PROJECT BACKGROUND

The U.S. Atomic Energy Commission (AEC) announced its decision on March 23, 1951 to build the Rocky Flats Plant. The plant was built to increase the quantity and quality of the nation's nuclear arsenal and has played an important role in the U.S. nuclear weapons complex in the years that have followed. Early plant operations were for the most part kept behind a "cloak of secrecy," with the main off-site concern being centered around two fire incidents in 1957 and 1969 that received public attention, an inadvertent release of tritium to surface waters in 1973, and a waste storage practice (waste oil drum storage at the site of the 903 Pad) that resulted in the spread of contamination to nearby soil during the late sixties. After the 1969 fire, the public learned for the first time that plutonium had been released routinely and accidently from the plant. In 1984, the site was proposed to be a Superfund site, and in 1989, it was included on the National Priorities List for cleanup of environmental contamination.

Public concern came to a high point in June 1989 when approximately 100 FBI and U.S. Environmental Protection Agency (EPA) agents raided the plant seeking documentation of alleged criminal acts and mismanagement. The Department of Energy (DOE) subsequently suspended plutonium processing to review and upgrade the plant's safety systems. Following the raid, Colorado's Governor Roy Romer negotiated with Energy Secretary Admiral James Watkins to secure funding for closer scrutiny of the plant's activities by the state and for health studies to address the public's concern of potential adverse health effects.

In June 1989, an Agreement in Principle was signed by Governor Romer and Secretary Watkins that included DOE funding for increased environmental surveillance and oversight, remediation, emergency preparedness measures, accelerated cleanup in areas of imminent threat, and health studies. This report is one of the products of Phase I of the health studies known as the Rocky Flats Toxicologic Review and Dose Reconstruction Project, which is being conducted by ChemRisk under contract to the Colorado Department of Health.

The Rocky Flats Toxicologic Review and Dose Reconstruction Project

The primary purpose of this project is to reconstruct potential doses of the contaminants of concern which might have been received by off-site individuals as a result of past Rocky Flats Plant operations. Two points should be emphasized regarding the project scope. First, this project is designed to address exposures from historical operations, not to estimate doses from present and future operations or anticipate future exposure potentials. Second, this project is concerned with doses to individuals off the plant site, as opposed to occupational exposures to plant workers. Information pertaining to workplace exposures or control devices will in general only be considered

if it is also relevant to prediction of off-site releases or exposures. The period of interest for this study begins in 1953 when production related emissions began and covers the period through 1989.

The technical tasks associated with the Phase I Health Studies are listed in Figure 1. The first several tasks focus on the development of an understanding of potential health impacts of contaminants released from the Rocky Flats Plant through a comprehensive look at all the materials and their quantities used at the plant since 1952.

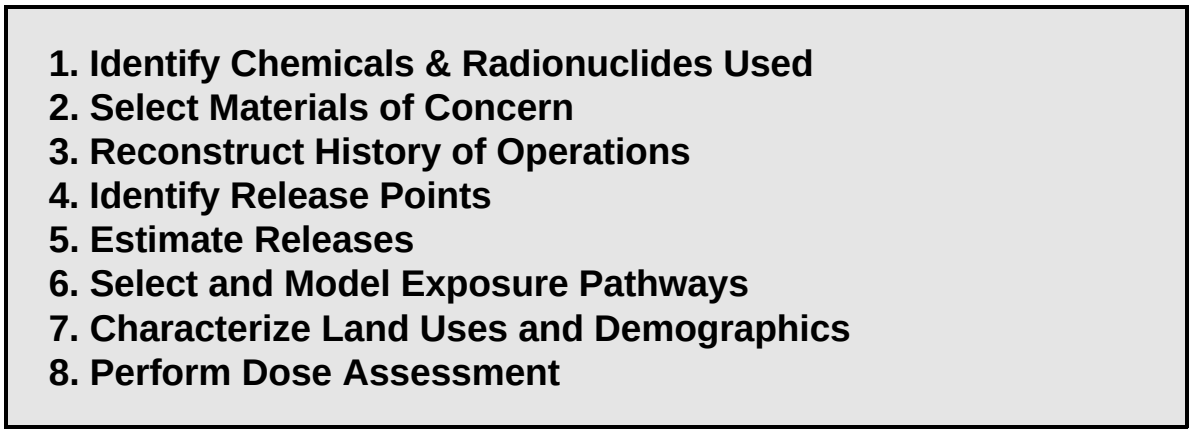

FIGURE 1: TASKS OF THE ROCKY FLATS TOXICOLOGIC REVIEW AND DOSE RECONSTRUCTION PROJECT

Task 1 involved identification of chemicals and radionuclides used on the Rocky Flats site. Unlike some similar dose reconstruction studies that have been undertaken for federal nuclear facilities, this project is concerned with not only radionuclide emissions, but also releases of hazardous chemicals and mixed wastes containing both radioactive and non-radioactive components. To identify materials used on the site, the ChemRisk team first reviewed radioactive source registries and inventories and chemical inventories produced by plant staff. Chemical inventories listed thousands of chemicals present in very small quantities and some chemicals used in very large quantities. Examples range from 4 milliliters of vinyl chloride kept in a laboratory refrigerator to over 400,000 pounds of nitric acid used at the plant each year. Classified and unclassified records were also reviewed for evidence of other materials used on the Rocky Flats site. The result of Task 1 was a list of over 8,000 materials used on the site (ChemRisk, 1991a).

The objective of **Task 2** was to select chemicals and radionuclides most likely to have posed an off-site human health hazard under historical routine plant operations. Radionuclides that have been included as contaminants of potential concern are those that were handled in substantial quantity,

were associated with production activities, were found in forms that were likely to be released, or were found to be present in plant effluents or in the environment.

For chemicals, a three-stage screening process was developed to narrow down the list of contaminants of potential concern. In the first stage, 629 compounds were identified for further, more refined screening based on their known toxicologic properties, Rocky Flats release histories, or reported inventory quantities. A second stage of screening was performed to roughly estimate if the quantity of a chemical on-site was sufficient to pose an off-site health hazard. Forty-six potential chemicals of concern emerged from Stage 2 Screening. In the final stage of screening, these chemicals were individually evaluated to determine the likelihood of their release, potential quantity of release based on actual storage and usage practices, likely routes of release, and known behavior in the environment.

Using both qualitative and quantitative screening criteria, and taking into account preliminary knowledge of actual storage and usage practices, 32 contaminants of potential concern were identified in Task 2 that could have been associated with off-site health impacts from normal operations of the Rocky Flats Plant (ChemRisk, 1991b). The initial list of contaminants of potential concern was subject to continuing review. As the work progressed, newly identified compounds were evaluated for possible addition to the list of contaminants of concern.

Concurrent with the identification of materials used on the Rocky Flats site, **Task 3** activities sought to document the history of operations at the facility as it might relate to off-site exposures, and **Task 4** activities sought to characterize emission points for radionuclide and chemical releases to the environment (ChemRisk, 1992a). Tasks 3 and 4 of the Rocky Flats Toxicologic Review and Dose Reconstruction Project involved extensive investigation and collection of information describing past operations of the Rocky Flats Plant. The objectives of the historical investigations were to:

- Document the basic history of the Rocky Flats facility, outlining its physical development and its historical mission,
- Document the nature of historical uses of the contaminants of potential concern identified in Task 2,
- Identify any significant historical uses of materials not evaluated as part of the Task 2 selection of contaminants of potential concern,
- Identify potential points of significant releases of materials of concern to air, surface water, or soil,

- Support work in Tasks 5 and 6 by characterizing the potential for significant uncontrolled radionuclide emissions from normal operations in the past that may have gone undetected by effluent monitoring systems, and,

- Identify any accidents, incidents, or waste disposal practices that resulted in contaminant releases with significant potential for off-site transport, also in support of Tasks 5 and 6.

Tasks 3 and 4 investigations consisted of an extensive campaign of document reviews and personnel interviews targeting active and retired Rocky Flats employees, local citizens, and other interested parties. The major outcomes of the investigations are an understanding of the historical uses of the contaminants of potential concern, identification of accidents that warrant detailed evaluation, and documentation of the nature of associated emission points.

The objective of Task 5 was to develop historical release estimates for the routine releases and events selected for detail study. This task was divided into the following categories:

- Routine radioactive airborne emissions,

- Routine nonradioactive airborne emissions,

- Routine surfacewater emissions, and

- Nonroutine contaminant releases.

Historical investigations carried out in Tasks 3, 4 and 5 resulted in the identification of the contaminants listed in Table 1 as the subject of quantitative evaluation.

TABLE 1: CONTAMINANTS IDENTIFIED FOR QUANTITATIVE EVALUATION

SOLVENTS	METALS	OTHERS
Carbon Tetrachloride	Americium-241	Tritium
Chloroform	Beryllium	
Methylene Chloride	Plutonium-239/240	
Tetrachloroethylene	Uranium-234/235 (enriched)	
1,1,1-Trichloroethane	Uranium-238 (depleted)	
Trichloroethylene		

The historical airborne radioactive effluent monitoring program at the plant was reviewed and evaluated to establish the utility of the data for dose reconstruction. Uncertainties in the monitoring data associated with the sampling and analytic practices at the plant were carefully characterized. The review indicated that the effluent monitoring data reported by the plant provided a good basis for estimating airborne releases from the facility provided the identified uncertainties were incorporated in the estimates. One notable exception was the plant's data for uranium emissions prior to 1961, which are underreported in plant summary documents. The uranium emissions for this period were recalculated using raw data from plant log books. The effluent monitoring data were used as the basis for establishing quantitative annual estimates of routine releases of the radioactive materials of concern.

Monitoring data for routine airborne emissions of nonradioactive materials are available only for beryllium, and these data served as the basis for the release estimates of this metal. Routine monitoring for organic solvents of concern was not performed by the plant. Estimates of the plausible ranges of historical emissions for these materials were developed using various types of documentation (e.g., Air Pollution Emissions Notifications, special studies conducted by the plant, and inventory quantities) and information obtained from personnel interviews.

Review of information regarding routine contaminant releases to surface water from the plant indicated relatively limited availability of data to directly quantify the releases. Those data that are available were used to examine whether plant releases measurably increased the radioactivity present in water from potentially impacted reservoirs and drinking water. While the data review suggested that it is plausible that plant-related releases may, during some periods of time, have measurably increased gross alpha radioactivity in the waters of the receiving reservoirs, the resulting measured levels were similar to levels found in other, unaffected reservoirs in the area. For tritium, some measured increases were clearly attributable to Rocky Flats.

Information and data associated with releases of contaminants from the plant for major nonroutine release events (1957 and 1969 fires and 903 Pad) were identified in the Task 5 report. The data and information on these accidental events are very limited. As a result, the analysis of these events requires the use of a number of estimates that introduce uncertainties that are accounted for in the final results. The product of Task 5 efforts is historical contaminant release estimates for contaminants routinely released by the plant and information and data regarding accidental releases requiring further analyses in Task 6 to predict historical contaminant concentrations in environmental media.

Project **Task 6** began the process of evaluating how plant releases traveled off-site and could have resulted in exposure of the public by predicting the concentrations of the contaminants in environmental media such as air, soil and foodstuffs (ChemRisk, 1992c). Based on the nature of contaminant releases, physical properties of the contaminants, local hydrogeology and land-use information, the following exposure pathways were identified to be important in Task 6:

- Inhalation of airborne contaminants due to direct release or soil resuspension,
- Incidental ingestion of contaminated soil,
- Consumption of contaminated vegetables, milk and beef, and
- Ingestion of contaminated drinking water.

An exposure model capable of evaluating these exposure pathways is also developed in Task 6.

One of the primary objectives of Task 6 was to predict the concentrations of contaminants in the air in areas around the plant site so that the amount of contaminant that could have been inhaled by people, deposited on the ground that people could come in contact with, and taken up by vegetation or grazing animals that could be eaten by people could be estimated. Air concentrations were

estimated for routine releases of contaminants by using computer models, information on the meteorological conditions at the site (such as wind speed and direction) and the conditions and size of the contaminant release (such as height of the stack, temperature of the exhaust air, and amount of contaminant).

A somewhat different technical approach was required to predict contaminant concentrations in off-site areas that resulted from accidental releases. To evaluate these accidental releases, since there were no or incomplete direct measurements of the releases, information was pieced together from the conditions that were reported during the accident and from monitoring data in the form of air, soil or vegetation samples taken during or shortly after the event. Computer air dispersion models were used to determine, under the estimated conditions of the accidental release, the size of the release that would have been necessary to produce the contamination that was measured at the few locations where air, soil or vegetation samples were taken. The model could then be used to predict the likely concentrations of contaminants at other locations where the public could have been exposed. In some cases, model predictions were compared to environmental sampling data that were not used in the initial estimate of the size of the release. These comparisons test the accuracy of the models in predicting environmental concentrations and add to the confidence that can be placed in the modeling.

The results of Task 6 provided the basis for making estimates of the environmental concentrations of contaminants released from the plant from routine operations, accidents, and resuspension to the air from the soil and the identification of the pathways that these contaminants were most likely to have traveled in reaching the public. These are critical pieces of information needed to calculate the doses of contaminants that the public in the vicinity of Rocky Flats would have received as a result of past plant activities. This information was used in Task 8 to calculate doses to the public.

Areas within several miles of Rocky Flats have changed over time in terms of land use and development since the plant first began operations in 1953. The objective of Project **Task 7** was to identify land uses and populations near the Rocky Flats plant during the period of operations from 1953 to 1989 (ChemRisk, 1992d). The task emphasized identification of the locations of nearby residents that would be most highly exposed and the approximate sizes of populations living near the plant. The use of the lands and waters surrounding the plant were also examined, because this can influence the pathways through which contaminants can migrate and ultimately reach people. Typically, land uses of interest include the raising of crops for human consumption, grazing land and hay produced as feed for cattle consumed by people, or the presence of dairies and drinking water or irrigation reservoirs.

A relatively limited amount of detail about land uses and populations was collected for this first phase of the health studies through personal interviews with long-term landowners and review of census data, historical topographical maps produced by the United States Geological Survey, aerial photographs, deed books and county assessor files to establish land ownership and land use, and

county and local government records. A number of other types of federal, state and local agency records were also explored for useful information.

The Task 7 work provides preliminary population information that would be required for the purposes of an epidemiological study, but additional information would ultimately be needed for such studies. The work does not provide detail agricultural production information, based on the contaminants released by the plant, food-related pathways are known to have made only a minor contribution to the total exposure of the public to contaminants released by the plant.

The last technical task is Project **Task 8**. This task combines the information produced in the preceding tasks on the amount of contaminants that were either estimated to be present or measured in the environment from plant releases with the exposure model developed in Task 6 to estimate radiation and chemical doses potentially received by the public. Dose estimates and the uncertainty in these estimates are provided for each of the contaminants listed in Table 1. While the endpoint of the Phase I studies are these dose estimates, and one of the purposes of Phase II is to thoroughly examine what these doses mean in terms of health risk, Task 8 provides some initial interpretations of the doses in terms of health risk in order to provide some perspective on the meaning of the results of Phase I.

This page intentionally left blank.

EXECUTIVE SUMMARY

The purpose of Task 5 of the Toxicologic Review and Dose Reconstruction project is to develop historical release estimates for those contaminants and events selected for detailed study in previous project tasks. This report discusses the development of estimates for the following major categories of releases:

- Routine radioactive airborne emissions,
- Routine nonradioactive airborne emissions,
- Routine surface-water-borne emissions, and
- Nonroutine contaminant releases.

The historical airborne radioactive effluent monitoring program at the plant is reviewed and evaluated to establish the utility of the data for dose reconstruction. The data review indicates that the effluent monitoring data reported by the plant provide a good basis for estimating airborne releases from the facility with the notable exception of uranium emissions prior to 1961 which are underreported in plant summary documents. The effluent monitoring data is used as the basis for establishing quantitative annual estimates of routine releases of the radioactive materials of concern. Estimates of uncertainty in the release estimates are based on the review of program practices.

Quantitative estimates of airborne release are derived for each of the radioactive materials of concern, with the exception of Th-232, using the effluent monitoring program data. Th-232 has not been specifically monitored and only saw limited use at the plant and is not believed to have been associated with significant emissions historically.

The nature of the data generated by the plant's historical airborne effluent monitoring program and the similarity in the dose factors for the radioisotopes of concern argue for consideration of the use of composite dose factors and emission estimates that would combine emissions for a number of individual isotopes, as opposed to evaluating all isotopes individually.

Monitoring program data for routine airborne emissions of nonradioactive materials are available only for beryllium, and these data serve as the basis for the release estimates of this metal. Routine monitoring for the organic solvents of concern was not performed by the plant. Estimates of the plausible ranges of historical emissions for these materials were developed using various types of documentation and information obtained from personnel interviews. In many cases, these emission

estimates are based on very limited information. However, the identified range of emissions are believed to bound the actual plausible emissions from the plant for these materials.

Review of information regarding surface-water-borne contaminant releases from the plant indicate relatively limited availability of data to directly quantify the release of materials of concern. Those data that are available are used to examine whether plant releases measurably increased the radioactivity present in potentially impacted reservoirs and drinking water. While the review of the data suggests that it was plausible that plant related releases may, during some periods of time, have measurably increased radioactivity in the waters of the receiving reservoirs, the resulting measured levels of radioactivity were similar to levels found in other unaffected reservoirs in the area.

A review of information and data associated with nonroutine releases of contaminants from the plant provides the basis for further modeling of major release events (1957 fire and 903 Pad), and for evaluation of the relative magnitude of lesser events in comparison to routine emissions. The information presented in this report relative to the major events will be employed in contaminant transport modeling efforts in Task 6 to finalize an emission estimate and to provide the basis for estimating off-site exposures from these events.

1.0 INTRODUCTION

Efforts on Tasks 1 through 4 of the Rocky Flats Toxicologic Review and Dose Reconstruction Project have resulted in the identification of contaminants for reconstruction of releases from historical operations of the Rocky Flats Plant. The contaminants that are the subject of further quantitative evaluation with regard to historical emissions are listed in Table 1-1. The list includes six organic solvents, one nonradioactive metal, four radioactive metallic elements and their isotopes, and tritium, the radioactive form of hydrogen.

TABLE 1-1: MATERIALS FOR SOURCE TERM DEVELOPMENT AS SELECTED IN TASKS 3 AND 4

SOLVENTS	METALS	OTHERS
Carbon Tetrachloride	Americium-241	Tritium
Chloroform	Beryllium	
Methylene Chloride	Plutonium-238,239,240,241,242	
Tetrachloroethylene	Thorium-232	
1,1,1-Trichloroethane	Uranium-233, 234, 235, 238	
Trichloroethylene		

A number of techniques can be employed to quantify releases from operations or facilities. The most effective method typically involves the use of release (effluent) measurement data. This technique uses information from samples collected at release points during process operations. The measured contaminant concentration in combination with established discharge flow rates or volumes is required to establish a source term. There are a variety of questions about the completeness of the sampling record and the adequacy of the methods that must be addressed prior to the use of release

measurement data. However, the use of monitoring data in establishing source terms requires the fewest number of assumptions and estimates, thereby reducing the degree of uncertainty in the release quantity. Unfortunately, the monitoring record is often incomplete or absent for the contaminants of interest and other approaches must be used. Alternative approaches can be grouped into three broad categories:

- Material mass balance calculations,
- Analogy to similar, well-characterized processes with established emission factors, and
- Process measurements/engineering calculations.

The mass balance calculation approach involves detailed accounting for each material of interest at a facility. Information on contaminant use such as amount purchased, amount used, amount of material that is incorporated in the product, amount disposed of, and the amount recycled during a defined period of operation must be established so that the amount lost from a process can be calculated. In processes where emissions are passed through contaminant control devices such as some type of filtration, further estimates of the efficiency of the control devices are necessary to finally calculate emissions to the environment. The mass balance calculation approach requires a considerable amount of operations information that is often unavailable. Where the available operations information is limited, the mass balance calculation approach may be effective only in providing relatively crude estimates of environmental release.

In the absence of effluent monitoring data for a specific process of interest, another approach that may be employed involves making analogies to other similar processes that have been well studied at other facilities. Published emission factors are available to estimate emissions of numerous materials from a wide variety of processes and operations. These emission factors may be based on emission point sampling, product analysis, engineering estimation, mass balance analysis, or a combination of these methods. Published emission factors are commonly given in units of contaminant emitted per unit of product throughput or some other process variable. Emission factors are most widely available for commonly used industrial processes, and their availability for many of the unique processes associated with a nuclear weapons plant is rather limited. As with any attempt to generalize complex or variable operations, emission estimates developed using this approach are subject to considerable error.

The third option identified for developing emission estimates involves the use of engineering calculations that may also use information from process measurements. Emission estimation using engineering calculations involves the use of standard principles of chemistry and physics in conjunction with information about process equipment design and operation to predict plausible rates of release of a particular contaminant from a given process. Again, emission estimates based on such calculations are subject to considerable error.

Given the approaches available to quantify contaminant releases, the effluent measurement approach is generally subject to the least error and uncertainty. The error and uncertainty introduced by any inadequacies in the sampling and analytic methods employed in obtaining measurement data are often far smaller than those associated with alternative methods. Therefore, carefully evaluated effluent measurement data have been used whenever possible in reconstructing emission estimates for the contaminants at the Rocky Flats Plant in this report. The extent of the effluent monitoring record at Rocky Flats varies greatly. The record is quite extensive for radioactive materials. The airborne release record for radionuclides is the most complete, while a far more limited record is available for waterborne radioactive releases. On the other hand, the chemical release effluent monitoring record is extremely limited for airborne effluents, and virtually nonexistent for the waterborne releases. To effectively review, evaluate, and present these records and emission estimates, this report has been organized into separate sections addressing airborne releases for both radioactive and nonradioactive materials and waterborne releases of the same materials.

As a general rule, we have presented release estimates to only two significant figures. However, data from original records may also be presented as they appeared in the source documents, which often reported more significant figures.

1.1 Routine Radioactive Airborne Emissions

A significant portion of the Task 5 investigation efforts involved the collection and review of records that characterize historical radioactive effluents from the Rocky Flats facility. The plant operated an extensive airborne effluent monitoring program that generated data that is directly relevant to the development of emission estimates for use in dose reconstruction. This report describes the characteristics of the plant's airborne effluents and provides a review of the historical sampling and analytic practices that were employed to measure these effluents. This review includes the evaluation of sampling system design, analytic method and data treatment practices affecting the accuracy of the reported effluent data. Emission estimates based on the sampling data generated from this monitoring program are presented for use in dose reconstruction, and the uncertainties associated with these estimates are also quantified.

This report also describes methods for estimating the isotopic composition of effluents for those periods during which the plant's sampling and analytic programs did not produce isotopic-specific release quantities. Estimates of potential releases of thorium, which was identified as a material of concern but which saw limited use at the facility, are also presented. Finally, based on the interest expressed by the public as reflected in comments received on previous project reports, a discussion is also included on the possible airborne releases associated with the performance of criticality experiments at the plant.

1.2 Routine Nonradioactive Airborne Emissions

In contrast to the airborne radioactive emissions, the nonradioactive emissions were not subject to routine monitoring, with the exception of beryllium. The beryllium monitoring program review that was performed is described in this report, and the emission data are summarized for use in dose reconstruction. Release estimates for the remaining non-radioactive materials, all organic solvents, are provided in terms of a plausible range of airborne release for various historical periods based on plant documents and other sources of data. The types of documentation and information used to develop these release estimates are described and summarized for each of the organic solvents. The estimated ranges of these releases will be used to reconstruct estimates of the potential off-site doses the public may have received of these organic solvents.

1.3 Uncertainty in Airborne Emission Estimates

Uncertainties in emission estimates can arise from a number of sources, many of which are described in early sections of this report. In Section 4, the methods that were used to quantify the uncertainties in the emission estimates of radioactive and nonradioactive materials that were based on airborne effluent monitoring data are described.

1.4 Routine Surface-Water-Borne Emissions

The plant operated a very limited monitoring program of waterborne effluents. The data that are available from these monitoring programs are not adequate to develop complete historical release estimates for the materials of concern, nor is sufficient information available to estimate releases using other estimating techniques. However, a considerable amount of data have been collected by the plant and the Colorado Department of Health relative to the presence of radioactive materials in reservoirs and drinking water in the vicinity of the plant. The various types of surface water data that are available are presented and evaluated for the purpose of determining whether the reservoirs or drinking waters that have historically received plant effluents and runoff have demonstrated measurably higher amounts of radioactivity than other waters in the area unaffected by the plant. In addition, the limited plant release data that are available are evaluated for the purposes of determining whether recorded releases were associated with increases in measured radioactivity in the receiving reservoirs.

1.5 Nonroutine Contaminant Releases

The final sections of this report provide a discussion of contaminant releases associated with accidents or incidents that were identified as a result of Task 3 and Task 4 efforts. The major release events, the 1957 fire and the events associated with the 903 Pad, require the application of extensive contaminant transport modeling to develop source terms for these events. This report describes the approach that is being employed to develop the source terms, and provides release estimates that have been reported by others for these major events. However, the release estimates that will be used for the purposes of dose reconstruction for these events will be finalized in the Task 6 report, which will address contaminant transport issues.

Other smaller accidental releases are described, and release estimates, which have primarily been developed by others, are presented to put these releases into perspective relative to other releases associated with routine operations and the major accidents.

This page intentionally left blank.