3.18 RISK ASSESSMENT: RADIOLOGICAL

DESCRIPTION

Radiation is the release of energy from unstable atoms. When atoms are unstable, the nuclei have too much energy and release the energy termed radiation in the form of electromagnetic (EM) waves or small particles at various speeds. (DOE, 1992) Examples of relatively low-energy EM radiation are visible light from the sun, or radio, television, and microwaves from transmission antennae. These interact with materials in various ways, but they do not carry enough energy to directly alter the chemical properties of atoms or molecules.

More energetic EM radiation can ionize atoms or molecules, altering their chemical properties. Ionizing EM radiation is generally hazardous to health because it can disrupt the bonds in biochemicals. Some non-ionizing EM radiation can be seen or felt (such as light or heat), but ionizing EM radiation (such as X rays and gamma rays) can only be measured with special instrumentation that senses the amount of ionization in its detector. This principle is used for ionization smoke detectors. Ionization can also occur when energetic particles such as neutrons, electrons (beta particles), or helium nuclei (alpha particles) pass at high speed through a material. Particulate radiation is usually measured by generally the same means as ionizing EM radiation. http://www.physics.isu.edu/radinf/.

LOCATION, EXTENT, AND MAGNITUDE

Natural sources of radioactive elements are found in air, water, soil, and our bodies. Ionizing particulate and EM radiation are generated in the environment by naturally occurring radioactive material in the earth's crust (terrestrial radioactivity, radon) or through the effects of cosmic radiation originating outside the earth's atmosphere. Thorium and uranium are naturally occurring radioactive elements that are used as nuclear fuels. Idaho has one of the largest concentrations of uranium nationally. A variety of industries (e.g., oil/gas extraction industries and community drinking water treatment) that process natural material create the unintended concentration of natural radioactivity – this is referred to as technologically enhanced naturally occurring radioactivity (TENORM). Technologically produced radioactive material is generated by nuclear reactors or high energy particle accelerators, and relatively high levels of ionizing EM radiation are produced using x-ray machines. Radioactive materials are often encapsulated so that the ionizing EM radiation they produce may be used without the hazard posed by uncontained radioactive contamination. Technologically produced radioactivity and radiation are used extensively in medical and industrial applications. Everyone receives varying amounts of radiation exposure from natural and technological sources. Figure 3.18.A shows the amount of radiation received by the average member of the US population.

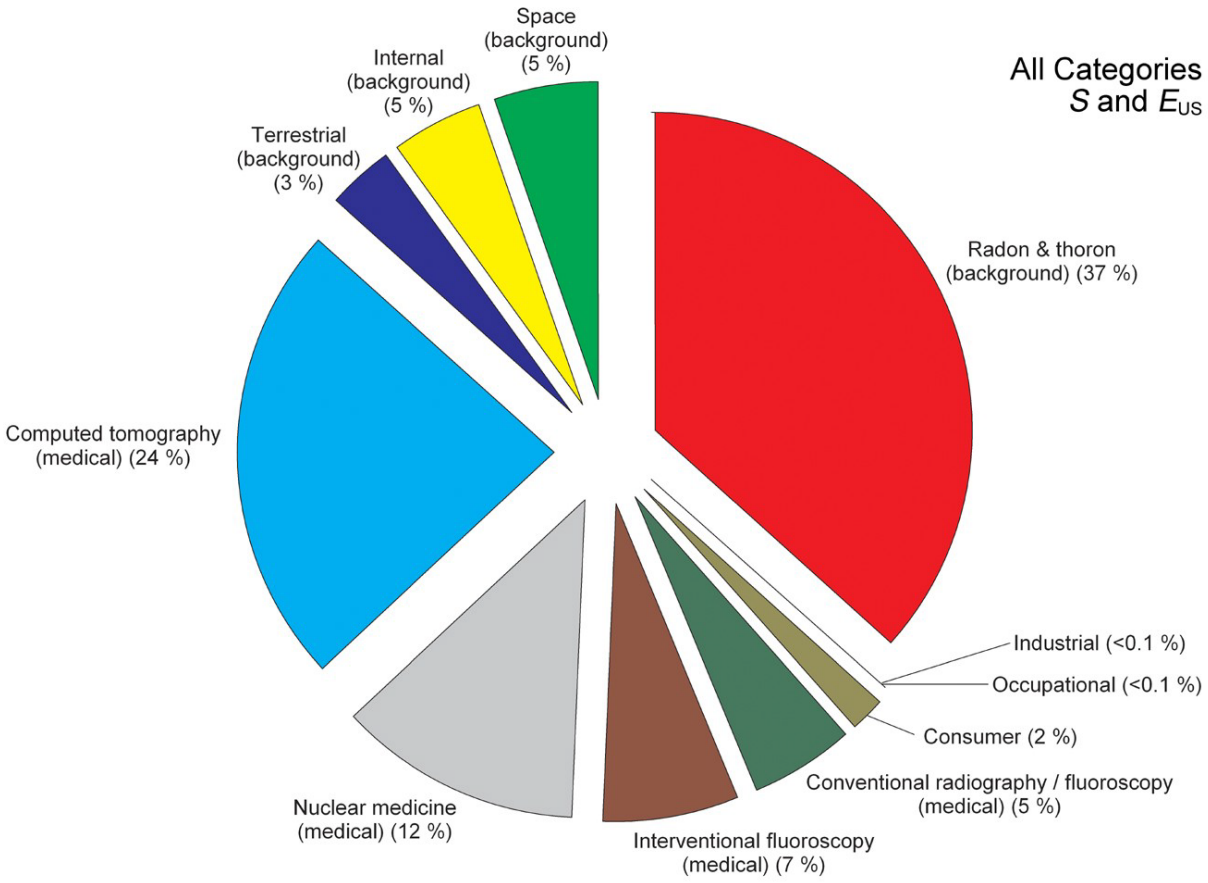


Figure 3.18.A: Source Distribution for all radiation dose – Percent combination of various sources of exposure to the total dose per individual in the U.S. population for 2006 [From National Council on Radiation Protection and Measurements (NCRP) 160], http://NCRPonline.org.

The National Oceanic and Atmospheric Administration (NOAA) have produced Space Weather Scales to communicate to the general public the current and future space weather conditions and the possible resulting effects on people and systems. Figure 3.18.B on the following page is the NOAA scale for Solar Radiation Storms.[1]

[1] http://www.swpc.noaa.gov/NOAAscales/

NOAA Space Weather Scale for Solar Radiation Storms

Category		Effect	Physical measure	Average Frequency (1 cycle = 11 years)
Scale	Descriptor	Duration of event will influence severity of effects		
Solar Radiation Storms			Flux level of >= 10 MeV particles (ions)*	Number of events when flux level was met (number of storm days**)
S 5	Extreme	**Biological:** unavoidable high radiation hazard to astronauts on EVA (extra-vehicular activity); passengers and crew in high-flying aircraft at high latitudes may be exposed to radiation risk.*** **Satellite operations:** satellites may be rendered useless, memory impacts can cause loss of control, may cause serious noise in image data, star-trackers may be unable to locate sources; permanent damage to solar panels possible. **Other systems:** complete blackout of HF (high frequency) communications possible through the polar regions, and position errors make navigation operations extremely difficult.	10^5	Fewer than 1 per cycle
S 4	Severe	**Biological:** unavoidable radiation hazard to astronauts on EVA; passengers and crew in high-flying aircraft at high latitudes may be exposed to radiation risk.*** **Satellite operations:** may experience memory device problems and noise on imaging systems; star-tracker problems may cause orientation problems, and solar panel efficiency can be degraded. **Other systems:** blackout of HF radio communications through the polar regions and increased navigation errors over several days are likely.	10^4	3 per cycle
S 3	Strong	**Biological:** radiation hazard avoidance recommended for astronauts on EVA; passengers and crew in high-flying aircraft at high latitudes may be exposed to radiation risk.*** **Satellite operations:** single-event upsets, noise in imaging systems, and slight reduction of efficiency in solar panel are likely. **Other systems:** degraded HF radio propagation through the polar regions and navigation position errors likely.	10^3	10 per cycle
S 2	Moderate	**Biological:** passengers and crew in high-flying aircraft at high latitudes may be exposed to elevated radiation risk.*** **Satellite operations:** infrequent single-event upsets possible. **Other systems:** small effects on HF propagation through the polar regions and navigation at polar cap locations possibly affected.	10^2	25 per cycle
S 1	Minor	**Biological:** none. **Satellite operations:** none. **Other systems:** minor impacts on HF radio in the polar regions.	10	50 per cycle

* Flux levels are 5 minute averages. Flux in particles·s^{-1}·$ster^{-1}$·cm^{-2}. Based on this measure, but other physical measures are also considered.
** These events can last more than one day.
*** High energy particle measurements (>100 MeV) are a better indicator of radiation risk to passenger and crews. Pregnant women are particularly susceptible.

Figure 3.18.B: NOAA Space Weather Scale for Solar Radiation Storms (Source: NOAA)

PAST OCCURRENCE

There have been relatively few incidents involving TENORM in Idaho, but they have been significant. The use of phosphate ore processing slag as fill material in southeast Idaho required an extensive remedial response, and the Salmon River Uranium Development site also required remediation. Incidents involving manmade radioactivity in industrial applications have been infrequent and generally have had minimal impact. Improper control of industrial radioactive sources has occurred in several counties in Idaho. Scrap yards and waste disposal facilities are likely places for improperly handled industrial sources to be discovered. Most of these facilities attempt to exclude hazardous/radioactive materials, and have at least basic radiation detection instruments. However, detection is not assured, and not all facilities are diligent. To date, these incidents have not resulted in any exposure of the general public.

The Idaho National Laboratory (INL) in eastern Idaho performs many activities involving nuclear technologies and radioactive materials including radioactive waste. As one of DOE's multi-purpose science laboratories, the INL conducts long-term programs for DOE or other funding sources. Prior to 2004, the INL management and operations (M&O) contractors were responsible for research and development (R&D) and environmental management programs including remediation required to comply with the Settlement Agreement. In 2004-2005, the DOE issued separate contracts for laboratory operations and cleanup operations to focus contractor management attention on development of laboratory programs and completion of remediation projects.

The INL site covers 890 square miles located in Butte, Bingham, Bonneville, Clark, and Jefferson counties. Work involving radioactive materials is conducted at INL site locations as well as in facilities in Idaho Falls. Work at the INL has included evaluation and storage of nuclear fuels, transportation of radioactive nuclear materials, management of radioactive waste, and operation of a wide variety of nuclear reactors. The only reactor currently operating at the INL is the Advanced Test Reactor which is used to determine the effects of radiation on materials. Butte County is the only local mitigation plan listing historical frequencies of a nuclear event due to the INL being located within the county boundaries. The most significant nuclear incident at INL occurred in 1961 at the Stationary Low-Power Reactor Number One (or SL-1), a small Army prototype reactor that had been running since 1958. It is believed that a central control rod was withdrawn beyond the safe limit, causing a large power surge. The resulting explosion destroyed the reactor, released large amounts of radioactivity, and took the lives of three reactor operators. Many industry-wide improvements followed. Exposure limits to individuals were curtailed, the basic design of the reactor was changed to prevent physical rod removal, and additional safety levels were added. (Harker, 2013) There have been no unplanned releases that resulted in measureable radioactivity outside the site boundaries. Past practices have resulted in intentional releases and detection of radioactivity at low levels in the air and groundwater beyond the INL site boundary. Also, past solid waste disposal practices included burial and sub-surface storage of transuranic/mixed transuranic waste, which has been targeted for the ongoing remediation work.

FUTURE OCCURRENCE

Currently, there are no identified TENORM issues in Idaho, although there is a relatively high potential for TENORM generation given the extractive industries operating in the state (and surrounding states) and the occurrence of uranium and thorium ore deposits in the state. Radioactive sources are used in a wide variety of industrial and consumer applications including soil density/moisture gauges, smoke detection, well logging, weld inspection, and radioluminescent devices. Incidents involving manmade radioactivity in these applications have occurred sporadically, so the future rate of occurrence of incidents involving industrial radioactive sources can't be projected on the basis of past experience. However, future incidents should be anticipated. The most prevalent use of radioactive material in Idaho is for nuclear medicine. Hospitals and clinics in every region use radioactive isotopes for diagnostics and treatment. Medical isotopes are typically transported by common carrier either by air or road. Typically, nuclear medical applications involve use of relatively large amounts of short-lived radioactivity. Incidents involving radiopharmaceuticals could result in unintended exposures, but are not likely to pose a long-lasting hazard.

International Isotopes, Incorporated (I3) is the largest privately owned nuclear technology enterprise in Idaho. I3 is located in Idaho Falls and is regulated by the NRC. They handle a wide range of medical- and industrial-use radioactive materials, and operate a large irradiation facility. As a for-profit corporation with considerable expertise, future operations can be expected to follow market opportunities and could involve use of substantial amounts of radioactive material. Significant increases in the scope of operations at I3 would be subject to review by the NRC.

As previously discussed, the INL is a DOE nuclear R&D facility that is managed and operated for DOE by private contractors. The prime contractor for laboratory operations is supported through the DOE's Nuclear Energy (NE) budget, and conducts ongoing R&D and technology programs including reactor and hot cell operations, as well as less intensive uses of radioactive materials. The INL Cleanup Project (ICP) contractor is funded through DOE's Environmental Management budget, and is responsible for decontamination, demolition, decommissioning, waste management, and remediation of INL site facilities. Ongoing ICP projects include preparing and shipping remote-handled transuranic waste for disposal, exhuming, preparing, and shipping targeted transuranic waste for disposal, and the Integrated Waste Treatment Unit (IWTU). The IWTU will be used to process the remaining tank farm wastes at INL. The Advanced Mixed Waste Treatment Project (AMWTP) is also funded through DOE/EM, and is operated to prepare and ship mixed transuranic waste for disposal at the Waste Isolation Pilot Plant (WIPP). The AMWTP may serve as a DOE system-wide resource for processing waste to meet WIPP acceptance criteria. Future laboratory operations are expected to be similar to recent past operations, while ICP and AMWTP operations are expected to be reduced as specific projects are completed.

Safe transport will remain a concern as long as nuclear spent fuels shipments continue in Idaho. Since hazardous material incidents usually occur on major highways and railways, transportation of nuclear waste is a public concern. No accidents have been reported in transporting spent fuel in Idaho. The use

of nuclear weapons is also of concern. The United Nations imposed new sanctions against North Korea due to an underground nuclear test conducted on February 12, 2013. The United States and South Korea conducted joint military exercises in March of 2013, and North Korea responded by declaring a state of war with South Korea on March 30, 2013 and threatened the United States with nuclear attacks. (BBC News, 2013)

RELATIONSHIPS TO OTHER HAZARDS

Radiation exposure is unlikely in Idaho even given the cascading effect from an earthquake. The INL is located less than 60 miles from the location of one of Idaho's largest earthquakes which registered 6.9 on the Richter scale, but the site is located in a geographic area that does not easily conduct seismic activity. (U.S. Department of Energy, 2013)

Radiation exposure is not currently understood nor expected to influence any other natural hazards. From a human-caused perspective, it is possible that a large-scale radiological event could initiate civil disturbances.

ENVIRONMENTAL IMPACTS

Environmental impacts of incidents involving radioactive materials are generally similar to impacts caused by hazardous materials (See Section 3.14). A large release (accidental air emission or spill) that causes soil contamination could result in EM radiation exposure and uptake of radioactive material into plants and animals living on the contaminated soil. The environmental and health impacts of a release that is large enough to cause concern for protection of the general public would be evaluated by the Federal Radiological Monitoring and Assessment Center (FRMAC), and State of Idaho responses would be developed with support of the federal Advisory Team for Environment, Food, and Health (A-team). Cleanup of small releases would avoid environmental impacts that might otherwise occur through the terrestrial environment and food chain, including runoff to surface waters. Monitoring of species is performed periodically to identify any effects in the ingestion pathways. The potential for impacts to groundwater caused by contamination of land surfaces is small because the relative immobility of most radionuclides in unsaturated soil would allow time for mitigation. Impacts to other environmental/cultural resources are expected to be minimal unless the primary release (i.e., a spill) is directly on or adjacent to that resource.

Snake River Plain Aquifer concerns were addressed and protected through the 1995 Settlement Agreement between the State of Idaho, DOE, and U.S. Navy which prioritized removal of stored fuel. Recycled fissionable materials for the US Navy and liquid radioactive waste from about 100 reactors nationwide were processed into dry, calcined waste. Solid waste – contaminated tools, clothes, trash – stored above ground in containers or buried in trenches posed the greatest threat to the Snake River Aquifer. In 2012, 90% above ground waste and more than 50% of buried waste at the INL were remediated and shipped out of Idaho. (INL, 2012)

DEVELOPMENT TREND IMPACTS

There are no land-use regulations that restrict building around facilities that handle radioactive materials or generate EM radiation. Mobile radiation sources (e.g., radiography sources or soil moisture/density gauges) are designed so that they may be transported and stored with minimal restrictions that are intended to avoid diversion.

The economy in Eastern Idaho benefits from the employment of thousands at the INL. Another economic boost to Idaho is the production of nuclear reactor components built for utility companies throughout the country. (Barker, 2012) Idaho Governor Butch Otter appointed the Leadership In Nuclear Energy (LINE) Commission to make recommendations on the "continued viability and mission relevance" of the INL in Executive Order No. 2012-01. (Otter, 2012) The LINE Commission reports that Idaho's economy benefits "more than $3.5 billion" annually from the employment and activities connected with the INL. (LINE Commission, 2013)

CRITICAL INFRASTRUCTURE AND STATE FACILITY IMPACTS

Highways, aircraft and rail lines are used to move radioactive materials around the State. Transportation of highly radioactive materials is regulated by the Department of Energy, Nuclear Regulatory Commission and the Department of Transportation. Requirements can include use of single purpose licensed shipping casks designed for either truck or rail transport. Casks are designed to withstand extreme forces including drop tests and direct hits from freight trains. The highway routes are preselected and notifications of shipments are provided to State Communications and Idaho State Police (ISP). Currently there are approximately 400 shipments of transuranic waste leaving the INL per year and all of those shipments are inspected by the ISP prior to leaving the INL facility of origin. Shipments of spent fuel come into the State by rail and truck. State Communications and ISP are notified regarding the number and timing of shipments.

VULNERABILITY ASSESSMENT

The risks of radiological materials incidents in Idaho are low but could have high consequences. As with hazardous material spills, transportation incident risk may increase through population growth and economic activity in Idaho and surrounding states. The Idaho National Laboratory (INL) site routinely stores, uses, and ships high-activity radioactive materials. Hazard mitigation for the INL is addressed in separate INL and county plans. Counties in the ingestion pathway planning zone, a 69-mile radius of the INL, identify mitigation actions to protect food, water, and animal contamination.

Hanford is the largest U.S. nuclear remediation site with projects of removing radioactive waste from leaking tanks and soil, and treating groundwater. (Dininny, 2013) Hanford is located in eastern Washington, and while Hanford is the closest nuclear power plant to northern Idaho, the ingestion pathway does not encompass any Idaho counties.

Local Hazard Mitigation Plan Vulnerability Assessments

Forty-seven local mitigation plans were analyzed to determine the major hazards in each jurisdiction. Twelve counties ranked radiological or nuclear event as a hazard. Map 3.18.C, at the end of this section, highlights those jurisdictions.

LOSS ESTIMATION

No specific, statewide loss estimation exists for the hazard of a radiological event. Radiation exposure is a low probability in Idaho. Potential costs could be for response, health care, restoration, remediation, and post de facto litigation. Direct costs related to transportation accidents could include materials, carrier damage, property damage, response, and remediation/cleanup.

Local Hazard Mitigation Plan Loss Estimations

The local mitigation plan roll-ups estimate that losses for a nuclear event could reach millions of dollars. Out of the 12 localities that ranked nuclear event as a major hazard, all provided loss estimations. (Bannock County - $1,000,000's, Bingham County - $1,000,000's, Blaine County - $1,000,000's, Bonneville County - $1,000,000's, Butte County - $1,000,000's, Custer County - $100,000's, Clark County - $1,000,000's, Fremont County - $100,000's, Jefferson County - $1,000,000's, Lemhi County - $1,000,000's, Minidoka County - $1,000,000's, Power County - $100,000's)

MITIGATION RATIONALE

Large inventories of radioactive materials are handled at only a few fixed facilities within the state, and shipments of large quantities of radioactive materials are relatively infrequent as compared to shipments of hazardous materials that pose comparable risks. Operations at fixed facilities and transportation of radioactive material are highly regulated by DOE and NRC to minimize the chance of occurrence of a significant release and provide mitigation if a release occurs. Planning for mitigation of accidental releases is performed to avoid or reduce:

- Death, acute or chronic debilitation, or increased risk of cancer,
- Damage or destruction of agricultural products – animals and crops
- Degradation of environmental resources
- Devaluation or loss of use of public and private property
- Costs associated with emergency response, including cleanup

GENERAL MITIGATION APPROACHES

The Department of Environmental Quality (DEQ) has an INL Oversight Program (OP) to evaluate the environmental and public health impacts of DOE activities at the INL, and participate in emergency response. Emergency response is generally directed towards mitigating the consequences of accidental or off-normal conditions. Mitigation is performed to manage the consequences during the initial phases of an incident through recovery. Goals for radiological emergency preparedness planning and training include:

- Promoting flexibility in management of emergencies, for efficient use of resources

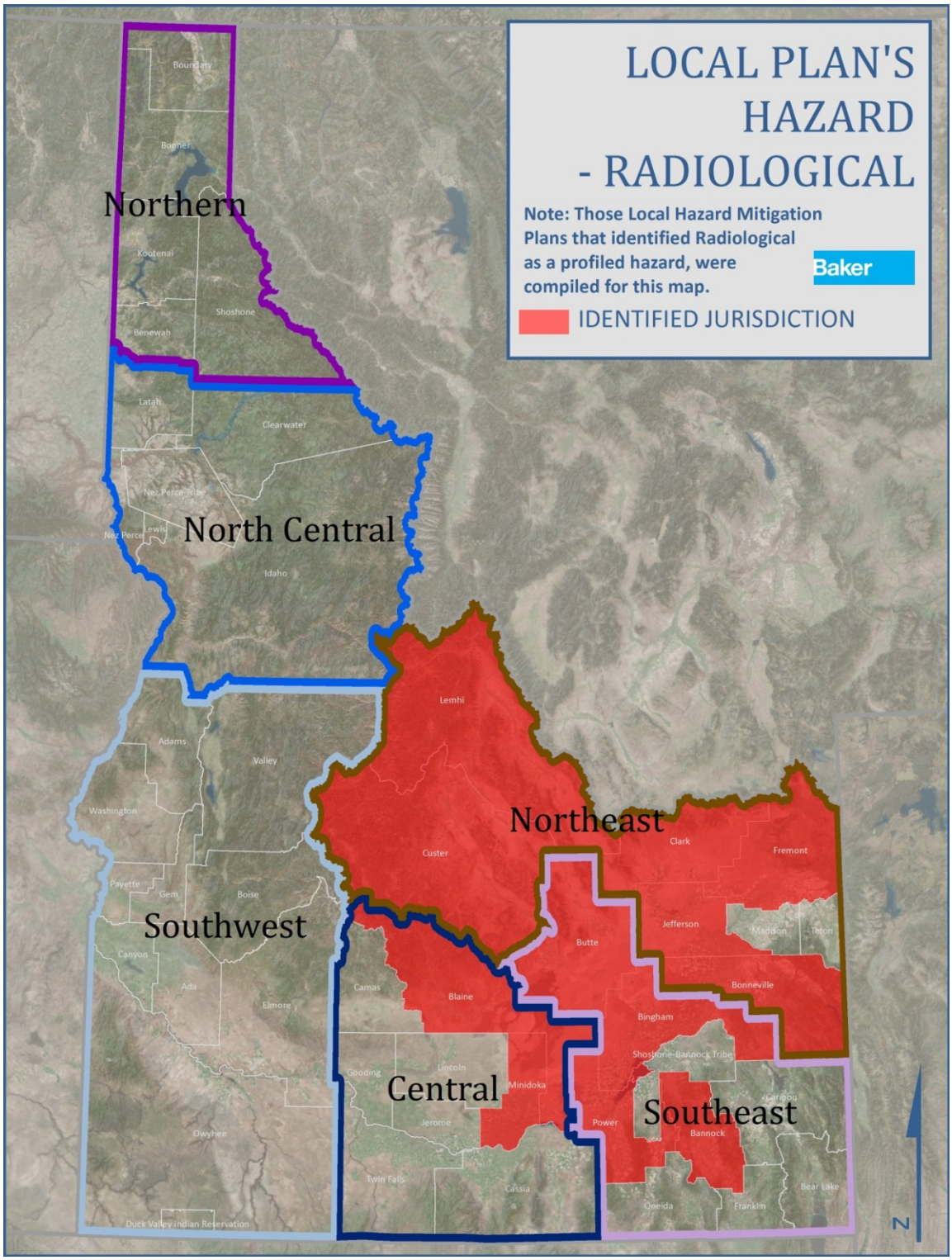
- Maintenance of full-time capability for immediate response
- Ensuring that responders, plans, facilities, and any necessary inter-organizational coordination are sufficient to provide the desired protection

The current approach for radiological emergency preparedness for large, potentially high-consequence incidents (e.g., a reactor accident or a release in a densely populated area) has been developed using the experience gained during major reactor accidents. Emergency Preparedness programs for DOE and NRC are generally similar, although these organizations operate under different regulations. Significant radiological accidents that could pose a risk to public health and welfare would result in a request from a local authority (the local Incident Commander (IC)) in the activation of the Idaho Hazardous Materials/Weapons of Mass Destruction (WMD) Incident Command and Support Plan which could then result in a request for federal assistance through the FRMAC. This would most likely include support from the Region 6 Radiological Assistance Program (RAP) team which operates from Idaho Falls. If the event occurs at an INL facility, DOE and its contractor(s) maintain emergency response organizations and OP staff coordinate their response with the INL, per a memorandum of understanding between the State and DOE. Since RAP Region 6 members are INL contractor employees and may be involved with on-site response for their employers, the Region 8 RAP team based in Richland, Washington will provide backup support. The INL conducts emergency drills and exercises and the State observes and participates in these activities.

The OP trains first responders in the State of Idaho along transportation routes used for shipments to WIPP. Responders include Regional Response Teams (RRTs), the Idaho State Police (ISP), and health care providers.

Mitigating criminal actions concerning radiological materials are coordinated with the "pre-incident prevention protocols set forth in federal, state, and local law enforcement and emergency response protocols to include those described within the Idaho Hazardous Materials/Weapons of Mass Destruction (WMD) Incident Command and Support Plan" and coordinated through the Idaho State Police in cooperation with the FBI through the support of the Idaho Attorney General. (Idaho Bureau of Homeland Security, 2012)

Mitigation planning takes into account actions to regarding consumption, food production and processing, sheltering animals and, covering stored water and feed. Self-help measures contribute to public protection such as heeding warnings to shelter in place and maintaining 72-hour kits.



Map 3.18.C: Radiological Identified as Local Plan Hazard