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Umatilla Chemical Agent Disposal Facility Quantitative Risk Assessment

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Volume I
Main Report, Appendices A & B
References and Acronyms

SECTION 16
SUMMARY AND CONCLUSIONS

A QRA of chemical agent disposal processing at UMCDF and chemical munition stockpile storage at UMCD has been completed. The risk to the public has been estimated using up-to-date methods and the latest information available on the specific disposal processes to be implemented at UMCDF. A summary of the risk is provided in section 16.1, including a comparison of disposal processing versus continued stockpile storage. Risk contributors and insights are discussed in section 16.2. Section 16.3 discusses the results of this assessment in comparison to the results of the previous UMCDF Phase 1 QRA that was published in 1996. Worker risk associated with the chemical agents also has been evaluated and is summarized in section 16.4. The QRA results must be used with an understanding of the study's uncertainties and limitations, which are summarized in section 16.5. Frequently, when presented to parties that are not directly involved in risk assessment, there is a request that some risk perspective be provided. Section 16.6 includes some information on risks that may be useful to decision-makers. The remaining sections discuss risk management and the overall conclusions.

The results presented in section 16 are summaries of results presented in section 13 for disposal processing and in section 15 for continued storage. Those sections include a great deal more discussion for readers wanting more detailed information about some of the risk results and displays included here.

16.1 Summary of Public Risk Results

Risk results are calculated and displayed in a variety of ways to help in the understanding and management of risk. Summaries of the material discussed in this report are provided here. The mean values, or averages, of the distributions are discussed first, followed by a discussion of the range of uncertainty.

16.1.1 **Public Societal Fatality Risk.** The risk of disposal processing is best viewed in comparison to the risk of continued storage of the stockpiled chemical munitions in the UMCD. Figure 16-1 is one way of illustrating all the risk results produced in this QRA. The figure includes the CCDFs for average public acute fatality risk, which are comprehensive representations of risk because they allow an understanding of the relationship between probability and consequence. The vertical scale on figure 16-1 illustrates the probability of exceeding the number of fatalities shown on the horizontal scale. (Both the horizontal and vertical scales are logarithmic, evenly subdivided by factors of 10.)

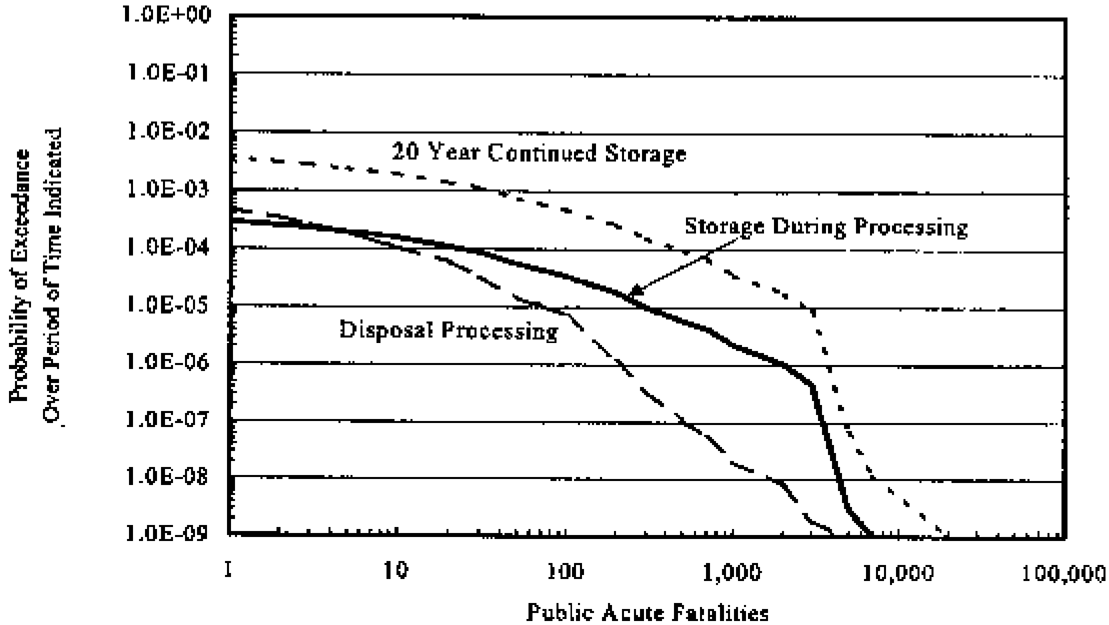

Figure 16-1. Average Public Societal Acute Fatality Risk for UMCDF Processing, Storage During Processing, and 20 Years of Continued Storage

This figure displays the differences in risk among disposal processing, storage during the disposal period, and continued storage. For example, the probability of one or more fatalities is approximately 4.7×10^{-4} (1 in 2,100) for the entire UMCDF disposal process, estimated to have a duration of almost 6 years. In contrast, the probability of one or more fatalities due to storage over this same processing period is 3.0×10^{-4} (1 in 3,300). Extended over 20 years to represent continued storage at UMCD, the probability of one or more fatalities is 3.6×10^{-3} (1 in 280).

The average total public risk during the 6 years of disposal operations is the sum of the disposal processing risk and storage risk during processing. (Storage risk during disposal accounts for the depletion of munitions from the storage yard once they have been processed at UMCDF.) The average total risk is shown compared against 20 years of continued storage in figure 16-2. From this figure it can be seen that the probability of one or more fatalities is 7.7×10^{-4} for the total risk during the disposal period. This value is about a factor of 5 times less than the risk of continued storage over 20 years.

Figure 16-3 is another way of comparing the relative risks. This figure shows the estimate of public acute expected fatalities per year for stockpile storage as it decreases with time during the munition disposal campaigns. Figure 16-3 also includes the risk of processing to allow comparison to the storage risk. Also shown on the figure (as a dotted line) is the fatality risk per year of continued storage with no processing, assuming that the risk remains constant.

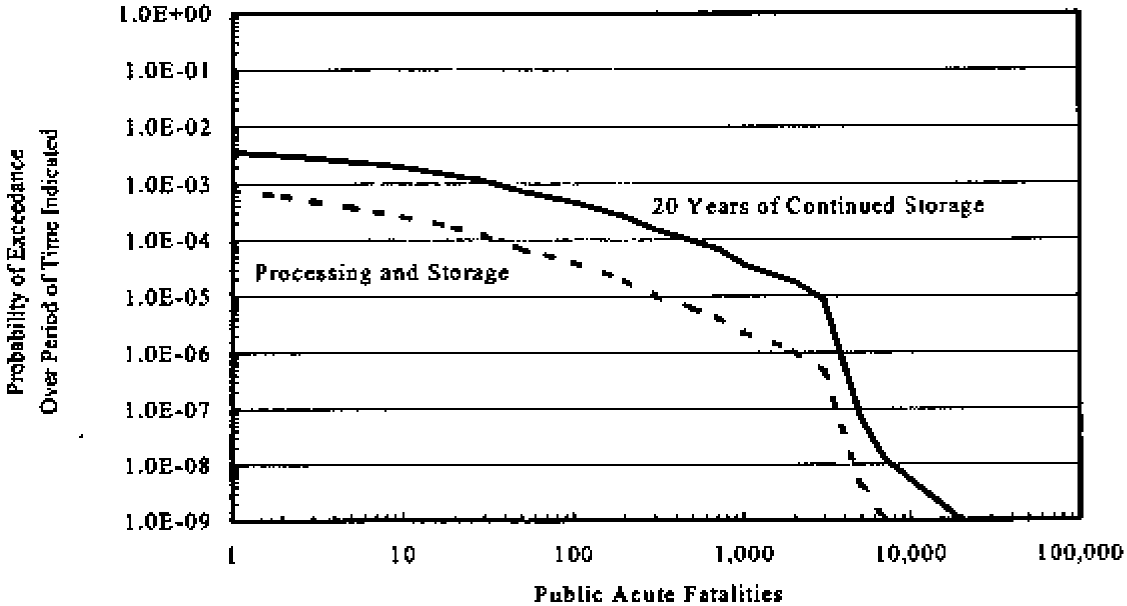

Figure 16-2. Total Average Public Societal Fatality Risk During UMCDF Operation (Processing plus Storage) and 20 Years of Continued Storage

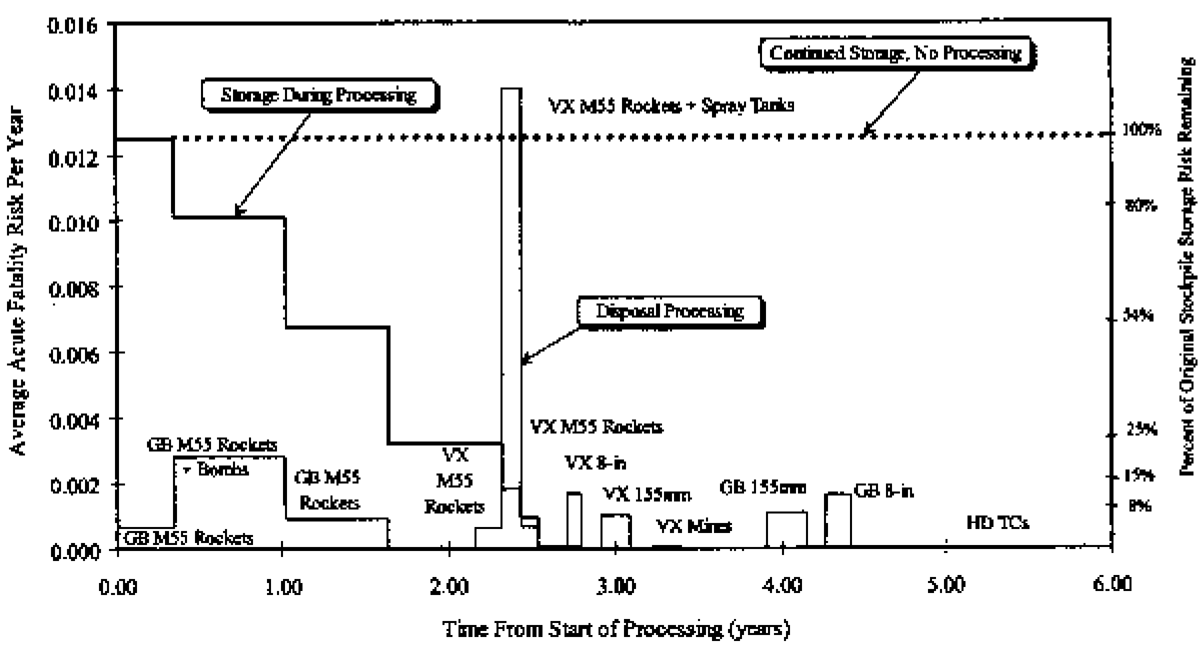

Figure 16-3. Average Public Societal Fatality Risk per Year for Stockpile Storage and Disposal Processing over the Disposal Duration at UMCDF (Linear Scale)

The risk measures depicted in the figure are the average public acute expected fatalities per year during each campaign. The total risk per campaign is the average expected fatalities per year multiplied by the campaign duration. For ease of display, the storage risk during disposal processing is shown as constant during individual campaigns (stepping down to the next level at the end of the campaign), although there would actually be a reduction in risk as each campaign progressed and portions of the munition stockpile were destroyed. From figure 16-3 it can be seen that risk to the public from the stockpile is greatly reduced following destruction of the GB and VX rockets. After the rockets are destroyed, the expected fatalities per year associated with disposal are sometimes greater than the expected fatalities per year associated with munition storage. This is because by then the storage risk is almost negligible (over 99 percent of the storage risk has been eliminated) and most of the remaining processing campaigns still have measurable risk.

As with figure 16-1, the first conclusion to be drawn from figure 16-3 is that the total risk of disposal processing is lower than the total risk of continued storage. It is important to note that even though there will be periods of time following the processing of M55 rockets that disposal risk is higher on a day-to-day basis, total storage risk will be higher than total disposal risk because the remaining munitions in the stockpile will continue to accrue risk as long as they are stored.

Figure 16-4 provides the same information as figure 16-3 on a logarithmic scale to more clearly illustrate the processing and storage risk differences. While the differences are graphically easier to see in this figure, it must be remembered that the risk scale is evenly subdivided by factors of 10. To more easily interpret this illustration, another scale is provided on the right side of the figure to show the current stockpile risk as 100 percent and the percent of that risk remaining as munitions are destroyed. For example, following the removal of GB rockets from the storage yard, annual storage risk will fall by approximately 75 percent. When the VX rockets are processed, the total storage risk rate will be reduced by over 99 percent. The items remaining in storage at that point have significantly lower seismic risk.

The processing risks (on a per-year basis) vary significantly among campaigns based on the munition and agent being processed and the campaign duration. As shown in figure 16-4, the changeover periods following processing of GB munitions have measurable risk due to the possibility of release of GB previously captured on the HVAC filters if there was a fire during changeover.

Figures 16-3 and 16-4 also show that the risk of continued storage will exist until some disposal activity is undertaken. In the past, such as during the development of the FPEIS, some of the decision-making was aided by comparing the total risk of disposal processing to the integrated risk of continued storage for 25 years. That comparison also has been made here, adjusted to

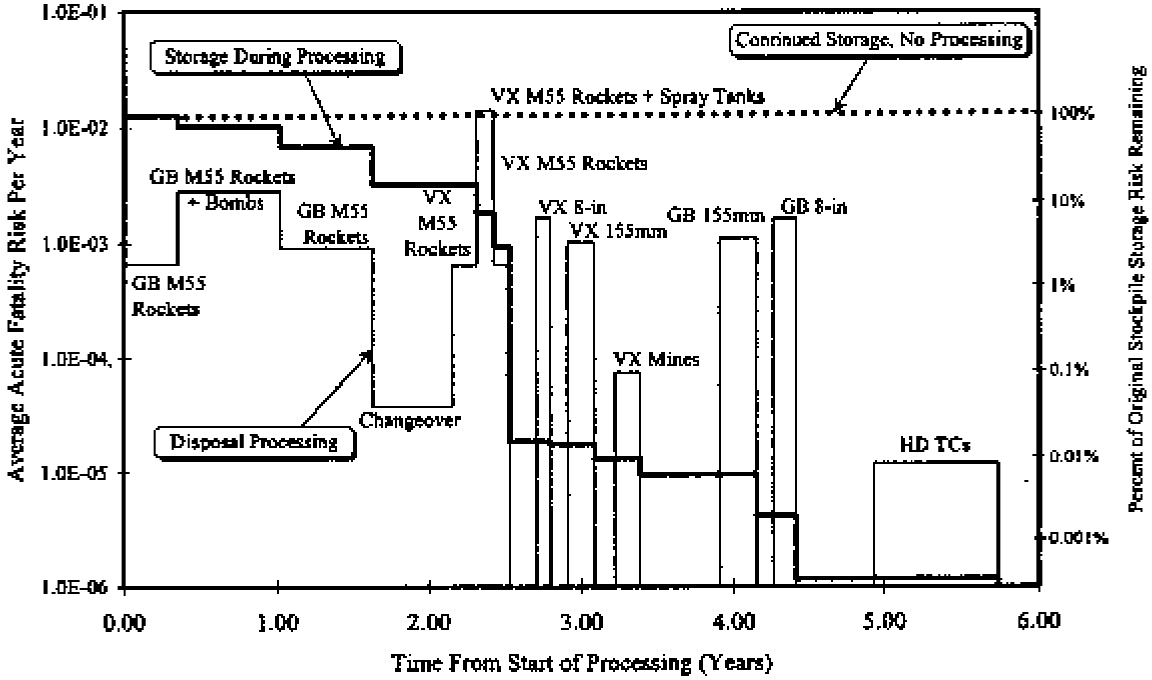

Figure 16-4. Average Public Societal Fatality Risk per Year for Stockpile Storage and Disposal Processing over the Disposal Duration at UMCDF (Logarithmic Scale)

20 years, consistent with the Phase 1 QRAs. While somewhat useful as a point of comparison, the comparison of all processing risk to 20 years of storage also has its limitations. First, the population surrounding the site would not likely remain static for 20 years, and an increase in population would translate to an increase in societal risk. Also, a comparison of processing to 20 years of storage could be misleading because the 20-year storage value does not include the additional risk of disposing of the munitions and agents that would still exist at the end of 20 years.

As indicated by the straight dotted line in figures 16-3 and 16-4, the continued storage risk is assumed to be constant over the 20-year period. It is frequently assumed that the risk per year will increase as the stockpile degrades. The QRA team did not uncover any evidence that a substantial increase in risk would be associated with long-term storage on the order of 20 years. The agent leakage rates have not shown any substantial increasing trend, and even if they did, the public risk associated with leakage of individual items is quite limited. In addition, the propellant in the M55 rockets, which had previously been thought to become unstable as it aged, has been found to be stable for time periods well exceeding 20 years. Thus, there are no contributors to risk that would become increasingly likely with time, and a straight-line extrapolation appears to be reasonable. The risk per year does not increase but the risk is cumulative, in that each additional year of storage exposes the population to another annual increment of risk.

Given these limitations, the average risk results (expected fatalities) over the 6-year and 20-year periods are presented in table 16-1. This is the integrated risk, or the area under the curves presented earlier. As indicated, the total risk of processing is less than continued storage risk and less than storage risk during the 6 years of disposal.

Table 16-1. Summary of Average Public Societal Acute Fatality Risk at UMCDF

Average Public Societal Acute Fatality Risk at UMCDF of:	
Disposal Processing (for 6 Years)	5.3×10^{-3}
Stockpile Storage During the 6-Year Processing Duration	1.8×10^{-2}
20 Years of Continued Storage	0.26

It should be noted that the risk is a summation over all accident sequences of the product of accident probabilities coupled with the associated consequences. Therefore, the risk of an infrequent accident with large consequences can contribute comparably with a frequent accident with smaller consequences. In fact, although the average risk for continued storage indicates an approximate 26 percent chance of a fatality in 20 years, the risk is dominated by less frequent events such as seismic-induced rocket igloo fires that could involve more than one fatality if they occurred, but that occur much less frequently than once every 20 years.

16.1.2 Public Fatality Individual Risk. Another way of expressing risk is the risk to individuals living various distances from the site. As described in box 16-1, individual risk is the societal risk divided by the number of people in a given area. Sections 13 and 15 list these risks in detail; table 16-2 summarizes the individual risk for people closest to the site (in the 2- to 5-kilometer ring). Even within this population ring the individual risk varies. The risks are provided for the entire processing duration and for 20 years of continued storage. The risks also are presented as average yearly values, which are the values presented most frequently in other assessments of individual risk.

Box 16-1. Societal and Individual Risk	
Societal	Risk to society, the total impact. For example, there are about 40,000 people killed in U.S. car accidents each year.
Individual	Per-person risk, the chance that an individual is affected. For example, typical citizens have a 1 in 6,000 chance of being killed in a car accident each year.

The individual risk is higher for disposal processing than storage during processing; disposal risk remains relatively constant because of fire risk whereas storage risk drops considerably after the

Table 16-2. Summary of Mean Individual Risk of Fatality for Population Closest to the Site

Mean Individual Risk of Fatality for Population Nearest the Site		
	Over Entire Duration	Average per Year
Disposal Processing for 6 Years	1.1×10^{-5}	1.9×10^{-6}
Stockpile Storage During the 6-Year Processing Duration	5.4×10^{-6}	9.5×10^{-7}
20 Years of Continued Storage	7.4×10^{-5}	3.7×10^{-6}

rockets are processed. Individual risk for continued storage is highest because of the storage of GB and VX rockets. Processing accidents generally result in smaller releases than storage accidents because the latter are dominated by severe accidents (e.g., earthquakes) that can result in large agent releases. The agent plume from a small release cannot reach the large population centers around the UMCDF, whereas the large releases can.

16.1.3 Public Cancer Risk. This QRA included an estimate of the public risk of latent cancers associated with a one-time accidental exposure to HD agent. This risk, summarized in table 16-3, was found to be much less than the fatality risk (summarized in table 16-1). Public latent cancer risk due to storage of mustard is almost negligible because ton containers having no lightning susceptibility and low seismic vulnerability. As a result, storage risk is dominated by accidental aircraft crash sequences, which are extremely rare events. Cancer risks from processing are also very small but are greater than storage because facility fires during HD processing are more likely than the very rare accidents (such as aircraft crashes) that could affect these items in storage.

Table 16-3. Summary of Average Public Societal Latent Cancer Risk

Average Public Societal Latent Cancer Risk of:	
Disposal Processing (for 6 years)	1.7×10^{-5}
Stockpile Storage During the 6-Year Processing Duration	1.0×10^{-6}
20 Years of Continued Stockpile Storage	2.1×10^{-6}

16.1.4 Public Fatality Risk Uncertainty. In order to simplify the presentations, the information provided to this point has not explicitly addressed uncertainty. Interpretation and use of the risk results must always consider the important fact that the estimates of numerical risk are very uncertain. In order to understand this uncertainty, the models used to estimate risk have been evaluated with uncertainty in the various model inputs included to generate a statistical distribution of risk results. From these evaluations it is possible to examine the characteristics of the uncertainty distribution, such as the upper and lower percentiles, as well as the central tendencies described by the mean and median. Although other values can be calculated, this report includes the 5th and 95th percentiles as the bounds of the distributions on risk values. When individual values are provided in this report, they are most typically the means (or average values) across all of the uncertainty distributions. The development of the uncertainties is described in more detail in section 12.

In this section the range of the results is provided to ensure that decision-makers have the necessary information about the mean value, as well as the full distribution including the upper and lower uncertainty bounds. There is a great deal of data generated when the QRA models are solved with full consideration of uncertainty. It is difficult to display all these data in ways that are useful to every various viewpoint of the different readers. The Quantus Risk Management Workstation can be used to further investigate specific aspects of the uncertainty distribution results that are not specifically included here.

One word of caution is in order. Not every uncertainty associated with the estimate of risk has been explicitly quantified. Also, the focus has been on risk-significant uncertainties, so the uncertainty in minor risk contributors was not included. Consequently, the lower end of the uncertainty distribution may not be fully characterized. The risk results are subject to further limitations as discussed in section 16.5.

Figure 16-5 illustrates the uncertainty distributions in comparison to the risks of disposal processing and 20 years of continued storage. The curves in the figure illustrate several important aspects of the uncertainty. First, at the lower levels of consequence, such as one-or-more fatality, there is about a factor of 100 between the upper and lower bounds of the disposal uncertainty distribution. At the higher level of consequence (e.g., 1,000 fatalities or more), there is about a factor of 30 between the upper and lower bounds. It is clear from the distribution that the risk of disposal processing, even when considering the uncertainty in the evaluation, is significantly lower than the risk from continuing to store the chemical agents and munitions for an extended period.

Figure 16-6 illustrates the uncertainty in the total risk during the 6 years of processing. Uncertainty distributions for the risk of disposal processing and the risk of storing munitions (accounting for the depletion in inventory as processing progresses) are displayed. The uncertainty in stockpile storage risk during disposal is similar to the uncertainty for continued storage over 20 years, as shown in figure 16-5. As indicated in figure 16-6, the mean value, which is quoted most typically as the risk value, is substantially above the median (50th percentile). This result is due to the shape of the various uncertainty distributions used in the model.

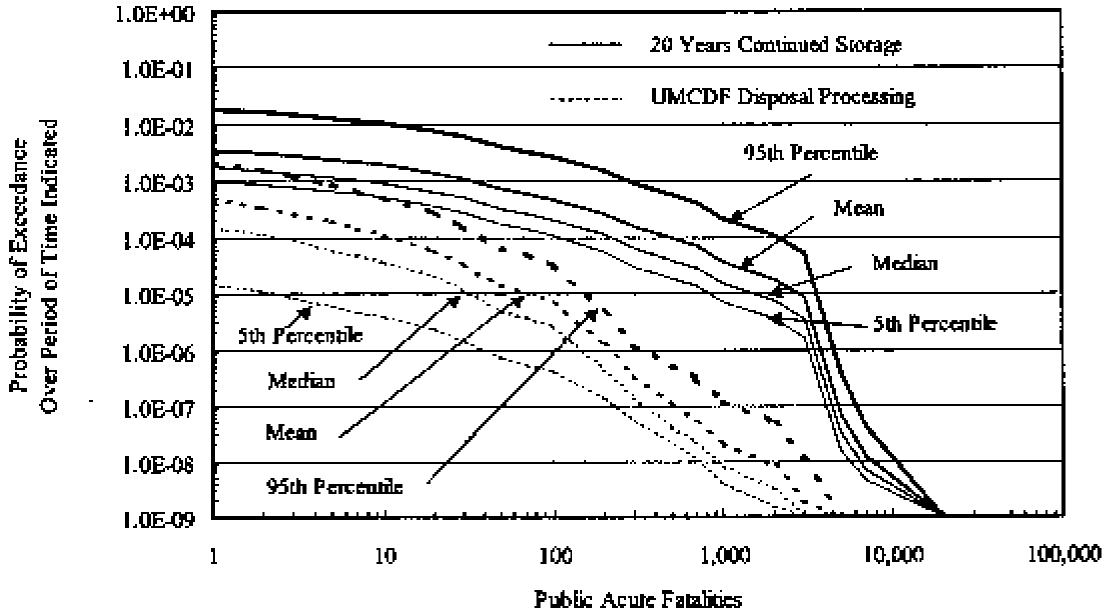

Figure 16-5. Comparison of Public Fatality Risk Uncertainties of UMCDF Disposal Processing for 6 Years with 20 Years of Continued Storage

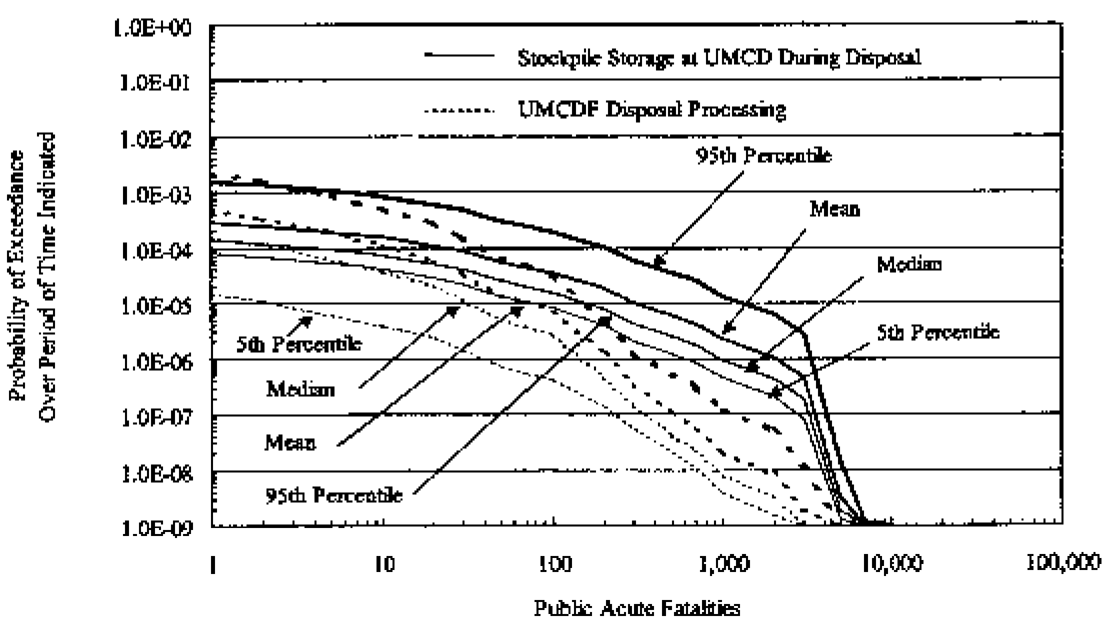

Figure 16-6. Comparison of Public Fatality Risk Uncertainties of UMCDF Disposal Processing for 6 Years and Storage During Disposal Processing

The results displayed in the figures 16-5 and 16-6 can be used to determine the uncertainty in the societal acute fatality risk. The risk comparisons previously presented should be considered in light of this uncertainty. Table 16-4 provides the mean, median, 5th and 95th percentiles of the uncertainty distributions. The results show that the upper bound on disposal risk is still lower than the lower bound on storage risk.

Table 16-4. Summary of Public Societal Acute Fatality Risk at Umatilla

Public Societal Acute Fatality Risk at Umatilla of:	Mean	5th Percentile	Median	95th Percentile
Disposal Processing	5.3×10^{-3}	2.6×10^{-4}	2.0×10^{-3}	2.2×10^{-2}
Stockpile Storage During the Processing Duration	1.8×10^{-2}	7.6×10^{-3}	7.8×10^{-2}	1.0×10^{-1}
20 Years of Continued Storage	2.6×10^{-1}	5.7×10^{-2}	1.1×10^{-1}	1.5

16.2 Summary of Public Risk Contributors

Sections 13 and 15 include discussions of the contributors to risk for disposal processing and stockpile storage, respectively. Figure 16-7 summarizes the contributors to the mean processing risk. For disposal processing at UMCDF, the following insights were developed:

- Public risk of the disposal process is dominated by the potential for a facility fire that affects agent inventories within the facility (MDB) and also can lead to release of agent from the HVAC filter units. Fire initiators account for 87 percent of the total mean risk. This type of facility fire originates within individual rooms of the MDB and spreads to other portions of the facility.

- A portion of the fire risk (27 percent of the 87 percent) is associated with fires in the MDB that, in addition to agent release from the building, also result in heating of the HVAC carbon filter units with a release by desorption of previously captured agent.

- Seismic-induced fires contribute approximately 6 percent to total public disposal risk. These fires result from earthquakes and can affect a large portion of the facility.

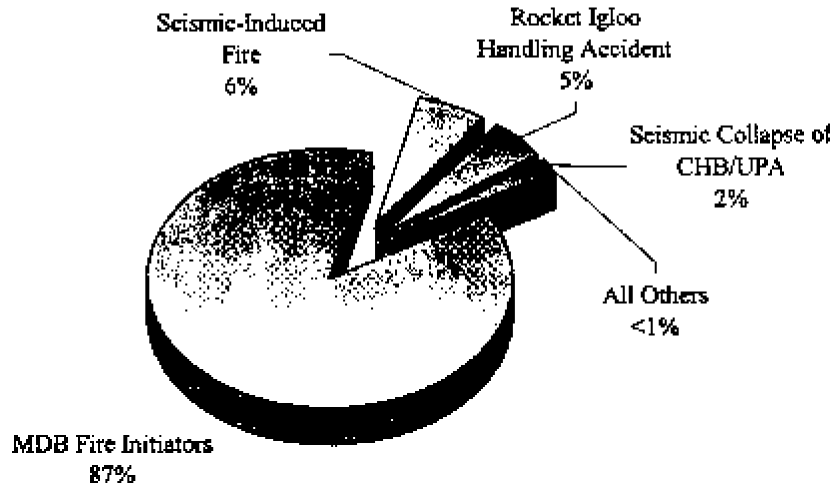

Figure 16-7. Contributors to Public Acute Fatality Risk from UMCDF Disposal Processing

- About 5 percent of the public fatality risk is due to handling of M55 rockets when they are being removed from igloos to be transported to the disposal facility. These scenarios are risk-significant because of the potential for an igloo fire involving the entire igloo inventory. Although handling accidents are not frequent events, this type of accident would have greater consequences than most other disposal accidents because of the relatively large inventory that could become involved in the igloo fire.

- Approximately 2 percent of the risk is associated with the potential for a structural failure of the CHB/UPA. While the facility is built to appropriate earthquake building codes, the second floor area has been determined to be vulnerable for large and infrequent earthquakes (larger than those for which the facility was designed).

- Other events associated with processing activities account for much less than 1 percent of the UMCDF risk. Very few of the processing-related activities contribute to risk. In general, the equipment fails in a safe status and the amount of agent involved in any step is quite limited.

The uncertainty results also have been examined with a conclusion that the contributors to mean risk are representative of the overall risk contributors. In other words, the bounds of the uncertainty distribution are not controlled by uncertainties in some particular type of accident initiating event. The uncertainty bounds include uncertainties in accident frequencies and their associated agent releases, but there are no unique insights concerning accident contributors at the bounds of the analysis.

The public risks associated with chemical stockpile storage at UMCD during munition processing or continued storage are described in detail in section 15. The dominant contributors to risk are illustrated in figure 16-8, and summarized as follows:

- Earthquakes completely dominate the risk of continued storage, accounting for 97 percent of the average public fatality risk. Even for the reinforced concrete igloos at UMCD, igloo collapse is possible. While earthquakes capable of producing this level of ground motion are extremely rare, a collapse could damage the munitions stored inside. This could result in a leak or explosion. If the igloo does not collapse, the munitions inside can still pose a risk because the munition pallets stacked inside the igloos could fall during an earthquake, causing a leak or explosion. The M55 rockets are the most significant contributors to seismic risk because they are more susceptible to accidental ignition than most other munitions and ignition of one rocket could cause a fire that spreads to the other rockets in the igloo.

- Lightning contributes approximately 3 percent to storage risk. If lightning strikes an igloo, a rocket could ignite if there is a direct arc from the igloo walls to the rocket stack. Arcing can occur if the reinforcing steel bar (rebar) in the floor and arch of the igloo is poorly connected or discontinuous. This could allow charge to buildup sufficiently in a portion of the rebar that an arc occurs. Arcing is very unlikely to occur if the rebar in the affected igloo forms a continuous, well-connected path for dispersing the electric charge. Although the igloos at

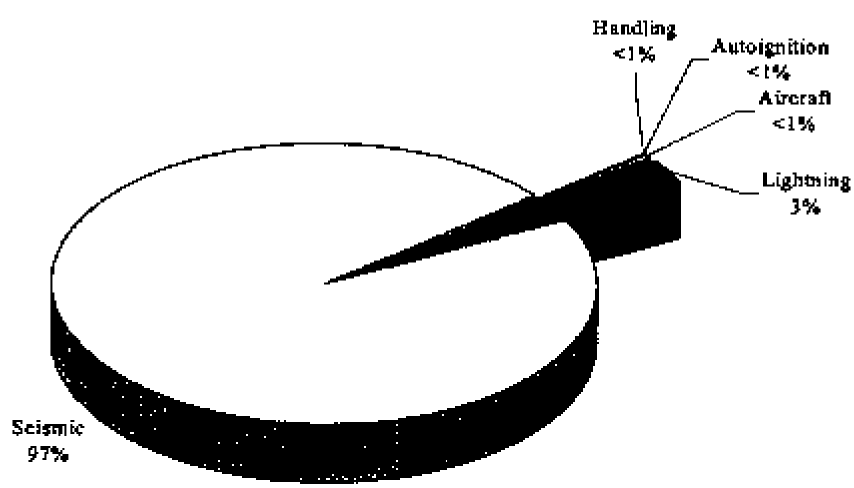

Figure 16-8. Contributors to Public Acute Fatality Risk from Continued Stockpile Storage at UMCD

UMCD have not been tested for lightning attenuation, the results from lightning testing of similarly constructed igloos were used in the analysis.

- Autoignition of M55 rockets accounts for much less than 1 percent of storage risk. The frequency of an autoignition for non-leaking rockets is negligible, while the frequency of autoignition for leaking rockets is higher, but still extremely small.

- Two other events with potentially high consequences but low frequency each contribute much less than 1 percent of storage risk. The only contributor during normal storage maintenance activities is a handling accident during isolation and overpacking of a leaking M55 rocket, which could lead to an igloo fire. The frequency of handling accidents that result in a rocket ignition is very small. An accidental aircraft crash could also lead to a significant agent release; however, the frequency of aircraft crashes is estimated to be very small.

One frequent question is why the handling operations at the igloo contribute to disposal risk but not to storage risk. This is principally a function of accident frequency. For disposal risk, every munition pallet must be retrieved from within the igloo and moved out of the igloo. Isolation of a leaking munition is a relatively infrequent event. Even though several pallets may have to be moved to isolate the leaking munitions, the total number of operations within a year is very small. Even though the human error and accident rates are increased during leaker isolation to account for the impact of the stress and encumbrance created by the necessary personal protective equipment, the frequency of a munition leak is still low.

The findings described here are some of the principal insights concerning contributors to the risk of both processing and continued storage. More discussion of the findings is provided with the results in sections 13 and 15. The key conclusion is that building fire initiators contribute significantly to disposal risk because a facility-wide fire can affect all agent within the MDB as well as agent on the HVAC filters. Fires, though rare, have the potential for larger consequences than other types of accidents.

16.3 Comparison to UMCDF Phase 1 QRA

The UMCDF Phase 1 QRA analysis of disposal processing and continued storage was completed in September 1996 (SAIC, 1996a). The results of the UMCDF Phase 2 QRA replace the previously published UMCDF Phase 1 QRA results. The Phase 1 QRA was similar in scope to this assessment; however, the UMCDF disposal assessment is now based on the as-built facility and there have been refinements in several key areas of the risk assessment. Table 16-5 summarizes some of the differences between the assessments.

Table 16-5. Summary Comparison of UMCDF Phase 1 and Phase 2 QRAs

Topic	UMCDF Phase 1 QRA	UMCDF Phase 2 QRA
Scope	All potential initiating events except sabotage. Public risk only. Point-estimate evaluation.	All potential initiating events except sabotage. Public and worker risk. Evaluation includes propagation of uncertainties in the model inputs.
Design Basis	TOCDF "as-constructed" with UMCD site-specific weather and external event initiators.	UMCDF "as-constructed" with UMCD site-specific weather and external event initiators.
Major Design Differences	CHB/UPA assessed at seismic capacity of 0.50 g, based on programmatic decision to change design to limit likelihood of seismically induced failure. LPG tank was assessed as a 50,000-gallon tank filled only to 10,000 gallons.	CHB/UPA assessed at seismic capacity of 0.50 g, based on analyzed capacity of structure. LPG tank was assessed "as built."
Munition Inventories	CHB holds up to 48 onsite containers; each onsite container holds multiple pallets.	Onsite containers replaced with EONCs. CHB capacity and onsite container/EONC capacity are the same.
Operational Information	Incorporated data and insights from JACADS operation and TOCDF systemization.	Reflects actual TOCDF and JACADS operations, including actual incidents, PLL data, and site observations by QRA team members. Manual operations and human actions modeled in more detail.
Facility Fire Analysis	Based on methodology used in nuclear plant risk assessments.	Industrial fire data were obtained and used in a new model and updated methodology.
Population/ Weather Data	1990 U.S. Census population data and UMCDF-specific weather data	2000 U.S. Census data projected to 2002 and UMCDF-specific weather data
Quantification	Various computer codes were used, as discussed in the Phase 1 report.	The Quantus Risk Management Workstation was used. The overall method is the same.

16.3.1 Comparison of Results. Table 16-6 lists the disposal processing risk results for the public acute fatality risk measures that are comparable between the two UMCDF QRAs: 1) expected fatalities, 2) probability of one or more fatalities, and 3) fatalities at a probability of 1×10^{-9}. As seen in this table, there was an increase in the estimate of all risk measures for the Phase 2 QRA. This is a direct result of the new fire methodology used in the Phase 2 QRA that better tracks industrial fire experience than the method used in the Phase 1 QRA. The new results have higher frequencies of fires with the potential for large agent inventory involvement.

Figure 16-9 shows the Phase 1 and Phase 2 CCDFs on one chart for easy comparison (the mean CCDF from the Phase 2 QRA is displayed as being most comparable to the Phase 1 QRA point estimate CCDF). The biggest difference between these two curves is that the Phase 2 QRA indicates more frequent events producing one or more fatalities. This effect also is largely due to the facility fire initiators, which have a much higher frequency than the seismic sequences that dominated disposal risk in the Phase 1 QRA. In the Phase 2 QRA, the recurrence rate of the

Table 16-6. Comparison of UMCDF Phase 1 and Phase 2 QRA Disposal Processing Risks

Risk Measure	UMCDF Phase 1 QRA	UMCDF Phase 2 QRA
Expected Fatalities	2.0×10^{-5}	5.3×10^{-3}
Probability of One or More Fatalities	3.0×10^{-6}	4.7×10^{-4}
Fatalities at 1×10^{-9} Probability	170	5,000

most risk-significant initiator, a second floor fire, is about once every 1,000 years and this event results in an average of 1.0 fatalities. In the Phase 1 QRA, the most risk-significant sequence was a CHB/UPA collapse with a recurrence interval of 30,000 years and resulting in 0.4 fatalities. Differences between the contributors for both QRAs are discussed in more detail in section 16.3.2. The Phase 1 QRA also did not fully account for the large amounts of agent on the HVAC filters during some campaigns. In addition to these differences, the Phase 1 QRA risk results were based on a disposal processing duration of 3.3 years compared to 5.7 years in the Phase 2 QRA.

A comparison of the risk of continued storage is presented in table 16-7. As seen from this table, the storage risk decreased by 50 percent between the Phase 1 and Phase 2 QRAs. The probability of one or more fatalities increased and the fatalities at a probability of 1×10^{-9}

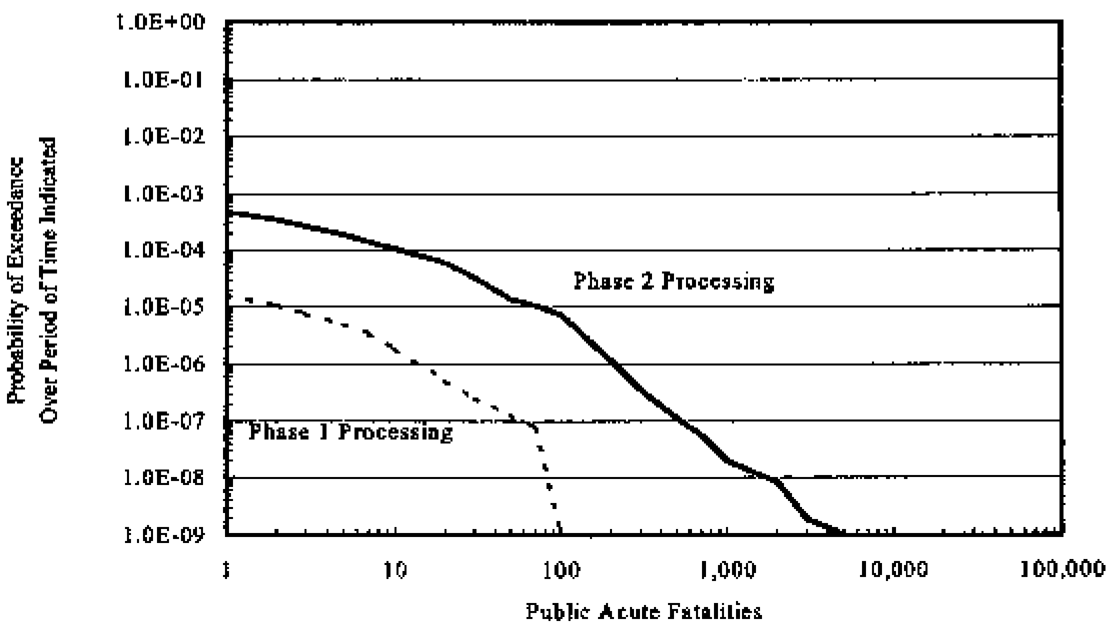

Figure 16-9. Average Public Societal Acute Fatality Risk for UMCDF Processing, UMCDF Phase 1 and Phase 2 QRAs

Table 16-7. Comparison of UMCDF Phase 1 and Phase 2 QRA
Societal Storage Risk Over 20 Years

Risk Measure	UMCDF Phase 1 QRA	UMCDF Phase 2 QRA
Expected Fatalities	0.60	0.26
Probability of One or More Fatalities	2.0×10^{-3}	3.6×10^{-3}
Fatalities at 1×10^{-9} Probability	30,000	20,000

decreased. The primary reason that the total risk is now lower than previously assessed is because the seismic analysis has been refined. Figure 16-10 shows both CCDFs on one chart for easy comparison. As with the Phase 1 QRA, seismic events are still the dominant contributors to storage risk. The overall conclusion from the comparison is that the processing risk is lower than the continued storage risk for both the UMCDF Phase 1 and Phase 2 QRAs. The dominant contributors to risk for the Phase 1 and Phase 2 QRAs are compared in section 16.3.2.

16.3.2 Comparison of Contributors. As described in section 16.2, facility fires dominate the processing risk at UMCDF (87 percent) with smaller contributions from seismic-induced fires (6 percent) and igloo handling accidents (5 percent). The UMCDF Phase 1 QRA reported that

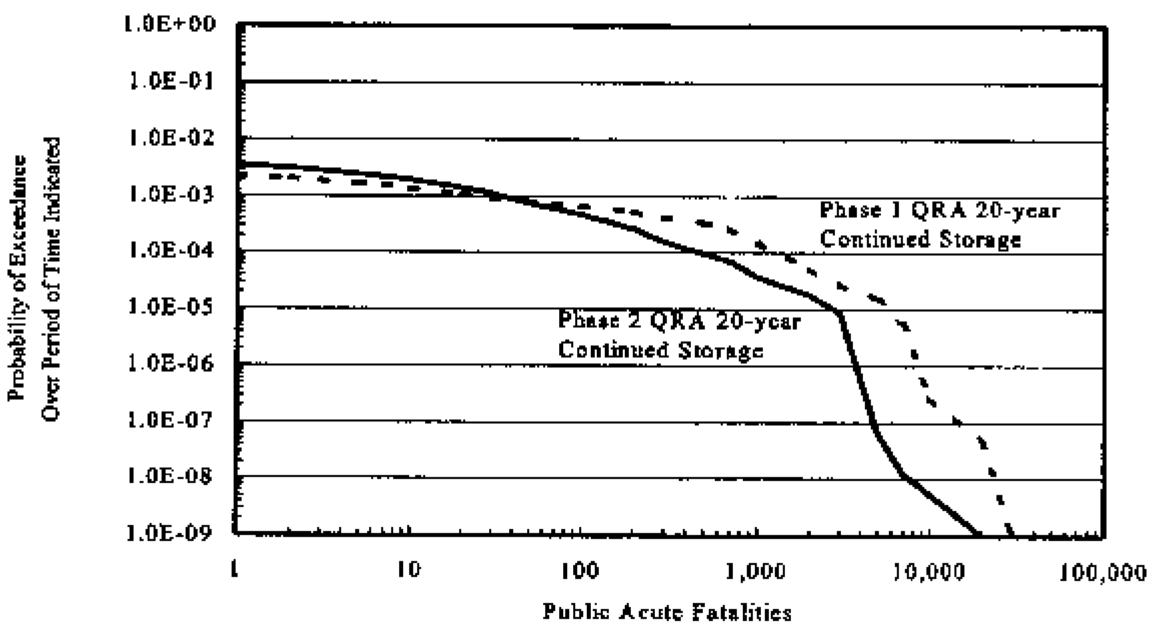

Figure 16-10. Average Public Societal Acute Fatality Risk for 20 Years of Storage at UMCD, UMCDF Phase 1 QRA Versus UMCDF Phase 2 QRA

public risk from disposal processing was dominated by seismic events (72 percent), handling-induced rocket igloo fires (14 percent), and accidental aircraft crash (13 percent). Table 16-8 summarizes these comparisons. No comparison table is shown for storage risk because the risk contributors are essentially the same.

Table 16-8. Summary of the Comparison of Disposal Processing Contributors

UMCDF Phase 1 QRA	UMCDF Phase 2 QRA
Seventy-one percent of disposal risk was associated with seismic collapse of the CHB/UPA.	This event was still important but because facility fires completely dominated facility risk, this event was a minor contributor (only 2 percent). Also, because of inventory refinements, this event resulted in fewer average fatalities than in the previous study.
Fourteen percent of disposal risk was associated with rocket handling in the storage yard.	Handling was less significant to overall risk but is still an important contributor (5 percent).
Thirteen percent of disposal risk was associated with aircraft risk.	Aircraft risk was much less important primarily because facility fire scenarios added significantly to risk.
Less than 1% of disposal risk was attributed to facility fires.	Previous QRA efforts relied on methodology used for nuclear power plant fire risk. The fire analysis for the UMCDF Phase 2 QRA was refined to include industrial facility fire data from the NFPA, which showed that similar purpose facilities have had catastrophic fires. These data were used as applicable.

16.4 Worker Risk Results and Insights

Worker risk associated with UMCDF processing also has been assessed quantitatively. The worker risk evaluation is limited to agent operations and therefore is not a comprehensive representation of all activities or hazards that could pose a threat to worker health. In spite of these limitations, the worker risk analysis has led to some insights regarding potential worker risk.

Worker risk has been evaluated for two populations:

a. *Disposal-Related Workers* – All workers at UMCDF, including all support and administrative staff located at the facility or in nearby buildings and munition handlers responsible for removal of the munitions from the stockpile and transportation to the CDF.

b. *Other Site Workers* – All other personnel working at UMCD.

The Other Site Worker risk is evaluated in the same manner as the public risk, and in essence acts as a population group around UMCDF where there is no public population. The average risk for Other Site Workers is 2.0×10^{-5}. The contributors to risk for Other Site Workers are essentially the same as for the public risk, with fire sequences dominating (see figure 16-11).

The risk for Disposal-Related Workers is substantially different from the risk for Other Site Workers. The processing and handling workers can be affected by the agent dispersion from an accident, but they also can be affected directly. For example, a munition handler could potentially be splashed with liquid agent in a handling accident, or workers in the vicinity of an explosion could be affected directly by the blast.

Disposal-Related Worker risk is discussed in sections 13.6 to 13.9. Many different scenarios that contribute to the risk are discussed in detail in section 13.7. The average Disposal-Related Worker fatality risk has been assessed to be 0.50 over the entire 6 years of disposal processing. This is a risk rate that results in an average of 0.09 fatalities per year. A summary of acute societal Disposal-Related Worker fatality risk is shown in table 16-9. The models for Disposal-Related Worker risk have been expanded considerably from the Phase 2 TOCDF QRA.

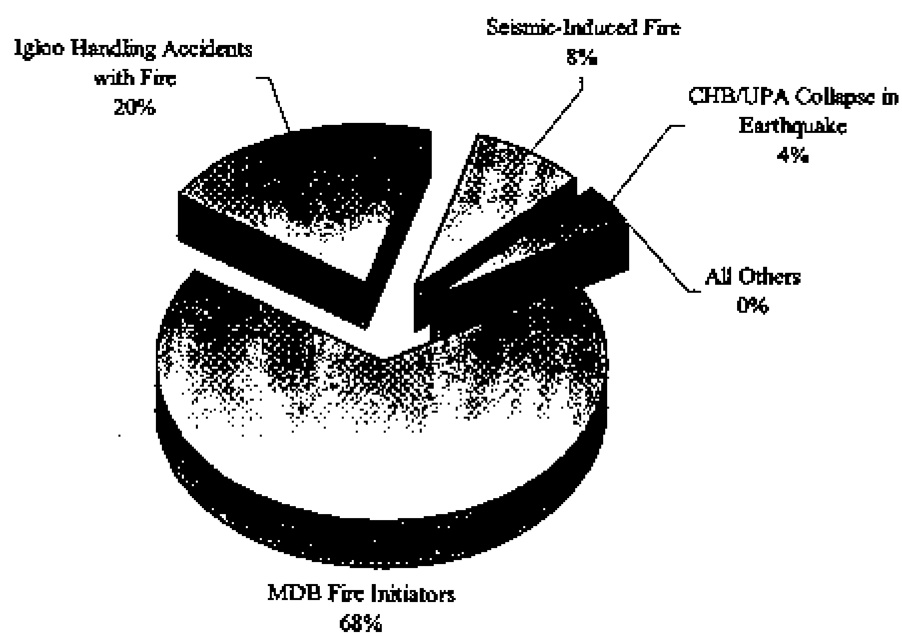

Figure 16-11. Contributors to Other Site Worker Acute Fatality Risk from UMCDF Disposal Processing

Table 16-9. Summary of Disposal-Related Worker Societal Acute Fatality Risk at UMCDF

Disposal-Related Worker Societal Acute Fatality Risk at UMCDF of:	Mean	5th Percentile	Median	95th Percentile
Disposal Processing (6 years)	5.0×10^{-1}	1.1×10^{-1}	3.2×10^{-1}	1.6
Disposal Processing (per year)	8.8×10^{-2}	1.9×10^{-2}	5.6×10^{-2}	2.8×10^{-1}

Disposal-Related Worker risk is composed of many different contributors. A summary of the types of contributors is provided in figure 16-12. Detailed discussion is provided in section 13.7. The following insights regarding worker risk have been developed:

- Worker risk is dominated by the potential for an explosion during activities to clear a DFS chute jam. The probability of an explosion of a pocket of energetics cannot be ruled out because of the possibility for many different types of jams and clearance activities. This scenario is currently 61 percent of the worker risk.

- About 13 percent of the Disposal-Related Worker risk is associated with building fires. These are the same fires that dominate public and Other Site Worker risk.

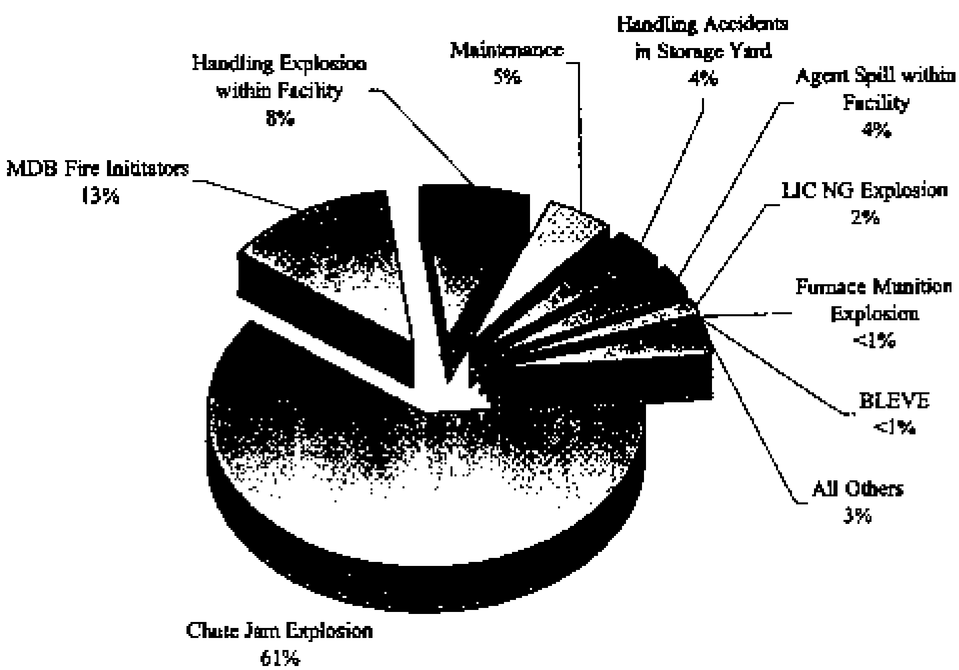

Figure 16-12. Contributors to Disposal-Related Worker Acute Fatality Risk from UMCDF Disposal Processing

This risk is associated with agent release during the fire, not a function of any efforts to fight the fire.

- Maintenance activities account for about 5 percent of the Disposal-Related Worker risk. This risk was assessed using available data and models of protective equipment reliability. This accounts for all activities involving maintenance that could involve agent contact—essentially all activities performed in DPE.

- Handling accidents in the storage yard account for approximately 4 percent of the Disposal-Related Worker risk. These accidents include munition explosions, fires and spills that result from handling accidents in the igloo or on the apron.

- Handling accidents in the facility leading to spills or explosions account for about 12 percent of the Disposal-Related Worker risk. These accidents include spills and explosions in the UPA and ECV during normal munition handling, as well as leaker handling in the ECV.

- Another important contributor to Disposal-Related Worker risk includes LIC natural gas explosions (2 percent).

The remaining Disposal-Related Worker risk is comprised of a large variety of sequences. The accidents dominating worker risk tend to involve energetic events. Even though explosions are much less likely than other facility upsets, they typically have higher consequences. This is understandable because explosions can potentially affect more people, and plant staff members are less likely to be protected by their equipment in an energetic event.

As described in section 16.5, the probabilistic assessment of worker risk should primarily be used to provide insight, because the numerical estimates are uncertain. Assessed uncertainties including those related to worker risk are provided in table 16-10. As with other estimates, the mean values being used as the risk results are above the median (or 50th percentile) risk value. Thus there is a considerable range of uncertainty below the provided mean.

The results can be compared to industrial statistics, although the industrial values are actuarial data while the QRA values are estimates generated from models. The mean worker risk fatality rate is 0.09 fatalities per year of operation, or 0.09 deaths per approximately 500 workers for a rate of 1.8×10^{-4} per worker per year. This can be compared to the average industrial fatality rate from actual statistics of roughly 4 deaths per 100,000 workers per year, or 0.02 per year for a facility like UMCDF with approximately 500 workers (National Safety Council, 1995). Thus the QRA estimate of agent-related fatalities appears to be high when compared to industrial statistics for all causes. This alone does not prove that the assessment is conservative, because there is

Table 16-10. Discussion of Uncertainties in the Risk Estimations

Element of the Model Used to Evaluate Risk	Uncertainty Included in Estimates?	Analysts' Discussion
Frequency of Accidents Resulting from Processing Activities	Yes	The accidents have been evaluated using available data for equipment and estimates of human reliability. Variables contributing to risk-significant sequences have been sampled in the uncertainty analysis. It is judged that the uncertainty in numerical values is fairly well captured directly in the uncertainty distributions.
Completeness of Accidents Resulting from Processing Activities	Not numerically estimated	Completeness is always an issue because it cannot be proven. The analysts judge that the step-by-step process (described in section 4) is good at capturing the types of accidents that could happen at each step of the process and lead to various size agent releases. Events that have already occurred at JACADS and TOCDF are evaluated for inclusion in the QRA, through use of the PLL Database. Thus it is judged likely that the range of potential releases is well represented in the QRA. However, given the uncertainties in human processes, the specific causes of accidents are unlikely to be fully captured. This is considered important to the worker risk evaluation; it is unlikely that all worker risk issues are captured in the QRA.
Frequency of Risk-Significant Fires	Yes	This is an important element because it now appears that previous analytical methods (in Phase 1 QRA) underestimated the risk. A detailed discussion is provided in appendix K2. While uncertain (as recognized in the numerical assessment), this assessment is well supported by industrial data. The analysts judge that fires are as well characterized as most of the processing accidents.
Frequency of Accidents Initiated by External Events	Yes	It is judged that the analysis and the associated uncertainty distributions well characterize the level of risk associated with the external events dominating risk. The specifics of the impact on the facility are probably not fully characterized, but the models have erred on the side of conservatism (overestimating risk) for most events and they still were not significant. For example, the exact impact of an earthquake at the facility is probably not well known, but the assumptions in the risk model characterize the range of possible outcomes. There has been less focus on less important events so the lower bound of uncertainty is less characterized.
Completeness of Accidents Initiated by External Events	Not numerically estimated	Given the number of other audits available for external events and the thorough assessment of a large list of possible initiating events that occur in nature and as a result of people's activities, the analysts have high confidence that this part of the analysis is complete.
Uncertainty in the Representation of the Amount of Agent Released	Yes	Each projected accident sequence requires an estimate of agent release and the conditions surrounding the release. The analysts judge that the uncertainty is largely captured in the distributions included in the analysis, but that any given accident could have greater uncertainty. In other words, the uncertainty in the overall answer is judged to be well characterized, but specific accidents pulled out for special consideration would likely have to be studied further to fully characterize the uncertainty for a single accident.

Table 16-10. Discussion of Uncertainties in the Risk Estimations (Continued)

Element of the Model Used to Evaluate Risk	Uncertainty Included in Estimates?	Analysts' Discussion
Randomness in the Amount of Agent that Could be Involved in an Accident	Yes	While not capturing all of the random aspects that could determine the outcomes, this QRA includes explicit accident sequences that account for the range of possible outcomes that might be generated by the random nature of how much chemical agent might be involved. For example, handling-induced igloo fires could occur in full or nearly empty igloos, or anywhere between. This was modeled by developing accident sequences for four levels of possible igloo inventory. This direct characterization of randomness was focused on risk-significant model inputs.
Uncertainty in the Dispersion of Agent in the Atmosphere	No	Even though the calculations are detailed, modeling atmospheric dispersion is a very difficult task. While there have been strides in recent years due to the advent of greater computing power, it is not yet practical to use highly sophisticated models. The relatively simple Gaussian plume models are used here, but the uncertainty in the various model parameters is not explicitly evaluated. It is judged by the analysts that the current analysis is somewhat conservative in this regard, in that the simplified model likely overestimates risk.
Uncertainty in the Weather Associated with an Agent Release	Yes	Weather is known to be a controlling influence. This is captured by analyzing the possible agent releases for 1,460 different weather samples. Thus, notwithstanding the uncertainties in the dispersion model, the range of weather is captured. However, due to the simplicity of the model, the dynamics of changing weather over the full time of the release are not well captured.
Modeling of Emergency Protective Actions in the Community	Not numerically estimated	Although not included in the uncertainty characterization, sensitivity studies have been included that report the results with and without protective actions. The models assume a 95 percent participation (based on data for other evacuations) but the uncertainty in this has not been evaluated. The models used here for protective actions are quite simple and are judged adequate for estimating risk but are judged inadequate for specific emergency planning issues, which are better evaluated with more detailed models.
Randomness of Number of Workers Near Accidents	Yes	Different accident sequences have been generated to account for the fact that the accident could occur when there were many workers in the immediate vicinity and when there were very few workers around. This remains uncertain, but it was explicitly evaluated.
Uncertainty in the Impact of Accidents on Nearby Workers	Yes	Uncertainty distributions have been developed for worker impact, but this area remains highly judgmental—detailed modeling is not practical. Thus there is considerable analysts' judgment and the simplified assessment of fatality/no fatality makes coverage of this difficult. The models have been greatly extended since earlier QRAs, but this area is still highly uncertain. It is judged that the numerical results, even including the uncertainty distributions, might have a conservative bias that would tend to overestimate risk.
Uncertainty in the Response of Humans to Various Agent Doses	No	This has not been explicitly evaluated using uncertainty distributions—there are accepted values for dose-response that were used. Work is underway to re-evaluate the standards and all the work to date has been aimed at workers, whereas risk also is estimated for the full range of population in the surrounding community. Sensitivity studies have been used to address this. Given the results of the sensitivity studies, it is the QRA analysts' judgment that this is the controlling uncertainty in the estimates of public risk.

wide variation in the industry. But there is another factor: the chemical agents were produced, uploaded into munitions, and shipped without a high incidence of agent-related fatalities. The demilitarization operations at CAMDS, JACADS, and TOCDF also represent over 20 years of agent operations without an agent-related fatality. Probabilistic evaluation of worker risk is a relatively new endeavor and should not be considered a precise predictive tool.

16.5 Uncertainties and Limitations

Use of the results of these analyses must be augmented with an understanding of the uncertainties and limitations. These factors do not negate the usefulness of the study but should be used to understand how best to use the information in risk management.

The QRA models have been solved with inclusion of uncertainty distributions for parameters in the models, generating an uncertainty distribution for the numerical estimates of risk. The use of uncertainty analysis in the assessment has been discussed in section 12 and the distributions assigned to individual parameters are described in appendix P and related appendices. Even with this characterization, the use of the numerical values in this study must be tempered with an understanding that there are additional uncertainties that are not fully assessed. Table 16-10 provides a discussion of the analysts' view of the relative importance of the uncertainties, whether quantified or not.

In spite of the uncertainties, the risk evaluations meet their objectives by providing a risk management tool. In other words, the risk assessment can be used by extracting the insights while recognizing the numerical uncertainties. For example, the evaluations have been examined and it has been concluded that the types of accidents contributing to risk are largely independent of the numerical uncertainty in the risk values. Thus the analysis, even considering uncertainties, suggests that seismic is the greatest storage risk and fire is the greatest disposal risk. In addition, while the numerical estimates are uncertain, they are useful for comparing different activities and in a more limited sense, for comparing to other risks.

In addition to the uncertainties, there are also some limitations. These are generally associated with the specific scope of analysis or the availability of information.

One timely topic is sabotage and terrorism. These are not included in the scope of the QRA. As described in section 5.7, sabotage and terrorism are addressed through other methods of assessment and protection. Assessments of sabotage and terrorism cannot be included in unclassified risk assessments because detailed assessments would, in effect, create a roadmap for such activities. There are two conclusions that can be drawn concerning terrorism and sabotage. The first is that the risk models very likely include the levels of agent release that could be associated with such events if they occurred in storage or processing areas. The QRA includes earthquakes and accidental airplane crashes and other very catastrophic events that include the potential for very large releases. The second conclusion is that the chemical agents and munitions only pose a threat as long as they exist. Therefore, whatever threat exists is a direct function of how long the stockpile continues to be stored.

A summary of some of the other key limitations is provided as follows:

- The current results represent a snapshot view of an ongoing risk management process. These risk results therefore should be used for insight, but are not anticipated to represent the final risk because PMCD has committed to continued efforts to manage and minimize risk.

- The analysis is only for agent-related risk of accidental releases and for the risks of disposing of the energetics associated with munitions.

- The QRA models have been developed to capture the UMCDF-specific operations, but not all details are available at this time. The models should continue to be updated as the specifics of UMCDF operations and the final procedures become available.

- The analysis is based on the current schedule of approximately 6 years. The RMP calls for an update of the QRA prior to new campaigns and any changes in schedule should be included at that time. Increases in schedule do not always have a linear impact on risk because the risk is very different for each munition and agent. Re-evaluation of the QRA models is needed to assess risk based on schedule changes.

- There were some assumptions made regarding the processes, as detailed in section 3.13. Some of these assumptions could be critical to the results, so it will be an important risk management activity to verify the assumptions or update the models as information becomes available.

- The HVAC carbon filters will collect significant amounts of agent. Currently, a final disposal method has been tested but details of implementation at UMCDF are not yet available. This risk assessment includes the risks of transporting the carbon to an onsite storage igloo and the risk of external events such as accidental aircraft crashes affecting that igloo. The risks of final carbon disposal, however, are not included in this evaluation.

- The results include consideration of protective actions in the community, because consideration of protective action provides a more realistic estimate of risk. The protective action model is very simple and cannot be considered a detailed planning tool. As discussed in sections 13 and 15, elimination of protective actions would increase these public risk results by approximately a factor of 16 or 10 for disposal processing or storage during disposal, respectively. The important contributors to risk remain the same.

- Continued storage risk estimates also do not include potential changes in population. Therefore, it is possible that risk estimates of long-term storage are underestimated.

- The analysis of continued storage does not include the risk of whatever disposal process would be implemented after 20 years.

- The relatively recent discovery of the possibility of hydrogen overpressure in mustard-filled munitions and containers has been examined but only partially modeled. Worker risk was modified to account for an increased probability of splash/spray contact given a leak after an upset. The possibility of hydrogen combustion during processing was examined, and it was concluded that there would be no public or worker risk from such an event, although there could be some damage to equipment.

- Assessment of worker risk with detailed probabilistic models is a fairly new and unique activity. As such, there is less past methodological experience to draw on in the development and implementation of the models. Being less mature technically, the assessment of worker risk is likely subject to larger uncertainties. The worker risk results therefore should be used to provide insight, but it should be recognized that the numerical values are subject to substantial uncertainties. While useful for insight, the QRA worker risk models should not be a substitute for other traditional means of ensuring that worker risks are understood and controlled. The RMP requires both methods of control.

When assessing risk, completeness is always a concern. It is impossible to attain completeness, but QRA methods have evolved to help ensure systematic approaches that provide some confidence that the evaluation has captured the significant risks. The required development of an RMP that includes the QRA, as well as OSHA, USEPA, and U.S. Army safety and risk initiatives, will help ensure that facility operations remain safe (PMCD, 1996). Review of the QRA and facility as well as a detailed program to capture lessons learned from operations further enhances the information base for the QRA. The commitment to update the QRA models is the best assurance that the QRA results are as complete as possible.

16.6 Perspective of Numerical Risk Estimates

The QRA is only an assessment of risks and does not include conclusions regarding acceptability of risk. Acceptability is determined by society, often through elected or appointed officials. Many readers of PMCD risk-related materials have expressed a desire to have additional explanation of the numerical risk values by comparison to other risks that society and individuals face in everyday life. Comparisons need to be carefully selected by decision-makers. Society, individuals, and decision-makers have different perceptions of risk that are the controlling factor in risk decision-making. Without claim that these are the only way to view the risks, some risk perspectives are provided here.

The first risk results are societal, impacting the entire community. Societal risk comparisons are problematic when considering one activity (such as UMCDF disposal processing) where possible effects are limited to a specific population when most societal risks are compiled across larger populations. The individual risks, discussed later, better capture the impact on the people closest to UMCDF. Table 16-11 lists some societal risks in Oregon in terms of expected deaths per year. All the entries in the table except those for the QRA (which are shaded) are actuarial in

Table 16-11. Some Societal Risks in Oregon (Expected Deaths per Year)

Deaths in Oregon per Year[a]	Cause
1,130	All Accidental Deaths
479	Motor Vehicle
58	Drowning
43	Fires
22	Machinery (Including Farm)
7	Railway Accidents
2	Electric Current
0.2[b]	Dog Attacks
0.01[c]	Stockpile Storage at UMCD
0.0009[d]	Disposal Processing at UMCDF

Notes:

[a] National Safety Council, 1995, based on 1 year; most years are similar
[b] On average, one death every 5 years
[c] QRA estimate, one death every 100 years
[d] QRA estimate, one death every 1,100 years

that they are based on data from past years. The QRA numbers are average estimates using the QRA methodology. As noted in the previous section, these estimated values are uncertain.

When considering risk it is also important that the scope of the risk evaluations be considered. The QRA estimates risk of fatality as a result of accidental releases of agent. That is why the other statistics listed for perspective are accidental deaths. PMCD and the State of Oregon consider other risks (e.g., exposure to normal emissions) through a health risk assessment required for an operations permit. It has thresholds set to ensure that the disposal activity does not account for a significant percent of the population's chronic exposure risk.

The accidental death rate in table 16-11 is made up a large variety of risks, some voluntary and some involuntary. The QRA mean estimates for the possibility of fatalities associated with processing and storage are much less than 1 percent of the total accidental death rate. The risks associated with UMCDF and UMCD are somewhat different than many other societal risks in that they are of limited duration. The disposal process lasts approximately 6 years and the storage risk will exist until the stockpile is eliminated.

QRA risks also have been reported on a per-person basis. This is typically referred to as individual risk, although it is calculated for groups of people living in various geographic sectors, not for specific individuals. Table 16-12 illustrates at a high level the QRA risk results compared to Oregon accidental death statistics. (Sections 13 and 15 include results at different distances from the site, which show that the individual risk drops substantially as distance from the site increases.) The storage and disposal individual risks are on the same order of magnitude close to the site. At about 7 miles, the disposal risk is very small because most facility accidents involve limited quantities of agent. Storage risk is higher because of the larger agent quantities that could travel farther from the site.

Table 16-12. Estimated QRA Risk Compared to Individual Accidental Death Risk in Oregon

Likelihood per Person per Year	Description
380 in one million[a]	All Accidental Deaths in Oregon
4 in one million	Continued Storage, Average for People Living within 3 Miles
2 in one million	Disposal Processing, Average for People Living within 3 Miles
0.4 in one million	Continued Storage, Average for People Living about 7 Miles Away
0.02 in one million	Disposal Processing, Average for People Living about 7 Miles Away

Note:

[a] National Safety Council, 1995.

Table 16-13 provides some additional perspectives on individual risks of accidental death, including very rare events. (Oregon statistics were not available at this level of detail, so national averages are used.) This type of information is useful because it can be used to compare to other risks that society perceives to be important or unimportant. Included in the table are other risks that are a small percent of the total accidental death rate and some risks that are substantially smaller than the chemical weapons risks. Again, the values shown are the mean values of uncertainty distributions that indicate that the risk could be about a factor of 10 higher or lower, and the individual risks are also dependent on their specific locations relative to the site.

Table 16-13. Some Individual Risk Rates in the United States

Risk of Death in U.S. per Person per Year	Percent of Total	Cause of Accidental Death
340 in a million[a]	100%	All Accidental Deaths
160 in a million[a]	47%	Motor Vehicle
28 in a million[a]	8%	All Accidental Poisoning
22 in a million[a]	7%	Pedestrian Struck by Vehicle
6 in a million[a]	2%	Accidental Firearms
5 in a million[a]	1%	Choking on Food
4 in one million	1%	Chemical Weapons Storage for People within 3 Miles of UMCD (per year until disposal starts)
2 in one million	0.6%	Disposal Operations for People within 3 Miles of UMCDF (per year for about 6 years)
0.4 in one million	0.1%	Chemical Weapons Storage for People about 7 Miles from UMCD (per year until disposal starts)
0.2 in a million[a]	0.06%	Lightning
0.03 in a million[a]	0.008%	Venomous Snakes/Spiders
0.02 in one million	0.006%	Disposal Operations for People about 7 Miles from UMCDF (per year for about 6 years)
0.01 in a million[a]	0.002%	Fireworks Accidents

Note:

[a] National Safety Council, 1995.

16.7 Using the QRA in Risk Management

A number of uses of the QRA are specified in section 1.9. To date, the risk models have been used to study individual issues such as the risk impact of different disposal schedules. The results and models can be used to support the site-specific risk management process. It is likely that some changes to facility operations will be identified as the UMCDF procedures continue to evolve. The QRA results can also be translated into PMCD's existing risk assessment codes to ensure appropriate mitigations of risks.

16.8 Conclusions

The overall conclusions of this study regarding public risk are most effectively displayed in figures 16-3 and 16-4. From these figures, it is clear that the public fatality risk of disposal processing is less than the risk of continued storage for any extended period. This is the same conclusion reached in the UMCDF Phase 1 QRA. Also shown in the figures is the impact of processing on storage risk and total risk, showing the decreasing storage risk as munitions and agent are destroyed.

The factors determining the risk of disposal processing and storage have been identified and are discussed in detail in sections 13 and 15.

The public risk results have also been calculated for latent cancer. This is the risk of exposure-induced cancer long after the accident, as opposed to the acute fatality risk described previously. Of the agent stored at Umatilla, only HD has a carcinogenic effect. The findings from the QRA indicate that the latent cancer risk from accidental releases of HD is much lower than the acute fatality estimates.

Worker risk due to potential agent exposures also has been estimated. Compared with other risks identified in this study, Disposal-Related Worker risk from plant processes is more significant than the risk from external influences such as earthquakes. One action, clearing the jams in the DFS chute, accounts for a large portion of the worker risk. The risk for Other Site Workers has been assessed to be somewhat higher than that of the public located closest to the facility with very similar accident contributors.

The analysis described here is one tool used within a comprehensive RMP at UMCDF. There have already been numerous risk management actions based on the results of the TOCDF QRA, and this process with the UMCDF Phase 2 QRA will continue over the life of the facility. The comprehensive RMP implemented at UMCDF will help ensure that PMCD's goals toward the minimization of risk are met as the stockpile is destroyed.