7.0 CONCLUSIONS

7.1 Summary

The majority of uranium production in the U.S. has come from several hundred underground and open-pit mines out of the thousands of mines and exploration workings known to exist. Some of these have been closed and remediated, at least two have been placed on the National Priorities List (Superfund) for cleanup, and others have been in standby mode where the owners have been waiting for the price of uranium to increase, as it has in 2006. The focus of this scoping report, however, has been on an investigation of potential risks from the thousands of relatively small mines and exploration sites that were abandoned over the years. With this report we have tried to identify the most likely exposure scenario for the abandoned mines, develop a first order estimate of cancer risks using some conservative assumptions, and identify if there are potential ecological effects that may develop around these mines.

Of the thousands of uranium mines in the continental United States, most are concentrated in Colorado, Utah, Wyoming, and New Mexico, and to a lesser extent, Arizona and Texas. For the small number of uranium mines in other regions, uranium is typically a byproduct of other mineral production. Many of the Four Corners States' mines are concentrated in a small number of watersheds. Though some Superfund removal actions have taken place within the Colorado Plateau, the two uranium mines on the National Priorities List are outside of the major uranium-producing states.

Most abandoned uranium mines are likely to have elevated radium and uranium concentrations, and possibly elevated levels of other contaminants such as arsenic. An analysis of the location of uranium mine records indicates that many are on federal lands, so a primary exposure scenario pertains to short-term recreational activities, including short-term occupation. Another scenario of concern is the use of mine waste material as building materials for those situations where the mines are not remote and material can be transported by nearby populations. In the recreation scenario, short-term exposure to radium, uranium, and arsenic appears to create only minimal additional cancer risk. This additional risk is dominated by external gamma exposure associated with radium in the waste material. The radioactivity in sub-ore grade uranium mine waste can be very high, so longer-term exposures from repeated visits to a high radium/high gamma site could begin to create a higher risk, even to a recreational user. The highest end of the risk spectrum is the scenario in which abandoned mine areas are used as home sites, which could pose a significant cancer risk to any long-term inhabitant. Long-term inhabitants who live near the mine sites might also use uranium mine waste material in building materials, and they would face additional risk from those radioactive building materials. It appears that those living on western Tribal lands appear to be most at risk as potential residents on or near abandoned uranium mine sites, or from the frequent visiting or passing through contaminated sites and wastes.

In general, the risks from these sites are primarily from occasional exposures and are likely to be minimal, even with conservative assumptions. The risk resulting from frequent use of a site, however, approaches a resident's exposure. Due to the predominant recreation scenario, the risk analysis examined risks in terms of days of exposure instead of the typical annual exposure,

although 350-day scenarios have been included to represent the exposure level for one year. From the estimates of the risk provided in this document, it is possible to quickly determine a first order estimate of the risks from a site, given the predominant contaminants, with the caveat that specific site conditions and site use would need to be factored in for a more realistic risk estimate.

Many of the abandoned uranium mines occur in areas with low precipitation and deep groundwater so that risk to ground-water drinking water sources is often low for at least the short-term (tens of years). However, some abandoned uranium mines occur in areas with higher precipitation. Abandoned uranium mines that are the most likely to affect groundwater are those that intersect groundwater (e.g., underground mines or deep surface mines) or are above shallow aquifers. Both radium and uranium have had MCLs established for them in drinking water supplies, but uranium is the most likely candidate to contaminate groundwater, since radium-226 is typically more immobile. In the case of uranium, the MCL is based on the limiting effect of chemical toxicity, not the radiological properties.

Ecological effects were not a focus of this report, but they were considered. Radionuclide and other heavy metal concentrations could be high enough to affect flora and fauna around abandoned mines, especially in watersheds with a high mine density. Indeed, it may be the flora and fauna that are affected much more than human health, and it may be the non-radioactive metals that produce the more significant ecological effects. This may be especially true where uranium is a secondary commodity, such as in the Lefthand Creek watershed in Colorado. At the same time, however, species may have grown accustomed to the presence of mine shafts that remain unreclaimed, and may, in fact, rely on them for habitat.

7.2 Potential Considerations for Site Prioritization

Ideally, all abandoned uranium mine sites would be remediated; however, given budget restraints, it is recognized that the most likely sites to be remediated are those that pose the greatest threat to human health and the environment. There are a number of items that could be considered when trying to prioritize the mines to be remediated. For example, in the cases where the radionuclides are likely to reach the groundwater, surface water, or springs, uranium may be the limiting radionuclide, because it is typically more mobile than radium. Radium may most often be the limiting factor in other cases because of the risk from external exposure. Less information is known about thorium values and the importance of thorium relative to radium. In some cases, the non-radiological metals may be the most hazardous of the mine waste constituents.

7.2.1 Depth to Groundwater and Annual Precipitation

EPA considers groundwater a resource for which it is easier to prevent pollution than to treat pollution after the fact. Those uranium mines that are located in areas with shallow (<50-60 feet or <~20 meters) groundwater resources have the potential to contaminate underlying aquifers within decades. Coupled with moderate amounts of precipitation (>~20 inches or >~50 cm), radioactive and metal contaminants at uranium mines could create a groundwater problem if not addressed. Large mines and underground mines that intersect aquifers have caused groundwater contamination. A scoping study such as this can identify some potential issues in this area, but it

cannot account for all the variations in site characteristics, so the geology and hydrology of a particular site would have to be examined (e.g., pH) when making remediation decisions.

7.2.2 Frequency of Use

The main tenets of protection from radioactive materials are time, distance and shielding. At one end of the spectrum, if one were to live on the mine waste materials or be exposed to mine wastes as part of construction materials, the risk of cancer from doing so could be relatively high. The scoping analysis in this report indicates that people who spend only small amounts of time at these abandoned mines probably have low risk. This low-risk consequence changes if one of these sites gets frequent use, creating a continuum of risk which we have tried to illustrate through the use of exposure calculations based on days per year of exposure.

In addition to current uses (e.g., recreation), the potential for future population growth and use could also be considered. The West and Southwest have experienced population growth in recent years, and second homes have also recently become popular in areas that were formerly primarily recreational. Anecdotal information suggests that home developments may be encroaching on areas of abandoned mines or mine wastes. In these cases, nearby populations may increase the potential use of these properties, with a concurrent increase in potential exposures.

The frequency of use may be related to their distance from roads. In other words, how remote are the mines? With the mines located on federal property, access may depend on fire roads or roads previously used during the mine's operation which are likely in disrepair so that access would be by foot, all terrain vehicles or possibly four-wheel drive vehicles. Some mines, however, may be located along well developed roads with easy access which may lead to more frequent visits or visits of longer duration.

7.2.3 Presence and Concentrations of Contaminants in Soils, Water, and Sediments

A major driver for the overall risk is the presence of contaminants. In the case of abandoned uranium mines, the contaminants would be both radioactive and stable metals. Radium, uranium, and possibly thorium could pose risks from external gamma exposures, but arsenic and other heavy metals (e.g., vanadium, selenium, copper, molybdenum) could pose a risk as well, especially to flora and fauna if there are enough waste materials. Some of the waste material quantities may be so minimal in area or volume that they do not pose a problem.

7.2.4 Density of Mines

One observation from this analysis is that the uranium mines are often along drainages where there can be a high density of mines or mine portals and associated wastes (see Figure 2.4 for example). While one mine may not pose a problem, a number of mines close together may increase the potential for adverse health or ecological effects, which may be seen at some distance from an individual mine site.

7.2.5 Level of Acceptable Risk

Lastly, the level of acceptable risk will also be important to determining how to prioritize the mines. The level of cancer risk typically used by EPA in the Superfund program is the risk range of 1 in 10,000 (10^{-4}) to 1 in 1,000,000 (10^{-6}) and the level of acceptable risk for non-carcinogens (i.e., some metals) is a hazard ranking less than 1. Sites which get frequent visitation may approach the upper end of the cancer risk range, while other sites would be at the lower end of the risk range. Residential exposure to uranium mine wastes, if it were to occur, would most likely be at the high end of risk range or even above.

The scoping analysis presented in this report indicates that at least some of the abandoned uranium mines have the potential to pose health and ecological hazards from both radioactive and non-radioactive materials. Data indicate that the concentrations of contaminants can be high enough to create adverse health effects if people were to spend substantial time on the sites. Non-radiological contaminants may be the most significant hazard, especially for flora and fauna. Since many of the sites are on federal lands, the largest exposure would be from recreational visits, or occupational use by a government employee or contractor, where the relatively short period of exposures would minimize the impact of high concentrations of contaminants. For the occasional visitor to abandoned mines, the mine wastes typically do not produce a significant radiation risk. However, individuals who visit a site frequently or for long periods of time can incur substantial risks. Residential exposure through on-site exposure or through the use of contaminated building material is not likely in most cases, except for some Tribal members, such as in the Navajo Nation, or other nearby residents. Where it does occur, the risks from these situations could be quite high.