportable release includes all unplanned solid and liquid releases of hazardous substances equal to or greater than one pound for solid substances, one pint for liquids, or any amount for gaseous releases. These criteria apply whether the release is inside or outside a building. A release of solid or liquid of less than one pound or one pint is also internally reportable if the release directly impacts the environment. All releases are reportable to the Shift Superintendent and the Emergency Operations Center (RFETS, 1994).

Response plans and procedures have been developed. They document both actions to be taken in response to a spill occurrence and arrangements for cooperative aid. The most pertinent of these documents are the *Rocky Flats Plant Emergency Plan* (RFETS, 1997), the *Occurrence Reporting Process Process* (RFETS, 1998), the *RCRA Contingency Plan* (RFETS, 1989), the *Release Response and Reporting Procedure* (RFETS, 1993b), and the *Rocky Flats Fire Department Hazardous Materials Team Standard Operating Procedure* (RFETS, 1990).

5.4.2.3.7 Off-Site Hydrology Projects

Standley Lake, located downstream of the site, supplies drinking water for the municipalities of Westminster, Thornton, and Northglenn. In October 1990, DOE agreed to fund an off-site surface water supply project known as Option B to further reduce any risks posed by the site to downstream water users. The plan included two primary components: (a) off-site improvements to physically isolate and protect Standley Lake water quality from future site impacts and (b) replacement of Great Western Reservoir as a drinking water supply for the City of Broomfield by the acquisition of an equivalent water supply (see below). In general, the purpose of Option B is to guard against potential accidental releases from the site and not to serve as a remedial response. Although funding for Option B is provided by DOE, the cities of Westminster, Thornton, Northglenn, and Broomfield are responsible for designing and implementing the project.

The Standley Lake Protection Project portion of Option B included the following major features: (a) a reservoir on Woman Creek, east of Indiana Street, to capture and store runoff from the Woman Creek watershed and a pipeline and pump station to divert this water to Big Dry Creek and (b) a pipeline to route Kinnear Ditch water to Standley Lake before it reaches Woman Creek. The Woman Creek Reservoir was completed in October 1995 and the Kinnear Ditch pipeline was completed in April of 1995. Included as part of the Standley Lake Protection Project is a 370-acre wildlife habitat and wetlands mitigation site.

The Great Western Reservoir replacement portion of the Option B project included (a) the purchase of an alternative source of raw water for the City of Broomfield; (b) the development of a delivery system from the raw water source to Broomfield; (c) a new water treatment facility for the incoming raw water; and (d) a raw water storage system. Carter Lake now supplies the raw water for Broomfield. The pipeline and water treatment plant were completed in 1998.

5.4.3 Conclusion

The climate at the site is characterized by dry conditions - low humidity and low precipitation. Annual average precipitation at the site is about 15 inches, with the heaviest precipitation occurring during the month of May. The most recent significant precipitation event occurred on May 17, 1995, which caused flooding throughout the site. There are no dams or tributary streams that would cause flooding of the site if they failed or overflowed. However, several areas were found to be vulnerable to flooding during a 25-year storm event under present drainage conditions. These areas include Buildings 335, the vicinities around Building 991 and between Buildings 444 and 460, as well as several T452 and T771 trailers. Therefore, these areas should not be used to store materials that could be damaged by exposure to moisture or potential flooding conditions unless appropriate physical precautions are taken. The off-site hydrology projects serve as a final level of protection for the public against the impacts of contaminated materials reaching public drinking water supplies during significant precipitation events or other water-mediated events.

5.4.4 References

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5.5 HEAVY SNOW

5.5.1 Introduction

This section summarizes the frequency and impacts of heavy snow events at RFETS, including historical snow conditions, and addresses heavy snow-load concerns. It presents a statistical analysis of snow event frequency using snow event data obtained from records and from the National Weather Service Station in Boulder. The relationship between heavy snow and building design loads is then examined. Structural design load information is based on guidelines from the American Society of Civil Engineers and the Structural Engineers Association of Colorado. From these data, two categories of hazard curves are created to allow the reader to determine the probable occurrence of damage from heavy snow events. These are the snow event frequency curves and a relation curve between snow design load and building category.

The amount of snow, the snow density and the water weight determine the total load on a building's structural elements. Heavy snow events are capable of causing properly designed structures to suffer either local or general collapse. An example of limited local collapse would be the loss of a roof section, caused by uneven snow loads, with resulting damage to only one area of an upper floor room. The damage could involve roof materials and/or structural supports falling onto and breaking open containers of hazardous materials. Also, large amounts of melting snow could potentially cause water damage, spread of contamination or criticality conditions. General collapse is the spread of an initial local failure from element to element resulting in the collapse of an entire structure or a disproportionately large part of it.

Snow loads are variable. Besides the frequency and amount of snowfall, which are influenced by meteorological conditions and elevation, several other factors must be considered in determining the appropriate design snow load. These factors include, but are not limited to, localized drift loads, wind exposure, sun exposure, projections on a roof, roof material, roof slope, distance to neighboring structures, the height of neighboring structures, heat sources and temperatures, thermal insulation, frequency of freeze-thaw days, and potential for ponding on the roof or other conditions that could prevent snow melt from draining. Each of these factors is considered before a structure is designed, although the severity of the climate at the site does not make these factors as important at the site as at higher altitudes in Colorado.

5.5.2 History

To date, there are no known consequences of heavy snow events resulting in major structural damage at the site. However, heavy snowstorms have caused personal and property damage, primarily due to the associated icy conditions, below-freezing temperatures, and poor visibility. Several times each year, joint decisions between site management and DOE have resulted in suspension of operations and release of nonessential personnel during adverse weather conditions. Snow itself is not a cause for site closure. However, when road and driving conditions have deteriorated to a level that would endanger people, then the choice is made to release personnel and suspend operations.

The *Rocky Flats Environmental Impact Statement* (DOE, 1980) includes long-term meteorological data from four National Oceanic and Atmospheric Administration (NOAA) stations: Denver, Fort Collins, Greeley, and Boulder. Because the Boulder station is closest to the site, the snowfall data for the time period from 1951 to 1973 was included in that report. An accident analysis was not performed for a snow event because the *Impact Statement* did not consider snow to be a hazard at the site.

The *Rocky Flats Risk Assessment Guide* (RFRAG), Revision 3, (RFETS, 1994) provides guidelines for performing risk assessments and rebaselines to Final SARs at the site. Included in the guide are the methodologies and hazard curves recommended for natural phenomena event analyses. However, there are no hazard curves for the heavy-snow accident. The RFRAG states, "Damage from excessive snow loadings is not addressed because buildings were designed to meet code requirements in effect when each building was built. It has been determined by Facilities Engineering and Construction that snow loads do not constitute an important structural design or accident factor." It is possible that snow loading could become an issue for waste storage buildings.

5.5.3 Evaluation Parameters

5.5.3.1. Necessary Conditions

Most failures associated with snow loads on roofs are caused not by moderate overloads on every square foot of the roof, but rather by localized significant overloads caused by drifting snow. The possibility of an increase in loading due to drifting snow has to be considered on a structure-by-structure (building) basis. Ice loads of 100 pounds per lineal foot should be applied at the edges of sloped roofs. On heated buildings with overhanging roofs, this should be applied in conjunction with full snow load on the overhang and no snow load on the interior span (SEAC, 1971). The goal of establishing a snow load design value is to reduce the risk of a snow load-induced failure to an acceptably low level. Since snow loads in excess of the design value may occur, the implications of such "excess" loads should be considered. For example, if a roof is deflected at the design snow-load such that an adequate drain slope is eliminated, an excess snow load may cause ponding and perhaps progressive failure. Additionally, the snow-load/dead-load ratio also becomes important when determining impacts from excess loads. Therefore, the importance, intended use, and projected lifespan of a structure are crucial factors to determine the snow load design strength and resulting cost implications.

5.5.3.2 Hazard Curves - Snow Frequency

The first step in snow load design is to determine the snow amount and snow event frequency for the structure in question. Snow hazard curves plot the magnitude of the snow event as a function of the frequency of occurrence, or return period of that magnitude. Historical snow data are evaluated statistically and then used to develop the frequency curve.

Historical site meteorological data collected from 1952 to 1977 and 1986 to autumn of 1991 provide only total precipitation data with no differentiation between precipitation as rain or snow. However, the site has collected snowfall data separately from total precipitation data, beginning with the 1991/1992 snow season. A snow season is defined as the time period from September through June. (There are no recorded snows in this area during July and August.) For each snow event, the database includes the date, time and duration, and depth of snow received, plus monthly snowfall totals.

Because the amount of site data is insufficient to determine long-term frequencies, additional data records from Denver, Colorado Springs, and Boulder have been considered for comparison and inclusion in this report. Denver and Colorado Springs data were eliminated because these cities are located far from the site, are at different elevations, and have different topography relative to the foothills. These different conditions resulted in significant meteorological differences. The Boulder weather station data were selected as being representative of the site. The Boulder station is physically close to the site (approximately 10 miles north), has nearly the same elevation (the site elevation is approximately 500 feet higher), and has similar topography, both being located on a plateau close to the foothills.

Records from the National Weather Service Boulder station were obtained from the State Climatologist Office and the National Oceanic and Atmospheric Administration. These records contain data on annual snow seasons, beginning in 1897/1898 and continuing to the present. It is only since 1948 that snow data have been collected on a monthly and event-day basis.

The amount of snowfall received in a given snow season is highly variable. This variability is illustrated in Figure 5-10 for the snow seasons in Boulder from 1897/1898 through 1994/1995. The top portion of the figure shows snow season amounts. The mean is 76.5 inches per year. Also shown are the upper and lower confidence levels at 3 sigma (Σ) or 99.7 percent. The lower graph uses the same data, but calculates the difference in total snow amount from one season to the next with similarly calculated confidence levels. These graphs show the variability in snow amount ranging from a recorded minimum of 21.6 inches per snow season to a maximum of 142.9 inches; the average difference or variability from snow season to snow season is only 27.9 inches. Figures 5-11 and 5-12 show the statistical distribution of these data to illustrate that the Boulder data follows a statistically normal distribution.

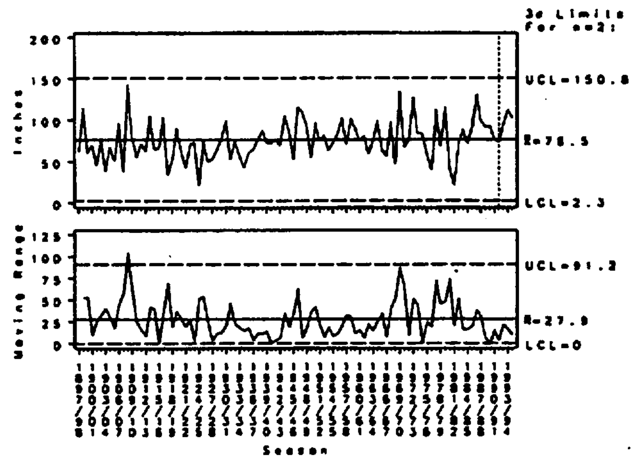

Figure 5-10. Boulder Seasonal Total Snowfall Amounts, 1897/1898 through 1994/1995

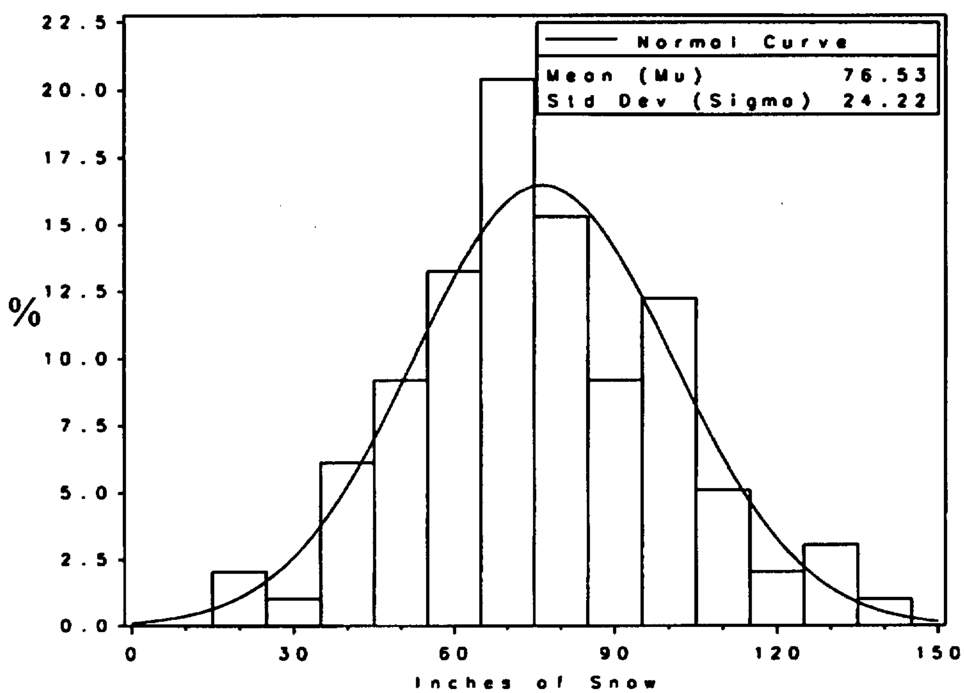

Figure 5-11. Boulder Season Total Snowfall Amounts, 1897/1898 through 1994/1995

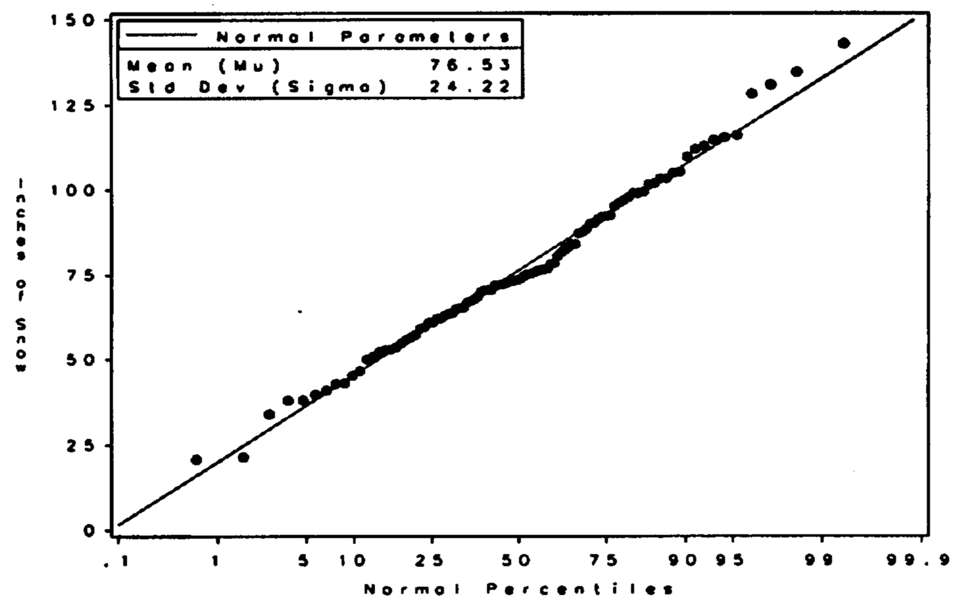

Figure 5-12. Boulder Season Total Snowfall Amount Normal Probability Plot

Differences in snowfall data between the site and Boulder were statistically evaluated in Nuclear Safety Engineering Calculation No. 96-SAE-032 for four snow seasons (RFETS, 1996). Snowfalls occurred in 29 months during this period. Boulder received more snow than the site during 14 months and the site received more snow than Boulder during 15 months. The average difference between the two locations was found to be only -0.74 inch and the standard deviation of the difference was 5.84 inches or about 8 times larger than the average difference. The site seasonal snowfall shows a linear correlation with that of Boulder, as shown in Figure 5-13, with a correlation coefficient of 0.84. Therefore, the Boulder snowfall data can be used to create a frequency curve for the site.

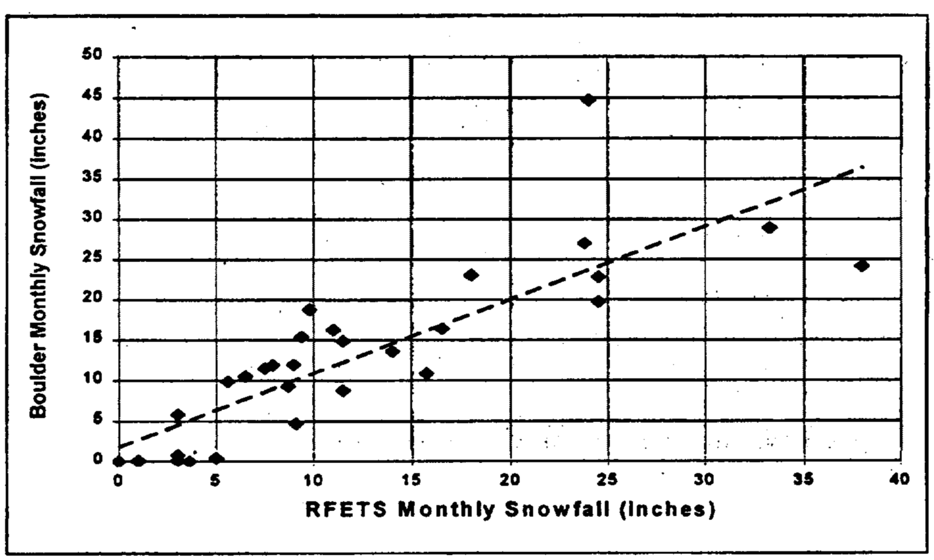

Figure 5-13. Comparison of Site and Boulder Snowfall, 1991/1992 - 1994/1995

The annual exceedance probability, or exceedance frequency, shown in Figure 5-14, was created by annualizing Boulder data for each snow event-day, i.e., each day that received more than 0.5 inches of snow. From Figure 5-14, it is possible to determine the frequencies of various snowfall amounts. For example, once per year a daily snowfall of 11 inches or more is expected and once every ten years a daily snowfall of 19 inches or more is expected.

The frequency curve has limitations because it was obtained from daily snowfall data and not total storm data. For example, if a snowstorm lasted for three days, it would be recorded as three separate event-days. Unfortunately, there are no data to support total snow amounts or total snow accumulation to determine maximum snow loadings for buildings.

5.5.3.3 Hazard Curves - Building Load

The Basic Building Code, Building Officials and Code Administrators International, Inc. (BOCA), provides recommended snow loads for consideration in the design of buildings and other structures in the United States. The design snow load in pounds per square foot (psf) is determined from maps of the United States that show isopleths of ground snow for 25-, 50-, or 100-year mean recurrence intervals. For example, the ground snow load isopleth value for the Denver area is 30 to 35 psf (Tartaglione, 1991). The design snow load is obtained by multiplying the ground snow load isopleth value for a geographic area by factors that consider wind exposure, slope of roof, snow-load distribution, etc., as given below.

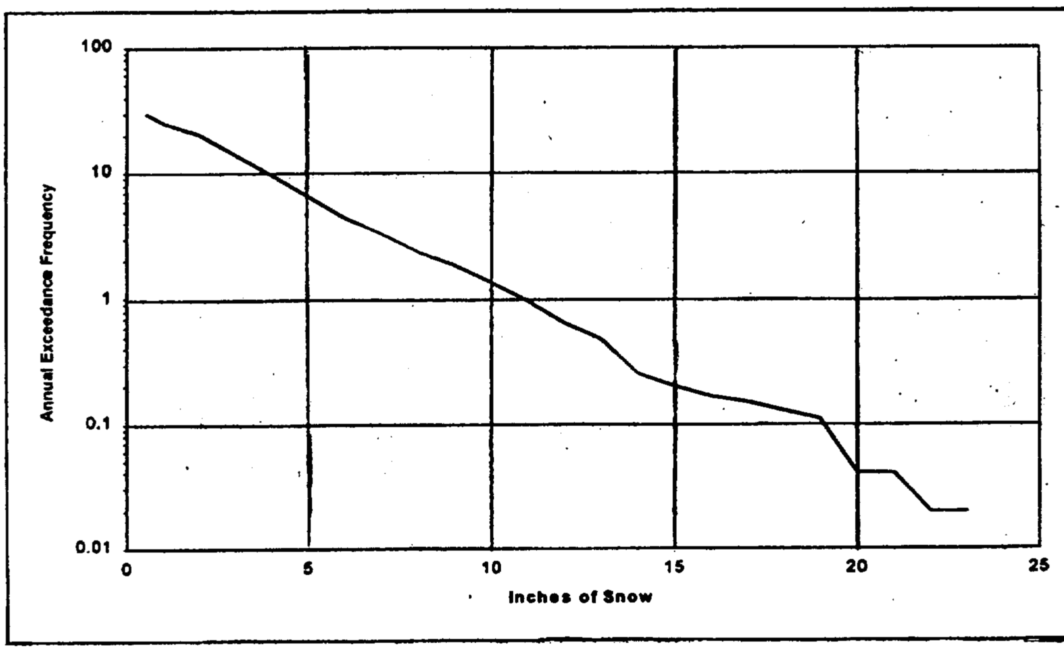

Figure 5-14. Annual Exceedance Frequency of Snow Received per Event-Day

The Jefferson County Building Department also publishes a basic snow load design table based on a formula that increases the required basic snow load design with elevation. Using this formula for the site, which is at 6,000-foot elevation, results in a snow load design criterion of 23 psf. However, elevations below 6,500 feet are recommended to use a basic snow design load of 30 psf instead of the lower calculated, or formula, value. Therefore, according to the Jefferson County Building Department table, the site should design to a basic snow load of 30 psf.

Snow Load Design Data for Colorado, published by the Structural Engineers Association of Colorado in 1971 (SEAC, 1971), provides guidelines for determining a basic design snow load at any location within Colorado. This report included a snow design load table created for principal cities in Colorado. The table was compiled from a formula that rated altitude as the most significant factor for each particular city. The recommended basic snow design load values are 30 psf at Boulder, 35 psf at Golden, and 30 psf at Denver.

To specifically determine how snow loads can impact buildings at the site, a more detailed analysis of snow loads is required. Load effects are defined as forces and deformations produced in structural members and components by specified loads. Snow loads are considered variable loads, because snow obviously is not present at all times, and even when snow is present, its effect can be influenced by many other factors.

The American Society of Civil Engineers reference book, *Minimum Design Loads for Buildings and Other Structures* (ASCE 1994), provides guidelines, formulas, and variables for calculating snow loads. These guidelines, formulas and variables selected as applicable for the site are detailed in Nuclear Safety Engineering Calculation No. 96-SAE-032 (RFETS, 1996). The results are summarized in the next few pages and are ultimately used to create conservative minimum snow load design curves for site buildings.

The procedure to determine roof design snow loads begins with calculations to generate a flat-roof snow load. This is particularly important for the site since most roofs are flat. The snow load, p_f (psf), on an unobstructed flat[a] roof is:

(1) $$p_f = 0.7\, C_e\, C_t\, I\, p_g + 5$$

where:

C_e = wind or exposure effect
C_t = thermal condition of building
I = building importance, based on building use
p_g = ground snow load (psf)
5 = rain-on-snow surcharge

a. "Flat" refers not just to dead-level roofs but to any roof with a slope less than 1 in/ft (5°).

The basic snow load on a flat roof is 0.7 p_g. The factors C_e, C_t, and I, are used by building designers to adjust the load up or down based on representative conditions that are likely to exist during the life of the structure.

The exposure factor, C_e, varies from 0.8 for windy areas with the roof exposed on all sides to 1.2 for densely forested areas that experience little wind. The value of 1.0 is used for locations for which snow removal by wind cannot be relied upon because of terrain or nearby buildings. For the site, a value of 1.0 would be conservative for all buildings on site.

The thermal factor, C_t, varies from 1.0 for a heated structure, to 1.1 for a structure kept just above freezing, to 1.2 for unheated structures. For the site, all buildings holding radiological materials are heated, so a value of 1.0 is appropriate.

The importance factor, I, relates design loads to the consequences of failure. Roofs of most structures having normal occupancies and functions are designed with an importance factor of 1.0, which corresponds to unmodified use of a statistically determined ground snow load for a 2 percent annual probability of being exceeded (50-year mean recurrence interval). For structures where the consequences of failure are more serious than normal, design loads shall be increased above normal. Where less serious consequences are present, design loads may be reduced. Appropriate values for I are presented in Table 5-8.

Table 5-8. Importance Factor, I.

Nature of Occupancy	ASCE Category	I
All buildings and structures except those listed below	I	1.0
Buildings and structures where the primary occupancy is one in which more than 300 people congregate in one area	II	1.1
Buildings/structures designated as essential facilities, including, but not limited to: - Hospital and other medical facilities having surgery or emergency treatment areas. - Fire or rescue and police stations. - Communication centers and other facilities required for emergency response. - Power stations and other utilities required in an emergency. - Structures and equipment in government.	III	1.2
Buildings and structures that represent a low hazard to human life in the event of failure, such as agriculture buildings, certain temporary facilities, and minor storage facilities	IV	0.8

For sloped roofs, the flat roof snow load described above must be multiplied by another factor, the slope factor C_s. Snow loads decrease as roof slopes increase. Generally, less snow accumulates on a sloped roof because of wind action. Also, such roofs may shed some of the snow that accumulates on them by sliding and improved drainage of meltwater. The ability of a sloped roof to shed snow by sliding is related to the absence of obstructions not only on the roof but also below it, the temperature of the roof, and the slipperiness of its surface. All values of the roof slope factor, C_s, are 1.0 or less. As a result, the design snow load is less for a sloped roof than for a flat roof. Values of C_s vary due to conditions such as whether the roof surface is slippery enough to allow snow to slide off the eaves, whether the roof is warm or cold based on heating and insulation, the shape and type of roof, balanced and unbalanced snow loads, drifts on lower roofs, and sliding snow. A value of $C_s = 1$ is used for flat roofs.

The ground snow load, p_g, is based on the following empirical relation between snow depth and weight of water content. The equation was developed from data collected from a set of weather stations located throughout the state of Colorado and refined using national data (ASCE, 1994 and SEAC, 1971).

(2) $p_g = 0.88\ D^{1.2}$
p_g = ground snow load
D = snow depth (inches)

This equation is appropriate for snow that has compacted somewhat. The water depth (inches) that corresponds to a given snow depth from this equation is $0.17\ D^{1.2}$. For freshly fallen snow, the factor of 0.88 for snow load (or 0.17 for water depth) should be reduced by a factor of two to three, depending upon the type of snow.

A rain-on-snow surcharge of 5 psf is added to the calculated value of roof snow loads, p_f, in areas where intense rains may fall on roofs already sustaining snow loads. Since heavy rains percolate down through snowpacks and may drain away, they might not be included in measured values. However, the temporary roof load contributed by a heavy rain may be significant. Its magnitude will depend on the duration and intensity of the design rainstorm, the drainage characteristics of the snow on the roof, the geometry of the roof, and the type of drainage provided. Because water tends to remain in snow much longer on relatively flat roofs than on sloped roofs, the recommended rain-on-snow surcharge for roofs that slope < 0.50 in/ft is 5.0 psf.

5.5.4 Conclusion

Together the factors of wind effect or exposure, thermal condition, building importance or purpose, and ground snow load were combined to create Figure 5-15 for design snow loads for flat roofs. These values were calculated to represent the minimum design snow load required for a flat roof at site conditions with a varying amount of snow. For example, in Figure 5-15, a storage shed of ASCE Category IV should have a minimum design load of 19 psf to withstand a snow depth of 20 inches. As long as the snow design load is equal to or greater than the value from the curve for the specific building category, the design should be sufficient for that snow depth. Figure 5-15 should be used in conjunction with Figure 5-14. One can determine the frequency or chance of a snow event-day for a specific snow amount and the snow load design that is required to withstand that amount of snow. Conversely, the specific snow load design for a particular structure can be used to determine the both the amount of snow that the structure can safely withstand as well as the frequency of exceedance for that amount of snowfall.

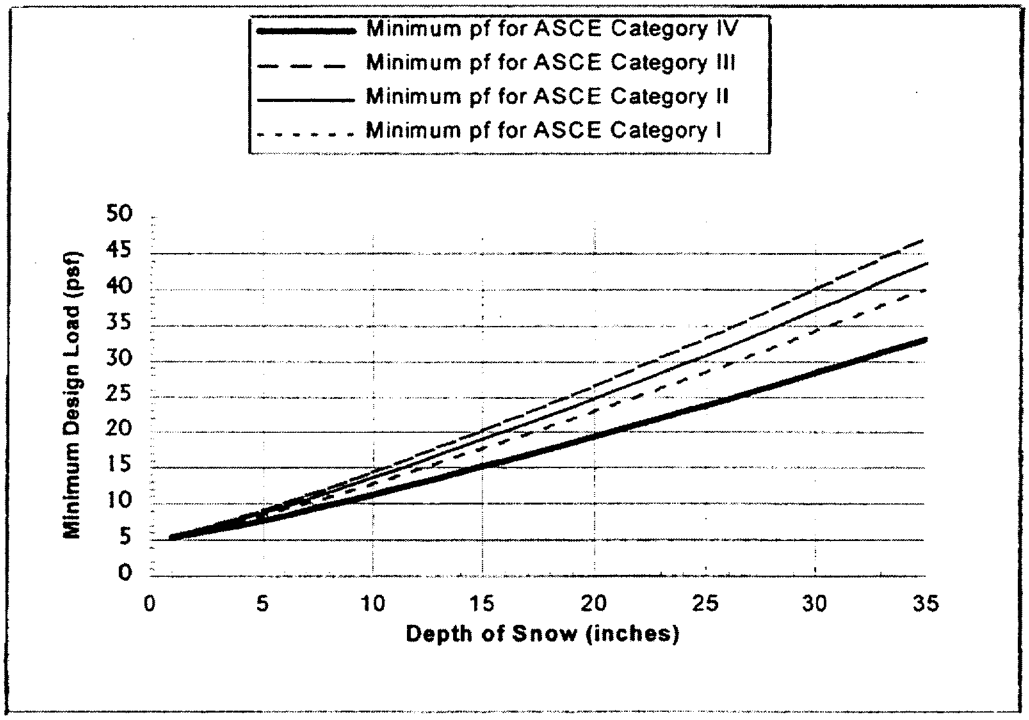

Figure 5-15. Design Snow Loads for Flat Roofs.

5.5.5 References

ASCE, 1994 — *Minimum Design Loads for Buildings and Other Structures*, American Society of Civil Engineers, NY, 1994.

DOE, 1980 — *Final Environmental Impact Statement (Final Statement to ERDA 1545-D) Rocky Flats Plant Site*, Golden, Colorado, 1980.

RFETS, 1994 — *Rocky Flats Risk Assessment Guide*, Revision 3, Safety Analysis, EG&G Rocky Flats, Inc., Golden, CO, September 30, 1994.

RFETS, 1996 — *Heavy Snow Frequency and Building Design Load Impacts for RFETS*, Calculation No. 96-SAE-032, Rev. 0, Nuclear Safety Department, Kaiser-Hill, L.L.C., Golden, CO, August 13, 1996.

SEAC, 1971 — Snow Load Design Data for Colorado, Structural Engineers Association of Colorado, 1971.

Tartaglione, 1991 — Louis C. Tartaglione, *Structural Analysis*, McGraw-Hill, Inc, NY, 1991.

5.6 LIGHTNING

5.6.1 Introduction

Lightning is a high-current electrical discharge in the atmosphere with a path length typically measured in kilometers. Natural lightning is always associated with clouds, normally those of weather, but also volcanic clouds and even dust clouds. Lightning can occur any time during the year but is primarily a spring and summer phenomenon. At any one time, there are about 2,000 thunderstorms and about 100 lightning strikes per second on the earth. Lightning is the number one weather-related killer in the United States, causing 100 to 200 deaths per year (DOE, 1995). The United States typically has about 100,000 thunderstorms per year. Colorado ranks second in the nation (after Florida) in the density of lightning strikes (i.e., strikes/km^2/yr); the lightning density in Colorado is greatest in the mountainous areas.

It is important to assess the severity and frequency of lightning strikes at the site for several reasons. Lightning can

- cause injury or death to site personnel through electrocution and/or burns;

- start a fire within a building, outside of a building but within the industrial area, or on the grasslands surrounding the industrial area of the site; fire can also arise from contact of combustibles with a lightning-heated non-combustible.

- breach a building, providing an open pathway for radioactive or other hazardous substances to be released into the atmosphere. Because filter plenums are electrically conductive, they can attract lightning and can therefore be breached by lightning even within a building; this would provide another leak path to the environment as well as to personnel within the building.

- cause sensors to fail or give false alarms, cause communications and electronic component failures, and cause power failures, which give rise to other system failures.

The following discussion of lightning first addresses the conditions for the occurrence of lightning, then reviews the history of past events, and finally discusses evaluation parameters.

5.6.2 Conditions for Occurrence

Lightning discharges derive from electrical charge separation within clouds. Although the distribution of charge within a cloud can be very complex, the upper part of a cloud is usually positively charged and the lower part negatively charged. The negative charge at the bottom of a cloud induces a positive charge on the ground below it, and this, in turn, can cause a lightning discharge. Lightning discharges often occur within clouds, called intra-cloud (IC) lightning, as well as between the cloud and ground, called CG lightning. Occasionally, lightning will also discharge between clouds (inter-cloud lightning) or even upward, into the upper atmosphere. Although the IC lightning is the most common lightning form, and the electromagnetic pulse associated with IC lightning can damage equipment connected to unshielded cables, it is the CG lightning that is of the most practical importance because of its potential for causing damage, injury, or death. Therefore, the following discussion of lightning is concerned only with CG discharges. Most CG lightning discharges are from the cloud bottom, yielding a negative discharge, although occasionally the discharge is from the upper portion of the cloud, yielding a positive discharge. The positive discharges, though rare, are typically more severe than the negative discharges.

When a thunderstorm becomes mature, some 10 to 30 minutes following the first IC lightning, discharges begin to emerge from the cloud bottom. These ionized channels, known as stepped leaders, move rapidly in short jumps. As the tip of a stepped leader nears the earth, it causes a streamer of oppositely charged ions to emanate from pointed, grounded objects. When the distance from a stepped leader's tip to one of the streamers becomes small enough (known as the striking distance, from 30 to 300 meters), the intervening air breaks down electrically and the leader is joined to earth, via the streamer. A very large quantity of charge (the return stroke current) then moves from earth, through the object from which the streamer emanated (the struck object or victim), and up into the cloud. It is the return stroke that creates the highly visible lightning channel and its associated thunder. Subsequent leaders, called dart leaders because they move more quickly than the stepped leaders, and subsequent return strokes often follow. The entire event is called a flash and typically lasts one-half to one second. It has several components, the most significant being three or more high-current pulses, called strokes, which can strike the ground in different places. Each stroke lasts about one millisecond, with a separation between strokes of tens to hundreds of milliseconds. The largest peak currents recorded are in the 200- to 300-kiloampere (kA) range. There often is a weak "continuing current" between the strokes. There is no obvious pattern to CG lightning; that is, it is best described as a random walk. However, if CG lightning hits once in an area of several square kilometers, it will typically hit another 20 times in that area in the next half-hour. The mean flash-to-flash distance, however, is 1.8 km. For more details, see (Uman, 1989), (Hasbrouck, 1989), or (DOE, 1995).

5.6.3 Site History

Kelly (1995), in work sponsored by DOE's Lawrence Livermore National Laboratory, searched the Occurrence Reporting and Processing System (ORPS) database for lightning-related "occurrences" at DOE facilities[a]. His work covered nearly a five-year period, from September 30, 1990 to July 26, 1995. Of the 365 reports referring to lightning, 89 were not applicable. Of the remaining 276 reports, 222 were for surges in electrical circuits (136 without damage to equipment or components and 86 with damage) and 54 were for damages unrelated to surges. Of the 222 electrical surges, 119 of them caused alarm malfunctions (112 false alarms and 7 alarm system failures). In the case of the site, there were a total of 21 lightning reports, four of

a. An "occurrence" is defined in ORPS as (1) an emergency that requires an increased alert status for on-sitepersonnel and perhaps even off-site authorities; or (2) an unusual event, not an emergency, that has an impact or a potential impact on safety, environment, health, security, or operations; or (3) an off-normal event (abnormal or unplanned) that affects, or could indicate a degradation in the safety, security, environmental, or health protection performance or operation of a facility.

which were not applicable. For a given occurrence report, several lightning strikes may have been involved. Of the 17 valid reports for the site, there were:

- fourteen reports of surges
  - eight temporary malfunctions where no damage was reported
  - two damaged circuit boards
  - three damaged arrestors
  - one damaged switch

- three reports of non-surge damage
  - two power-pole hits, one of which caught the power pole on fire (from further inspection of the occurrence reports, not Kelly's report)
  - one range fire. This range fire, curiously enough, may not have been caused directly by the lightning. The firemen inspecting the fire site noted fragments of a broken insulator at the base of a power pole where the fire was. They speculated that the insulator was struck by lightning. It fractured, fell to the ground, and started the grass fire, as the fragments were very hot. This fire was small, growing only to a 50-foot diameter before being extinguished by the fire department.

The site had alarm malfunctions nine times. Six were false fire alarms that affected several buildings, two were alarm failures, and one was a false security alarm that affected several buildings.

One surprising result from Kelly's report is that the number of lightning reports is *not* well correlated with the number of days per year with thunderstorms ("thunderdays")[a] at a site. In the case of the site, the ratio of the number of valid lightning reports in this five-year period to the number of thunderdays per year was 0.43, which was above average for DOE sites. Other sites had ratios ranging from 0.01 to 3.40, with an average of 0.31 and a median of 0.10. No explanation was offered for this curious result[b], but it does illustrate that the number of reported lightning strikes per year at one site cannot be used to infer the number of strikes per year at another site, based on the ratio of the number of thunderdays per year. This is not to say, however, that at a given site the lightning rate is unrelated to the thunderstorm rate. Indeed, thunder is caused by lightning, so the thunder rate must be a function of the lightning rate. Not all lightning flashes, however, produce perceptible thunder; in fact, only 60 percent to 78 percent of all lightning flashes produce discernible thunder (DOE, 1995).

a. A thunderday, according to the NFPA 780 Lightning Protection Code (NFPA, 1992b), is a day in which a trained observer hears thunder; the thunder can arise from either IC or CG lightning. The number of occurrences of thunder during the day is not a factor. A storm that produces lightning but no thunder is not counted.

b. The poor correlation between the number of lightning occurrences reported and the number of thunderdays per year may be more of a reflection on the reporting systems at the different sites than on the meteorology.

The site has about 50 thunderdays per year, based on the isokeraunic map[a] of the United States given in the Lightning Protection Code, NFPA 780 (NFPA, 1992). (Hasbrouck, 1995) presents a methodology for estimating the density of lightning flashes at a given location, based on the number of thunderdays per year and the latitude of the site. Using 50 thunderdays per year, the average flash density is $8.4/km^2/yr$. Since the inner portion of the site (the industrial area) has an area of approximately 1.6 km^2 (388 acres), this area would thus be expected to receive about 13 lightning strikes per year, on the average. The entire site has an area of about 26 km^2 (6,266 acres) so the number of lightning strikes per year on the entire site is expected to be about 215. Because the ORPS study cited above found only 17 valid lightning-related "occurrences" at the site over a five-year period, it appears that only one lightning strike out of about $13 \times 5/17 \approx 4$ gives rise to an "occurrence," as only the industrial area need be considered in the "occurrences" reported, the one exception being the range fire.

5.6.4 Evaluation Parameters

The severity of a lightning flash is usually defined by the peak amplitude of its return stroke current (DOE, 1995). These currents range from one to hundreds of kA. The one-percentile current (i.e., 99 percent of all lightning flashes have a lower current) has been determined to be about 200 kA; this is identified (by lightning scientists) as the severe threat level. The median (50th percentile) value lies in the 20 to 30 kA range. Figure 5-16, which is taken from the DOE draft report on lightning (DOE, 1995), shows the exceedance probability of a lightning strike as a function of the peak current of the first return stroke.

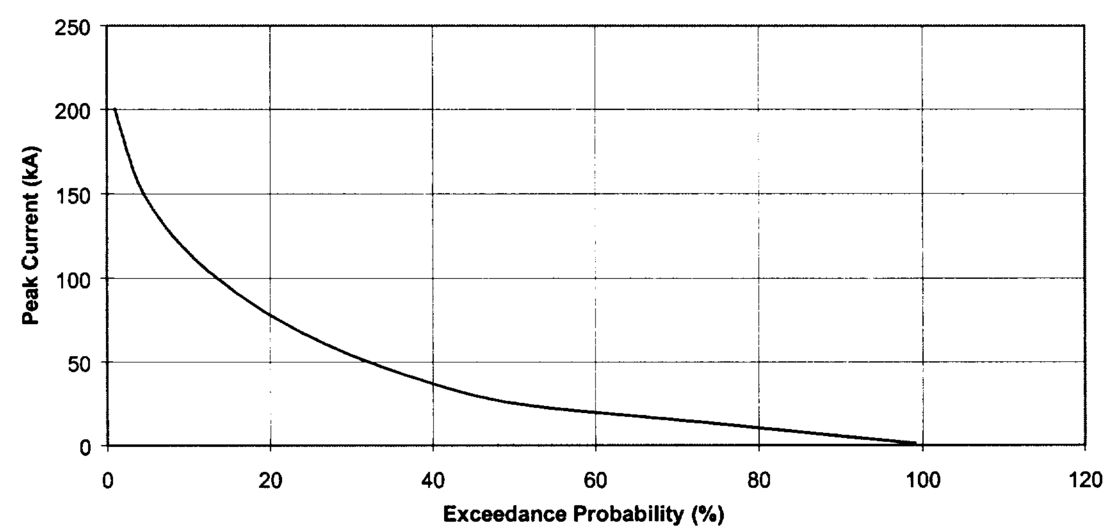

Figure 5-16. Lightning Exceedance Probability versus Peak Current

a. An isokeraunic map is a map that show contours of equal numbers of thunderdays per year.

For flat terrain without buildings or other structures, the probability of a lightning strike is the same throughout the area. Structures, however, especially tall ones such as stacks, water towers, and power poles, attract lightning and increase the probability of a strike at those locations, thus decreasing the probability at other nearby locations. These taller structures thus provide some protection for the shorter structures nearby. The "circle of protection" offered by a tall structure depends upon its height and upon the peak current in the lightning strike. The higher the structure, the larger the circle of protection. As a rule of thumb, for a medium-current strike, the radius of the circle of protection is equal to the height of the grounded lightning attractor. This is not valid for all lightning, however, as the radius of the circle of protection also depends upon the current in the lightning strike: the larger the current, the larger the circle of protection. A building that may be protected by a larger nearby structure for a high-current lightning strike may not be protected from a lower-current strike. Elevated conducting wires that are horizontal and grounded can also protect facilities below them. Power lines could therefore be considered to provide some protection for certain buildings. In general, the stacks, water tower, and power lines of the site offer protection for only a small portion of the industrial area.

If a particular facility is not protected, the expected number of lightning strikes per year can be found by multiplying the footprint area of the facility by the lightning strike density, which was estimated above as being 8.4 strikes/km^2/yr for the site. For example, Building 460, which has a footprint area of 152,383 ft^2, or 0.0142 km^2, would be expected to suffer about 0.12 lightning strikes per year, without protection. If this facility has a life expectancy of, say, eight to ten years, it can expect to suffer one lightning strike sometime during its remaining life, if no lightning protection is provided. (Note, however, that the adjacent water tower should offer some protection, in the case of Building 460.) If NFPA-specified lightning protection is provided, the likelihood of lightning damage is of course greatly reduced.

Not every lightning strike is a damaging strike. The amount of damage depends on the amount of current in the return stroke, the magnitude of any continuing current, and the susceptibility of the target to lightning damage. Electronic equipment, for example, is more susceptible to failure from a lightning strike than a concrete pad is to fire damage. The main danger from lightning for the site is from fire, as fire can potentially lead to a release of radioactive or chemically hazardous material. Lightning-induced fire can be caused in several ways:

- Fire can be started in dry combustible material, such as a wooden structure or dry grass, by the continuing current between lightning strokes[a]. About 20 percent of the lightning strikes have a continuing current large enough to start such a fire (Hasbrouck, 1989). The magnitude of the peak current is not relevant here, as the return stroke is too brief to start a fire. For the site, this type of fire will be mainly confined to range fires and wooden power poles, as there are few wooden structures on the site and there is a requirement that any wood brought onto the site be treated with fire retardant. Range fires can occur only when the range grass is dry. As stated above, the site can expect to receive about 215 lightning strikes during the typical year. Twenty percent of these (or about 40 strikes) are

a. The continuing current will probably not start a fire within a concrete structure or Butler-type building.

capable of starting a range fire if the conditions are right. Since the site has had only one lightning-induced range fire in five years (and that may have been indirect, as noted above), the conditions are clearly not right for a fire for most of the strikes. This is not surprising as lightning usually occurs during rainstorms, which dampen the grasses even if they are combustible, and most lightning strikes occur before the grasses have dried out. Nevertheless, lightning-induced range fires are *anticipated* (frequency ≥ 1.0E-02/year). The power pole that was set on fire by a lightning strike shows that type of fire must also be considered *anticipated.*

- A lightning strike on a building can induce large currents in the electrical wiring in the building. It is possible that the high current will cause a breakdown in both the insulation on the wiring and the insulation provided by the air, causing an electrical arc to form between the wire and a nearby grounded object. A follow-on current from the wire would then sustain the arc and could continue for many seconds or even minutes, long after the lightning strike is gone. Combustible material in the immediate vicinity could then be ignited. Although arcing is more likely with the larger-current strikes, any magnitude of strike could produce it. To be conservative, all lightning strikes on a building should be considered. This type of fire has not been reported at the site, even though many buildings have been hit by lightning, indicating that such an arc has not formed and/or combustible material was not nearby. This type of fire may thus be considered *unlikely* (1.0E-04/year < frequency < 1.0E-02/year).

- A lightning-induced spark in the building could ignite volatile gases, such as from rags damp with cleaning fluids. This could occur with a lightning strike of any magnitude current. As with the previous type of lightning-induced fire, this type of fire has not been reported at the site, even though many buildings have been hit by lightning, indicating that either such an spark has not formed and/or the spark occurred where volatile gases were not present. This type of fire may thus be considered *unlikely.*

Damage to electronic components from lightning strikes can generally be ignored for facility safety analyses as such damage is usually not associated with the release of radioactive or chemically hazardous materials. The breach of the building by lightning can also be ignored in safety analyses as building breaches are bounded by seismic events.

5.6.5 Performance Categories

The Draft DOE Standard on lightning hazard management (DOE, 1995) suggests applying to lightning the Performance Categories defined in DOE-STD-1020-94 (DOE, 1994), which were discussed earlier in this chapter, i.e., having exceedance probabilities for damage to structures, systems, and components (SSCs) of 1.0E-03/yr, 5.0E-04/yr, 1.0E-04/yr, and 1.0E-05/yr for PC-1, PC-2, PC-3, and PC-4, respectively. The higher performance categories for lightning are obviously desirable for the facilities that contain larger amounts of dispersible radiologically and/or chemically hazardous materials. The probability of lightning damage given in the previous section (the high end of the range of *unlikely*, corresponding to PC-1, for fires started in buildings) is based on the assumption that the building has no lightning protection. If it does have protection, a higher category (lower exceedance probability) can be assigned.

The Lightning Performance Category of a facility depends on its degree of safety from lightning. Safety from lightning can be obtained through a Lightning Safety System (LLS). This system has four components (DOE, 1995):

- **Lightning Threat Warning System** (LTWS): a system for acquiring and displaying timely and reliable lightning threat warnings. The site has such a system in the Voltek Storm Tracker system used by the Shift Superintendent.

- **Lightning Warning Response Plan** (LWRP): a plan that contains site-specific procedures for responding to lightning threat warnings. The site uses the Life Safety/Disaster Warning (LS/DW) system for announcing approaching thunderstorms and issuing warnings about outdoor activities.

- **Lightning Protection System** (LPS): an integrated system for protecting SSCs from the effects of a lightning discharge. It consists of a lightning grounding system (LGS) and systems and components protection (SCP). The site does have a LPS for all the major buildings. Some are in a state of disrepair (primarily for budgetary reasons) and cannot be relied on to provide the needed protection but others have been recently refurbished. There is also a requirement that all computers and other surge-sensitive equipment be protected with surge protectors, a type of SCP. Such surge protectors are of little help for a direct lightning strike, however.

- **Lightning Safety System Certification Plan** (LSSC): a plan that contains site-specific requirements and methodologies for certifying, maintaining, and recertifying the LTWS and LPS. An integrated plan for the site does not exist, although the design plans for individual buildings requires the installation of an LPS that meets the National Fire Protection Association Code, NFPA 780 (NFPA, 1992). There is no site-specific requirement or methodology for certifying, maintaining, or recertifying the LTWS or LPS.

The Lightning Performance Category for a particular building is based on the integrity and completeness of its LLS. Because the LPS for many buildings have not been inspected on a regular basis, credit for an LPS for a particular facility cannot be taken in safety evaluations unless it can be demonstrated that it has been inspected recently and is operating as designed. To be conservative, any given building on the site should be considered PC-1 for lightning unless it can be shown to merit a higher category based on verified LPS functionality and the existence of an LSSC.

5.6.6 Conclusion

A lightning-initiated scenario is assumed to result in a fire. For facilities with considerable combustible loading that would sustain a fire, a lightning-initiated fire is considered to be unlikely. If the facility has no combustible loading, a lightning-initiated fire is physically impossible and does not require analysis.

5.6.7 References

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5.7 AIRCRAFT CRASH

5.7.1 Introduction

Aircraft accidents are evaluated in the safety analyses because they have the potential to breach facility confinements and provide an energy source to promote the release and transport of radioactive or other hazardous material. In the event of an aircraft accident involving RFETS, a pilot would be expected to attempt a minimal impact landing; however, data show that approximately 59 percent of accidents happen under conditions in which the pilot has no control, and 31 percent where the pilot has only limited control (Cooper, 1993). Thus, the potential for aircraft accidents involving site facilities requires evaluation.

The Department of Energy has issued a standard, DOE-STD-3014-96 (DOE, 1996), containing specific guidance for the analysis of aircraft accidents at sites with hazardous materials. There are two types of risk from aircraft accidents: first, the risk from nearby airports, and second, the general risk from in-flight operations over the site. Both of these risks must be considered when performing aircraft accident analysis.

A wide variety of aircraft operate in the vicinity of the RFETS. The aircraft range from small single-engine aircraft to large multi-engine airliners. In terms of frequency, the greatest numbers of aircraft are represented by the small plane category associated with the Jefferson County (Jeffco) Airport due to its operational volume and proximity to the site (Jordan, 1997). This includes 143,000 combined annual takeoffs and landings for small planes, and 7,150 combined helicopter takeoffs and landings per year, which are added to the small plane frequency data. Small aircraft are those which weigh less than 12,500 pounds.

5.7.2 Aircraft Accident Screening Criteria

DOE-STD-3014-96 (DOE, 1996) sets up a series of screening criteria to determine the need for aircraft accident analysis at a site. These criteria are as follows:

1. Exposure screening. This screen consists of a simple, conservative analysis of an unmitigated release of all the hazardous material in a facility. The amount of material that would have to be present to create the potential for site boundary exposure guidelines to be exceeded is calculated. This amount is compared to the amount actually present in the facility. The guidelines are:

    a. Radiological exposure - 5 rem (0.05 Sv) committed effective dose equivalent (CEDE).

    b. Hazardous material exposure - Emergency Response Planning Guidelines Level 2 (ERPG-2), as established by the American Industrial Hygiene Association, or:

c. Where no ERPG-2 guideline is established, the level of concern established by the Environmental Protection Agency.

d. There is further guidance in DOE-STD-3014-96 for exposure to collocated workers where there is a concern that risks from exposure add considerably to the direct risks from the impact itself.

2. Impact frequency guideline evaluation. The results of the impact frequency evaluation is compared to a probability of impact from all aircraft of 1.0E-6 per year. A frequency less than this value is considered acceptable without further analysis.

3. Structural screening. The specific accident is analyzed in terms of potential structural damage and impact on safety-related structures, systems, and components (SSCs). If the damage is not significant and SSCs are not affected for all possible impact locations, this screen is considered satisfied.

4. Release frequency screening. The calculated material release frequency for the facility accident is calculated and compared to the criterion of 1.0E-6 per year.

If the screening criteria for a specific facility are not met, an accident evaluation is required. A specific sequence of steps in the evaluation is followed to determine the risk for the safety analysis. Those steps are detailed in the following sub-sections.

5.7.3 Calculation of Aircraft Crash Impact Frequency

There are two parts to the impact frequency calculation. First, since there is a nearby airport, traffic associated with that airport is evaluated. Second, the general guidance in DOE-STD-3014-96 is used to address the risk associated with in-flight traffic over the site.

The general formula used to evaluate impact frequency from airport operations is:

$$F = \sum_{i,j,k} N_{ijk} P_{ijk} f_{ijk}(x,y) A_{ij}$$

where:

F	=	estimated annual impact frequency for the facility of interest
N_{ijk}	=	estimated number of aircraft operations
P_{ijk}	=	aircraft crash rate (for aircraft type)
$f_{ijk}(x,y)$	=	crash location conditional probability
A_{ij}	=	calculated effective area for the facility in square miles
i	=	index for flight phases (takeoff, in-flight, landing)
j	=	index for aircraft category
k	=	index for flight source (multiple runways)

While the use of this formula is specific to each facility under consideration, data for the site has been compiled (Jordan, 1997) for Building 991 in terms of the first three variables. The location tables are not sensitive to exact distances, so this data may be used for any site facility. The compilation of the data is shown in Tables 5-9 and 5-10. The calculation then depends only on the effective area of the facility under consideration and is reduced to:

$$F = (3.06E\text{-}03)\, A_{if}$$

The probability above is influenced heavily by the in-flight general crash probability for the site as presented in DOE-STD-3014-96. If the airport data from Jeffco were used and the in-flight probability not included, the probability is reduced from 3.06E-03 to 7.7E-04. The later probability was concluded in the Emergency Planning Technical Report, 97-EPTR-004 (Jordan, 1997). Use of the in-flight data increases the probability by a factor of 4.7.

In order to meet the 1.0E-06 screen, the effective area of the facility must be less than 7700 square feet. Most facilities on site obviously do not meet this screen, since effective area includes factors that add significantly to the basic building footprint. The effective area is calculated as follows:

$$A_{eff} = A_f + A_s$$

where:

$$A_f = (WS + R)\, H \cot \Phi + \frac{2LW\,(WS)}{R} + LW$$

and

$$A_s = (WS + R)\, S$$

where:

A_f	=	effective fly-in area
A_s	=	effective skid area
WS	=	aircraft wingspan (DOE-STD-3014-96, Table B-16)
R	=	length of facility diagonal
H	=	facility height
$cot\phi$	=	mean of the cotangent of the impact angle (DOE-STD-3014-96, Table B-17)
L	=	length of facility
W	=	width of facility
S	=	aircraft skid distance (DOE-STD-3014-96, Table B-18)

Table 5-9. Jeffco Airport Operations Data, Impact Frequency per Square Mile

Aircraft Type	Takeoff Runway				Landing Runway				Total	Percent Contrib.
	AB-NW	AB-SE	C-North	C-South	AB-NW	AB-SE	C-North	C-South		
General Aviation	8.74E-05	0.00	0.00	8.54E-06	3.67E-04	2.47E-04	3.55E-05	1.33E-05	7.59E-04	99.94%
Single	7.28E-05	0.00	0.00	7.16E-06	2.88E-04	1.94E-04	2.81E-05	1.05E-05	6.00E-04	79.05%
Twin	1.31E-05	0.00	0.00	1.29E-06	7.07E-05	4.75E-05	6.90E-06	2.58E-06	1.42E-04	18.71%
Turboprop	9.27E-07	0.00	0.00	9.10E-08	4.78E-06	3.22E-06	4.67E-07	1.74E-07	9.66E-06	1.27%
Turbojet	5.22E-07	0.00	0.00	0.00	3.82E-06	2.56E-06	0.00	0.00	6.90E-06	0.91%
Commercial Air Carrier	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00%
Comm. Air Taxi	4.06E-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.06E-07	0.05%
Military Large	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00%
Military Small	2.79E-09	0.00	0.00	0.00	5.17E-09	1.72E-08	0.00	0.00	2.51E-08	0.00%
							Total - All Aircraft		**7.59E-04**	**100.00%**

Table 5-10. In-flight and Combined Impact Frequency Results

Aircraft Type	Impact Frequency per Square Mile		
	In-flight Data	Combined Data	Percent Contribution
General Aviation	2.30E-03	3.06E-03	99.93%
Commercial Air Carrier	2.00E-07	2.00E-07	0.01%
Commercial Air Taxi	6.00E-07	1.01E-06	0.03%
Military Large	9.00E-08	9.00E-08	0.00%
Military Small	9.00E-07	9.25E-07	0.03%
	Total	**3.06E-03**	**100.0%**

5.7.4 Structural Screening and Evaluation

Once it has been established that the facility in question exceeds the screening guidelines for impact frequency, a structural evaluation is required. The evaluation should consider three possible damage types:

1. Local effects. These include penetration or perforation by parts of the aircraft that can be considered as missiles, such as the engines.

2. Global effects. Global effects involve structural failure of all or a part of the structure caused by the kinetic energy of the aircraft.

3. SSC vulnerability. Safety-related SSCs involved in the potential accident should be evaluated to ensure that their functionality is not impaired by the accident.

The structural effects should be evaluated by a structural engineer with experience in impact analysis. If there is significant structural damage, the extent of the potential damage should be quantified for use in determining the extent of the potential release.

The evaluation of structures is done on a case-by-case basis. However, there are some types of site structures known to have little resistance to impact accidents. The most obvious of these are prefabricated metal buildings with thin gauge siding and roofing and tents used for waste storage. Penetration and partial collapse of these structures can be assumed without analysis.

Structures of tilt-up construction with precast columns and beams, such as Building 707, also would exhibit local penetration and partial collapse near the area of impact.

On the other hand, Building 371 is a reinforced concrete structure designed for tornado missiles. However, while the structure would not be penetrated by the aircraft engines, the kinetic energy of a twin engine aircraft has been shown to cause global failure of a thick concrete wall panel.

Because of the diversity of site structures in terms of type of construction, size, height, relative location to other structures, and year of construction, there are no general guidelines that can be prepared to preclude individual structural evaluations, except for those structures with little resistance to aircraft impact..

5.7.4.1 Types of Accidents

Potential accidents which could result from an aircraft accident initiator are a breach of facility confinement (for facilities with confinement zones) and a breach of confinement for materials, with and without the presence of a fire associated with fuel from the aircraft. Analysis of small aircraft accident fires can assume that 227 gallons of fuel present a pool fire scenario (Jordan, 1997).

5.7.5 Release Frequency Evaluation

For each impact location that is determined in the structural response evaluation to have the potential for a release, a scenario is developed. The release frequency can then be determined based on the effective area for the scenario and the subset of aircraft that have the potential to cause the release. The following steps are recommended in DOE-STD-3014-96:

1. Obtain the description of structural damage from the structural evaluation.

2. Assume all available fuel burns in combination with other combustibles in the area.

3. Evaluate the extent that secondary effects spread the scenario to other areas.

4. Determine if a release could occur for the scenario.

5. If a release could occur, the impact frequency should be recalculated for the specific scenario.

6. Repeat the process for all scenarios and sum the results to obtain the final release frequency.

7. If the release guideline is exceeded, provide a detailed analysis of each scenario in accordance with DOE-STD-3014-96, Section 7.3 and document the results.

5.7.6 Helicopter Site Activities

Helicopters are utilized at the site for several activities. These include photography, weed control, medical emergencies, and occasional transportation for visiting dignitaries. Helicopter operations not associated with specific site activities are included in the general aviation data.

DOE-STD-3014-96 states that a mean crash location 1/4 mile from the flight path and a mean crash angle of 60° should be considered for helicopter operations. Applying a minimum safety factor of 2 to those requirements, and also considering requirements from USQD-98-0935-KGH (Hukari, 1998), the altitude restrictions shown in Figure 5-17 can be applied. An additional requirement is that the helicopter flight path must be parallel to or away from the nearest industrial area boundary when operating within the altitude restricted zone. Proposed flights not meeting these requirements must be evaluated on a case-by-case basis.

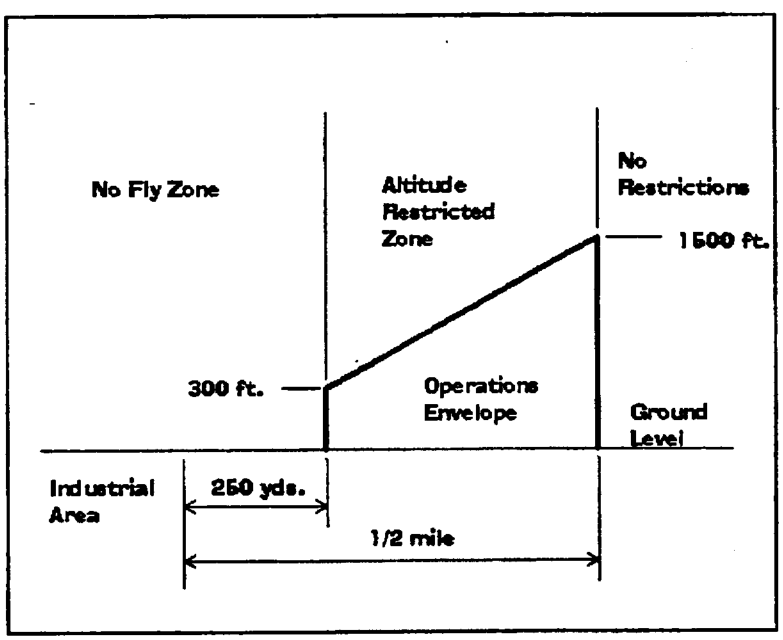

Figure 5-17. Altitude Restrictions for Helicopter Operation at the Site

5.7.7 Conclusion

DOE-STD-3014-96 provides requirements for considering the effect of potential aircraft accidents that could involve hazardous facilities. A variety of aircraft regularly operate in the vicinity of the site and there is a busy county airport in close proximity. Because of the airport activity and the risk given in the standard from general overflights, the site risk probabilities calculated in accordance with the standard exceed basic screening criteria for impact frequency for all but very small structures. Aircraft accidents should therefore be considered in accident analyses for all facilities containing hazardous materials.

5.7.8 References

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5.8 RANGE FIRES

5.8.1 Introduction

Range fires present an external exposure to RFETS facilities, and as such, their potential severity must be evaluated. Range fires can be initiated by a number of sources including lightning, human action such as careless disposal of smoking materials, improperly extinguished campfires, and malicious mischief, and mechanical initiators such as sparks from a train or automobile. The potential severity of a range fire may be assessed through an analysis of the chief factors which contribute to their growth and spread. These factors include the characterization of the fuel available, the terrain, and environmental conditions. The damage potential from a range fire is dependant on factors including the construction of potential target structures, spacial separation distances, existing automatic fire suppression, and the effectiveness of the responding fire fighters per NFPA-299 *Protection of Life and Property from Wildfire* (NFPA, 1991). A range fire in the site buffer zone may expose site facilities located in the zone and facilities located in the industrial area.

This analysis will assess the potential for a damaging range fire through identification of the factors which contribute to the fire severity and the exposures to facilities.

5.8.2 Event Characteristics

Range fires may be caused by various natural and human initiators. These initiators include lightning (RHO, 1984), human action, mechanical incidents, and an explosion and/or fire at an offsite facility (see Section 5.10). Lightning can occur any time during the year; however, it is primarily a spring and summertime phenomenon along the Front Range. The area around the site experiences approximately 50 thunderdays (days during which a potential for strikes exist) per year according to NFPA-780 *Lightning Protection Code* (NFPA, 1992). Human action caused incidents include improper disposal of smoking materials (RFETS, 1994), poor control of a campfire (Jeffco, 1996), ignition by tracer fire during training (M&H, 1993), ignition by explosives during training (CTAW, 1995), carelessness (SU, 1994), and arson (WHC, 1992). Mechanical incidents include sparks generated from railways (M&H, 1991) and passing automobiles (EG&G, 1994).

Expected range fire intensity may be determined by characterizing the material available for combustion. The site buffer zone vegetation consists primarily of grasses, forbs (weeds), and low shrubs typical of mixed prairie regions. Five vegetation types are identified within the Buffer Zone: marshland, woodland, shrubland, grassland, and disturbance, with grassland the dominant vegetation type. Other vegetation types are located in small isolated pockets. The grassland vegetation is dominated by mesic mixed (tall grasses) species. Dominant species include big bluestem, prairie dropseed, Canada bluegrass, and a number of associated forbs. Average plant production among the mesic sites surveyed is 1699 kilograms per hectare or 0.76 tons/acre (RFETS, 1992).

Low precipitation, drying winds, and a permeable soil result in an arid environment. This environment contributes to a drying out of the native grasses resulting in conditions susceptible to ready ignition and rapid fire spread. Per the National Wildfire Coordinating Group Fire Behavior Field Guide (NWCG, 1981) Fire Behavior Fuel Model classification, fire spread in tall grasses averaging about 3 feet display high rates of spread under the influence of wind. The intensity is expected to be low to moderate.

RFETS occupies approximately 6,550 acres, (including the area occupied by the Wind Site); however most of the facilities are located in the Industrial and Protected Areas which encompass about one half square mile. The remainder of the site is known as the Buffer Zone and is surrounded by a perimeter fence. This zone separates the site facilities from the public. The land is predominately flat with several natural cuts forming trenches. Slopes through the cuts are quite steep (45 degrees); however, due to the separation distances and relatively small areas covered, fire growth and spread would be dominated by the shallow grades characterizing the majority of the zone.

Fires in the Buffer Zone would expose numerous plant facilities. Multiple Individual Hazardous Substance Sites (IHSS) are located within the Buffer Zone. An IHSS is an area exhibiting similar contaminant characteristics and/or geography. Several structures are located within the Buffer Zone, including Building 944, carbon filter units, a building and trailer with used oil stored northeast of Building 944, a tent with two 1000 gallon propane tanks and a 250 gallon diesel fuel tank north of the building and trailer. Trailer T900D is also located north of the east access road. Several site systems are located in the Buffer Zone. Electric power lines supported by wooden utility poles pass through the zone. Alarm system and phone lines are contained in polyvinyl chloride pipe laid on the ground through the east side of the site. Meteorological towers and pumping facilities are present. Buried natural gas lines are also located in the zone.

A range fire would expose these structures and facilities. In the bounding scenario, a range fire would burn the entire Buffer Zone, facilities within the Buffer Zone, and damage facilities within the Industrial Area that are susceptible (i.e. trailers). Smoke may necessitate site evacuation, road closures, and reconfiguration of building ventilation systems.

Radiological contamination levels for Weapons Grade Pu in the soil in the Buffer Zone range from 1.45 E-9 Ci/g soil (approximately 2.2 percent of the area) to 0.8 E-12 Ci/g soil (approximately 78 percent of the area). The remaining twenty percent has 2.61 E-11 Ci/g soil (Litaor, 1995). The vegetation is expected to have from 0.1 to 0.3 percent of the soil level contamination (Arthur, et al., 1982). Studies undertaken to investigate the potential for radioactive material in contaminated soil to become airborne during a range fire have determined that airborne activity from burning soil resulted in negligible releases. The release fraction for such a soil fire is taken as less than 2.0E-6 and the release fraction for vegetation, detritus, droppings, etc., is 1.0E-3 (Mishima, 1973). Given the low contamination levels coupled with the low release fractions, it is not expected that a significant radiological release exposing immediate workers, collocated workers, or offsite individuals would occur with the complete burning of the Buffer Zone.

Chemical releases from the facilities located in the Buffer Zone are also expected to be insignificant. Chemical inventories include 2000 gallons of propane, 250 gallons of diesel fuel, and two carbon filter units. These chemicals do not exceed threshold levels of concern (reportable quantities) for off-site exposures. Immediate workers may be injured should a propane tank rupture and explode. Collocated workers would not be injured due to this explosion (SAE, 1996).

Several facilities within the industrial area are located close to the Buffer Zone. Most are separated from the Buffer Zone by a perimeter road and /or parking lots. In addition, the Protected Area is separated by a security boundary consisting of approximately 100-feet wide clear space with trap-rock surface. The majority of the plant facilities are not susceptible to damage from a range fire exposure as they are constructed of noncombustible materials. Tents are fabricated with fire retardant materials which will reduce the probability of ignition by flying brands. Trailers, particularly the T130 complex, are susceptible to ignition by fire brands. The most susceptible material located in the industrial area is yard storage, for example, excess wooden pallets stored north of Building 130 and cargo containers used for storage of waste drums. A fire in the pallets may expose Building 130 to damage, however building sprinklers would likely minimize the extent. Cargo containers are constructed of steel and are not susceptible to ignition from range fire exposures unless directly exposed.

Building 881 is not separated from the Buffer Zone by the perimeter road. As the building is constructed of non-combustible materials, the exposure is not considered significant.

5.8.3 Probability of Occurrence

The primary initiators of range fires at or near DOE facilities include lightning strikes, cigarettes thrown from vehicles, vehicle exhaust systems, and tracer/spent ammunition rounds. These ignitions sources are probable at the site because:

- Thunderstorms with lightning are common at the site;
- Vehicle traffic within the Buffer Zone is routine;
- The Buffer Zone abuts heavily traveled roads; and
- A firing range located in the Buffer Zone is used on a regular basis for training activities.

As there have been more than 30 range fires at DOE facilities since 1990, including several at RFETS, the frequency of range fires at the site is expected to be on the order of once every one to five years.

5.8.4 Conclusion

Range fires are anticipated to occur at RFETS. These fires are expected to be of low to moderate intensity and fast moving due to the arid conditions and easily ignitable fuel. The site arrangement, including the natural firebreak formed by the perimeter road and parking lots will reduce the exposures to important plant buildings. Protection afforded by noncombustible construction and the plant fire department provides adequate assurance that a fire resulting in unacceptable consequences will not occur.

5.8.5 References

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5.9 CONCLUSION

The natural phenomena/external event most likely to result in a breach of confinement and a release of hazardous materials at RFETS are earthquakes and aircraft crashes. The severity of these events on a specific facility is dependent on the construction of the facility and is evaluated in the facility safety analysis. Historically the site has not experienced a release of hazardous materials from any of the natural phenomena events or externals events identified. The following paragraphs are based on the conclusions of the discussions presented above.

Earthquake

Earthquakes have the potential to initiate nuclear criticalities, explosions, fires and spills. Typically, an earthquake is considered to result in a bounding spill scenario. The site is located in a low seismic activity area. The design basis earthquake (DBE) for the site has an occurrence frequency of 1.2E-03/yr with a horizontal bedrock acceleration of 0.14 g. and is therefore, considered an unlikely event. The response associated with site buildings depends upon their structural capability. In general, site buildings are assumed to collapse during a DBE unless specific design information contradicts this assumption.

High Wind and Tornado

High winds, rather than tornadoes, pose a major threat to RFETS with the potential to cause building and structural damage. Although tornadoes are common in parts of Colorado, they are rare as close to the mountains as the site, therefore, destructive tornadoes are considered incredible for the site. High-winds initiated accident scenarios are considered to result in spills, and are dependant on the construction and configuration of the individual facility.

Significant Precipitation Events

Consequences of heavy rainstorms may be the loss of human life and property, including damage to equipment and buildings, or transport of spilled materials. The climate at the site is characterized by dry conditions -- low humidity and low precipitation. The rainiest season at the site is the spring, during the month of May with thunderstorms the most frequent in the spring and summer. The site has not historically experienced flash floods or other extreme precipitation events. There are no dams or tributary streams that would cause flooding of the site if they failed or overflowed. However, several areas on the site were found to be vulnerable to flooding during a 25-year storm event under present drainage conditions. These areas include Buildings 335, the vicinities around Building 991 and between Buildings 444 and 460, as well as several T452 and T771 trailers. Therefore, these areas should not be used to store materials that could be damaged by exposure to moisture or potential flooding conditions unless appropriate physical precautions are taken. The off-site hydrology projects serve as a final level of protection for the public against the impacts of contaminated materials reaching public drinking water supplies during heavy rain or other water-mediated events.

Heavy Snow

The amount of snow, the snow density and the water weight determine the total load on a building's structural elements. Heavy snow events are capable of causing properly designed structures to suffer either local or general collapse. The damage could involve roof materials and/or structural supports falling onto and breaking open containers of hazardous materials. Also, large amounts of melting snow could potentially cause water damage, spread of contamination or criticality conditions. To date, there are no known consequences of heavy snow events resulting in major structural damage at the site. The probability of a snow related structural failure which could potentially release hazardous materials is dependant on the structural integrity of the facility and the design basis used in construction.

Lightning

Lightning can occur any time during the year but is primarily a spring and summer phenomenon. Lightning is the number one weather-related killer in the United States, causing 100 to 200 deaths per year (DOE, 1995). Colorado ranks second in the nation (after Florida) in the density of lightning strikes (i.e., strikes/km^2/yr), with the density in Colorado greatest in the mountainous areas. In addition to injury or death to personnel, a lightning strike can result in a fire both in or outside a facility, cause a breach in the facility, or cause sensors to fail or give false alarms. A lightning-initiated scenario is assumed to result in a fire. For facilities with considerable combustible loading that would sustain a fire, a lightning-initiated fire is considered to be unlikely. If the facility has no combustible loading, a lightning-initiated fire is physically impossible and does not require analysis.

Aircraft Crash

The potential for an aircraft accident at the site is a function of the number and types of aircraft operating in the area. In considering an aircraft crash as an initiator for a release of hazardous materials two factors are considered: (1) the probability that an aircraft will impact the facility, and (2) the feasibility that once hit, the aircraft will penetrate the facility. An aircraft accident is considered credible for the site if the area of the facility is greater than 12,949 square feet. Reinforced concrete structures that are at least 12 inches thick are likely to resist penetration and perforation. Therefore, the majority of the facilities at RFETS for which an aircraft crash is credible, are assumed to be penetrated.

Range Fires

Range fires are anticipated to occur at RFETS and present an external threat to site facilities. Range fires can be initiated by a number of sources including lightning, human action, and mechanical initiators. The damage potential from a range fire is dependant on factors including the construction of potential target structures, spacial separation distances, and the effectiveness of the responding fire department. Range fires at the site are expected to be fast moving due to the arid conditions and easily ignitable fuel, and will be of low or moderate intensity which will not sustain a fire hot enough to impact the construction materials of facilities containing hazardous materials. The site arrangement, including the natural firebreak formed by the perimeter road and parking lots will reduce the exposures to site buildings. Protection afforded by noncombustible construction and the site Fire Department provides adequate assurance that a fire resulting in unacceptable consequences will not occur.