Appendix I. List of Acronyms and Abbreviations, and Glossary of Terms

List of Acronyms and Abbreviations

Ac	actinium
ac	acre
ac-ft	acre-feet
ACAA	American Coal Ash Association
AEA	Atomic Energy Act
AEC	Atomic Energy Commission
ALARA	As low as reasonably achievable
AML	abandoned mine lands
As	arsenic
ATSDR	Agency for Toxic Substances and Disease Registry
Ba	barium
BASINS	Better Assessment Science Integrating Source and Non-point Sources (USGS computer model)
BAT	best achievable technology
Bi	bismuth
BPCT	best practicable control technology
Bq/kg	Becquerel/kilogram.
BRC	Bureau of Radiation Control
CAA	Clean Air Act
$CaSO_4$	calcium sulphate (formula for gypsum)
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act (Superfund)
CFR	Code of Federal Regulations
Ci	Curie(s) (unit of radioactivity, 3.7×10^{10} disintegrations per second)
cm	centimeter
COD	chemical oxygen demand
Cr	chromium
CRCPD	Conference of Radiation Control Program Directors
Cu	copper
CWA	Clean Water Act
D&D	decontamination and decommissioning
DOE	Department of Energy
DOI	Department of the Interior
dscm	dry standard cubic meter
E	used to denote exponents (3.7E+10)
EIA	Energy Information Administration (U.S. Department of Energy)
EPA	Environmental Protection Agency
ESRI	Environmental Systems Research Institute
^oF	degrees Fahrenheit
Fe	iron
$FeCl_3$	ferric chloride
FeP	ferro-phosphorus
FeS_2	pyrite
FIPR	Florida Institute of Phosphate Research
Fr	francium

ft	feet
g	gram
g/cm^3	gram per cubic centimeter
Gy	Gray
H	hydrogen
ha	hectare, 2.471 acres
HDS	high-density sludge
Hg	mercury
hr	hour
ISL	*in situ* leaching
K	potassium
K_d	element-specific soil–water partition coefficient
kg	kilogram
L	liter
LTSP	long-term surveillance plan
μ	micro, 10^{-6}, used in combination with specific units
μg/m	microgram per meter
μg/m^3	microgram per cubic meter
μm	one-millionth of a meter (micron)
μR/hr	microRoentgen per hour
m	milli, 10^{-3}, used in combination with specific units
m	meter
m^2	square meter
m^2/s	square meters per second
m^3	cubic meter
MAS/MILS	Minerals Availability System/Minerals Industry Location System (USGS database)
mbd	million barrels per day
MCL	maximum contaminant level
mg	milligram
mL	milliliter
Mn	manganese
Mo	molybdenum
MOU	memorandum of understanding
mrem	millirem
mR/hr	milliRoentgen per hour
mSv	milliSievert
MT	metric ton(s), 1000kg, or 2,200 lb
MMTs	millions of metric tons
n	nano, 10^{-9}, used in combination with specific units
NAAQS	National Ambient Air Quality Standards
NAMLRP	Navajo Abandoned Mine Lands Reclamation Program
NARM	naturally occurring and accelerator-produced radioactive material
NAS	National Academy of Sciences
NCRP	National Council on Radiation Protection and Measurements
NEPA	National Environmental Policy Act
NESHAP	National Emission Standards for Hazardous Air Pollutants
NFS	National Forest Service
NNEPA	Navajo Nation Environmental Protection Agency
NORM	naturally occurring radioactive material
NPDES	National Pollutant Discharge Elimination System

NPL	National Priorities List
NPS	National Park Service
NRC	Nuclear Regulatory Commission
NSPS	New Source Performance Standards
O_2	oxygen
ORIA	Office of Radiation and Indoor Air (U.S. EPA)
OSM	Office of Surface Mining
p	pico, 10^{-12}, used in combination with specific units
Pa	protactinium
Pb	lead
pCi/g	picocurie per gram
pCi/L	picocurie per liter
pCi/m^2/s	picocurie per meter squared per second
pH	negative log of hydrogen ion concentration (measure of acidity and alkalinity)
Po	polonium
ppb	parts per billion, 10^{-9}
ppm	parts per million, 10^{-6}
Pu	plutonium
QA/QC	quality assurance/quality control
R	Roentgen
r^2	correlation coefficient
Ra	radium
RCRA	Resource Conservation and Recovery Act
Rem	Roentgen equivalent in man
RESRAD	computer model to evaluate risks/doses from RESidual RADiation materials (DOE's Argonne National Laboratory)
ROD	record of decision (Superfund)
s	second
SAB/RAC	Science Advisory Board/Radiation Advisory Committee (with U.S. EPA)
SARA	Superfund Amendments and Reauthorization Act
SDWA	Safe Drinking Water Act
Se	selenium
SEO	State Engineer's Office
SIP	State Implementation Plans
SMCRA	Surface Mining Control and Reclamation Act
Sr	strontium
SSL	soil screening level, in pCi/g
Sv	Sievert
tpd	tons per day
TDS	total dissolved solids
TENORM	technologically enhanced, naturally occurring radioactive material
Th	thorium
Tl	thallium
TNRCC	Texas Natural Resources Conservation Commission (now Texas Commission on Environmental Quality)
TRC	Texas Railroad Commission
TSD	treatment, storage, and disposal
TSS	total suspended solids
TWC	Texas Water Commission
U	uranium
U_3O_8	oxide of uranium

$U_4+Ti_2O_6$	brannerite
UIC	underground injection control
UMTRA	Uranium Mill Tailings Remedial Action program (U.S. DOE)
UMTRCA	Uranium Mill Tailings Radiation Control Act of 1978
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
UO_2	uranium dioxide
UO_2SO_4	uranium sulfate
$USiO_4$ßnH_20	coffinite
U.S. ACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
y^3	cubic yard(s)

Glossary of Terms

Adits	Horizontal or nearly horizontal passages driven from the surface for the working or dewatering of a mine. If driven through a hill or mountain to the surface on the other side it would be a tunnel.
ALARA	Acronym for As Low As Reasonably Achievable: A basic concept of radiation protection which specifies that exposure to ionizing radiation and releases of radioactive materials should be managed to reduce collective doses as far below regulatory limits as is reasonably achievable considering economic, technological, and societal factors, among others.
Alpha Particle	A positively charged particle emitted by some radioactive materials undergoing radioactive decay. A helium nucleus (two protons and two neutrons)
Aquifer	An underground geological formation, or group of formations, containing water. Sources of groundwater for wells and springs.
Background	Radiation from cosmic sources, naturally occurring radioactive material, including radon (except as a decay product of source or special nuclear material), and global fallout as it exists in the environment from the testing of nuclear explosive devices or from nuclear accidents like Chernobyl which contribute to background radiation and are not under the control of the cognizant organization.
Becquerel (Bq)	The International System (SI) unit of activity equal to one nuclear transformation (disintegration) per second. 1 Bq = 2.7x10^{-11} Curies (Ci) = 27.03 picocuries (pCi).
Berm	A horizontal shelf or ledge built into the embankment or sloping wall of an open pit, quarry, or ground surface to break the continuity of an otherwise long slope and to strengthen its stability or to catch and arrest slide material.
Beta Particle	An electron emitted from an atom's nucleus during radioactive decay.

Beneficiated	The initial attempt at liberating and concentrating a valuable mineral from extracted ore. This is typically performed by employing various crushing, grinding and froth flotation techniques. The remaining (beneficiated) material is often physically and chemically similar to the material (ore or mineral) that entered the operation, except that particle size reduction has often occurred.
Bioremediation	The use of biological agents, such as bacteria or plants, to remove or neutralize contaminants, as in polluted soil or water.
Brannerite	A radioactive uranium bearing mineral, $(U,Ca,Y,Ce)(Ti,Fe)_2O_6$
Breccia	A coarse-grained clastic rock, composed of angular broken rock fragments held together by a mineral cement or in a fine-grained matrix. Breccia may originate as a result of talus accumulation, explosive igneous processes, collapse of rock material, or faulting.
Byproduct Materials	Tailings or wastes produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material content, including discrete surface wastes resulting from uranium solution extraction processes. Underground ore bodies depleted by such solution extraction operations do not constitute “byproduct material” within this definition.
Carbonates	A sediment or sedimentary rock formed by the organic or inorganic precipitation from aqueous solution of carbonates of calcium, magnesium, or iron; e.g., limestone and dolomite.
Cleanup	Actions taken to deal with a release or threatened release of hazardous substances that could affect public health or the environment. The term is often used broadly to describe various Superfund response actions or phases of remedial responses, such as remedial investigation/feasibility study. Cleanup is sometimes used interchangeably with the terms remedial action, response action, or corrective action.
Coffinite	A naturally occurring uranium mineral, $U(SiO_4)_{1-x}(OH)_{4x}$
Consolidated	In geology, any or all of the processes whereby loose, soft, or liquid earth materials become firm and coherent, either cemented or non-cemented together.
Contamination	The presence of residual radioactivity, heavy metals or other pollutants in excess of levels which are acceptable for release of a site or facility for unrestricted use.
Core Sample	A soil, rock, or sediment sample taken by core drilling.
Conventional Mining	Mining which uses either mechanical open-pit surface mining methods, or underground mining methods, or a combination of both, to extract ore

	from the ground. This is opposed to unconventional or solution mining methods.
Curie (Ci)	The customary unit of radioactivity. One curie (Ci) is equal to 37 billion disintegrations per second (3.7 x 10^{10} dps = 3.7 x 10^{10} Bq), which is approximately equal to the decay rate of one gram of Ra-226. Fractions of a curie, e.g. picocuries (pCi) or 10^{-12} Ci and microcurie (μCi) or 10^{-6} Ci, are levels typically encountered in radiation measurements of NORM or TENORM.
Decline	A downward ramp.
Decommission	To remove a facility or site safely from service and reduce residual radioactivity to a level that permits release of the property and termination of a source materials license and other authorization for site operation.
Decommissioning	The process of removing a facility or site from operation, followed by decontamination, and license termination (or termination of authorization for operation) if appropriate. The objective of decommissioning is to reduce the residual radioactivity in structures, materials, soils, groundwater, and other media at the site so that the concentration of each radionuclide contaminant that contributes to residual radioactivity is indistinguishable from the background radiation concentration for that radionuclide.
Drill Cuttings	The particles of rock produced in a borehole or drill hole by the abrasive or percussive action of a drill bit; erosive effect of the circulating liquid; or cavings from the borehole. At some mines and operations sites, cores of rock from a well or borehole may be left behind as waste—referred to in this report as drill cuttings for convenience.
Drilling Wastes	Wastes associated with a drillhole operation at a mine or extraction facility that are not considered cuttings or cores. May include drill muds or other drilling fluids, sludges, or evaporation products collected in excavated pits from waste water produced during drilling.
Dose	A general term used to refer to the effect on a material that is exposed to radiation. It is used to refer either to the amount of energy absorbed by a material exposed to radiation, or to the potential biological effect in tissue exposed to radiation
Electrodialysis	A means of extracting one or more dissolved materials from a liquid mixture, the process is dialysis assisted by the application of an electric potential across a semi-permeable membrane.
Elution	Process of removing an economic mineral (uranium) from an ion exchange filter or resin.
Evaporative Ponds	Areas where mine water or other produced water is placed and dried by evaporation, leaving a residue of solids or sludges.

Evaporite	An inorganic chemical sediment that precipitates when the salty water in which it had dissolved evaporates.
Excavated Wall	A wall of mineral ore that has been exposed by mining over a considerable width at one time.
Exposure Pathway	The route by which radioactivity travels through the environment to eventually cause radiation exposure to a person or group (e.g., air or water). Also, the route by which a member of the public is exposed (e.g., ingestion, inhalation).
External Radiation	Radiation from a source outside the body.
Extraction Facility	An industrial complex and land on which are located buildings, wells and pipelines, mechanical and chemical equipment, storage and transportation equipment licensed by the Nuclear Regulatory Commission or its Agreement States for the purposes of extracting uranium (source material) in accordance with the Atomic Energy Act.
Extraction Process	A process used to extract uranium from ore, either by milling and chemically treating the ore, or using chemical solutions to treat underground ore (*in situ* leaching), or by treating mined and crushed ore on the surface (heap leaching). These processes are licensed activities by the Nuclear Regulatory Commission or its Agreement States in accordance with the Atomic Energy Act.
Gamma Radiation	Penetrating high-energy, short-wavelength electromagnetic radiation (similar to X-rays) emitted during radioactive decay. Gamma rays are very penetrating and require dense materials (such as lead or steel) for shielding.
Gangue	The valueless minerals in an ore; that part of an ore that is not economically desirable but cannot be avoided in mining. It is separated from the ore minerals during concentration.
Garnet	A group of silicate minerals found in igneous rocks, usually red in color, used as a semi-precious stone in crystalline form, or ground into smaller particles and used for abrasives such as in sandpaper coating.
Half-Life ($t_{1/2}$)	The time required for one-half of the atoms of a particular radionuclide present to disintegrate.
Heap-Leaching	A method of extraction by which mineral bearing ores are leached on the ground surface from weathered low-grade ore. The crushed material is laid on a slightly sloping, impervious pad and uniformly leached by the percolation of leach liquor trickling through the beds by gravity to ponds. The metals are recovered by conventional methods from the solution.

Igneous	Rock or mineral that solidified from molten or partly molten material, i.e., lava or magma. These rocks constitute one of the three main classes into which all rocks are divided: igneous, metamorphic, and sedimentary.
Ilmenite	An iron-black, opaque mineral ($FETiO_3$) which is the principal ore of titanium.
Incline	A slanting shaft from the surface into an underground mine. Most commonly referring to an upward slope.
In Situ Leaching (ISL)	A method of extraction by which mineral bearing ores are leached underground by the introduction of a solvent solution, called a lixiviant, through injection wells drilled into the ore body. The process does not require the extraction of ore from the ground. The lixiviant is injected, passes through the ore body, and mobilizes the mineral, and the mineral-bearing solution is pumped to the surface from production wells. The pregnant leach solution is processed to extract the mineral sought after.
Ion Exchange	A common water-softening method often found on a large scale at water purification plants that remove some organics and radium by adding calcium oxide or calcium hydroxide to increase the pH to a level where the metals will precipitate out.
Lab Waste	Wastes of any kind generated by a laboratory, usually on-site, analyzing rock, sediment, water or other samples obtained at the mine or extraction facility, or its vicinity.
Leachate	A solution obtained by leaching; e.g., water that has percolated through soil containing soluble substances and that contains certain amounts of these substances in solution.
Leach Liquor	Lixiviant which contains minerals dissolved from host rocks.
Leuxocene	General term for a fine-grained, opaque, whitish alteration (weathering) product of ilmenite in mineral form.
Lithologic	Character of a rock described in terms of its structure, color, mineral composition, grain size, and arrangement of its component parts; all those visible features that in the aggregate impart individuality to the rock. Lithology is the basis of correlation in coal mines and commonly is reliable over a distance of a few miles.
Longwall Retreat	A method of mining flat-bedded deposits, in which the working face is mined over a considerable width at one time. The excavation retreats towards the shaft. In this method, all the roadways are in the ore body and the waste areas are left behind.
Lixiviant	A liquid medium that selectively extracts the desired metal from the ore or material to be leached rapidly and completely, and from which the desired metal can then be recovered in a concentrated form.

Mill Tailings	Residue of raw material or waste separated out during the processing of uranium mineral ores. Byproduct material in accordance with the AEA.
Mine	Mining is the mechanical process by which mineral ores are extracted from the earth.
Mine Footprint	The areal extent of land physically disrupted by a mine operation.
Mineral Sands	Eroded and generally unconsolidated sedimentary particles of rock minerals of sand size which have accumulated in a geologic deposit, and may be exploited or concentrated for economic purposes.
NORM	Naturally Occurring Radioactive Materials. Materials which may contain any of the primordial radionuclides or radioactive elements as they occur in nature, such as radium, uranium, thorium, potassium, and their radioactive decay products, that are undisturbed as a result of human activities.
Ore	The naturally occurring material from which a mineral or minerals of economic value can be extracted profitably or to satisfy social or political objectives. The term is generally but not always used to refer to metalliferous material, and is often modified by the names of the valuable constituent; e.g., iron ore; ore mineral.
Overburden	Designates material of any nature, consolidated or unconsolidated, that overlies a deposit of useful materials or ores, especially those deposits that are mined from the surface by open cuts or open-pit methods.
Permeable Reactive Barrier	An emplacement of reactive materials in the subsurface designed to intercept a contaminant plume, provide a preferential flow path through the reactive media, and transform the contaminant(s) into environmentally acceptable forms to attain remediation concentration goals at points of compliance.
Pillar	A column of ore left to support the overlying strata or hanging wall in a mine, generally resulting in a "room and pillar" array. Pillars are normally left permanently to support the surface or to keep old workings water tight.
Pit Lake	A lake which has formed by accumulation of water in an open-pit mine excavation.
Pit Lake Water	Water which has filled an open-pit mine excavation, usually derived as water from underground workings of the mine.
Protore	Mineral bearing rock that cannot be further processed at a profit under existing conditions but that may become profitable with technological advances or price increases.

Pseudomorph	A mineral whose outward crystal form is that of, or which resembles another mineral species: it has developed by alteration, substitution, incrustation, or other mineral process.
Radiation Survey Radiological Survey)	Measurements of radiation levels associated with a site together (or with appropriate documentation and data evaluation.
Radioactivity	The mean number of nuclear transformations occurring in a given quantity of radioactive material per unit time. The International System (SI) unit of radioactivity is the Becquerel (Bq). The customary unit is the Curie (Ci).
Radioactive Decay	The spontaneous transformation of an unstable atom into one or more different nuclides accompanied by either the emission of energy and/or particles from the nucleus, nuclear capture or ejection of orbital electrons, or fission. Unstable atoms decay into a more stable state, eventually reaching a form that does not decay further or has a very long half-life.
Radionuclide	An unstable nuclide that undergoes radioactive decay.
Reclamation	Restoration of mined land to original contour, use or condition.
Reductant or Reduction	The addition of hydrogen, removal of oxygen, or addition of electrons to an element or compound.
Regulation	A rule, law, order, or direction from federal, state, or Tribal governments regulating action or conduct. Regulations concerning radionuclides in the environment in the United States are shared by the Environmental Protection Agency (EPA), the U.S. Nuclear Regulatory Commission (NRC), the U.S. Department of Energy (DOE), state and Tribal governments.
Rem	Radiation Equivalent in Man. The conventional unit of dose equivalent. The corresponding International System (SI) unit is Sievert (Sv): 1 Sv = 100 rem.
Remediation	Cleanup or other methods used to remove or contain a toxic spill or hazardous materials from a Superfund site, or uranium mine or extraction facility, including those included under the Uranium Mill Tailings Radiation Control Act (UMTRCA).

Refuse	Solid waste. Non-liquid, non-soluble materials ranging from municipal garbage to industrial wastes that contain complex and sometimes hazardous substances. Solid wastes also include sewage sludge, agricultural refuse, demolition wastes, mining equipment and mining residues. Technically, solid waste also refers to liquids and gases in containers.
Removal	The cleanup or removal of released hazardous substances, or pollutants or contaminants which may present an imminent and substantial danger; such actions as may be necessary taken in the event of the threat of release of hazardous substances into the environment; such actions as may be necessary to monitor, assess, and evaluate the threat of release of hazardous substances; the removal and disposal of material, or the taking of other such actions as may be necessary to prevent, minimize or mitigate damage to the public health or welfare or the environment.
Rill	A small channel, as one formed by erosion.
Risk Assessment	Qualitative and quantitative evaluation of the risk posed to human health and/or the environment by the actual or potential presence and/or use of specific pollutants.
Room and Pillar	A conventional method of underground mining in which natural pillars are left unmined for support between the mined rooms.
Rutile	A usually reddish-brown mineral (TiO_2) that is an ore of titanium.
Saturated Zone	A subsurface zone of soil or rock in which all the pore spaces are filled with water under pressure greater than that of the atmosphere. This zone is separated from the zone of aeration (above) by the water table.
Scanning	An evaluation technique performed by moving a detection device over a surface at a specified speed and distance above the surface to detect radiation.
Secular Equilibrium	A state of parent-daughter equilibrium that is achieved when the half-life of the parent radionuclide is much longer than the half-life of the daughter radionuclide decay product. In this case, if the two are not separated, the daughter will eventually decay at the same rate at which it is being produced. At this point, both parent and daughter will decay at the same rate until the parent is essentially exhausted.
Sievert (Sv)	The special name for the International System (SI) unit of dose equivalent. 1 Sv = 100 rem = 1 Joule per kilogram.
Site	Any mine or extraction facility installation, or discrete, physically separate parcel of land or lands disturbed by mining or uranium extraction, or any building or structure or portion thereof.
Soils	All unconsolidated materials above bedrock.

Solution Process	A method of extracting sought-after underground elements or minerals from in-place ore, or elements or minerals from ore previously mined and crushed. This is accomplished through the use of fluids which dissolve the mineral from the rock, putting it into liquid solution which is then processed or evaporated to obtain the desired element or mineral.
Solvent Extraction	A process for extracting a mineral or element (e.g., uranium) from ore by soaking rock with a (solvent) that dissolves the target element from the rock and putting it into liquid solution. The liquid is then processed or evaporated to obtain the desired element.
Source Materials	Uranium or thorium, or any combination thereof, in any physical or chemical form or (2) ores which contain by weight one-twentieth of one percent (0.05%) or more of: (i) Uranium, (ii) thorium or (iii) any combination thereof. Source material does not include special nuclear material. chemical
Special Nuclear Material	Plutonium, U-233, and Uranium enriched in U-235, material capable of undergoing a fission reaction.
Stewardship	Institutional controls (private or publicownership or governmental) which may be put in place to ensure that a specific site meets its closure goals. Institutional controls can be either active, involving some form of continuous or intermittent human activity to maintain the condition of the site, or passive, which do not require human intervention and have an amount of redundancy built into them to deter or prevent disturbance of the closed site.
Stope	An excavation from which ore has been removed in a series of steps. A variation of step. Usually applied to highly inclined or vertical veins or beds.
Survey	A systematic evaluation and documentation of radiological measurements with a correctly calibrated instrument or instruments that meet the sensitivity required by the objective of the evaluation.
Survey Plan	A plan for determining the radiological and other characteristics of a site.
TENORM	Acronym for Technologically Enhanced Naturally Occurring Radioactive Material. Naturally occurring radioactive materials that have been concentrated or exposed to the accessible environment as a result of human activities such as manufacturing, mineral extraction, or water processing.
Underground Injection	The method by which fluids are placed under pressure in a well such that the fluid enters an underground rock formation. A means by which ISL wells inject lixiviant to dissolve uranium from underground ore bodies.
Unconsolidated	Rocks consisting of loosely coherent or uncemented particles, whether occurring at the surface or at depth.

Underflow	Flowing bottom waters containing dissolved or suspended solids.
Unsaturated zone	The zone in which the pore opening of the functional permeable rocks are not (except temporarily) filled with water under hydrostatic pressure; the interstices are either not filled with water or are filled with water that is held by capillarity.
Uprate	The process of increasing the maximum power level at which a commercial nuclear power plant may operate.
Volcaniclastic	A sedimentary rock containing volcanic material without regard to its origin or environment of deposition.
Waste Rock	Rock void of uranium ore which may have been set aside as waste after removal of top-soil, overburden and uranium ore or veins. Waste rock is defined as barren or submarginal rock or ore that has been mined, but is not of sufficient value to warrant treatment and is therefore removed ahead of the milling processes.
Wastewater	The spent or used water from a mine that contains dissolved or suspended matter.
Working Level	A special unit of radon exposure defined as any combination of short-lived radon daughters in 1 liter of air that will result in the ultimate emission of $1.3\text{x}10^5$ MeV of potential alpha energy. This value is approximately equal to the alpha energy released from the decay of progeny in equilibrium with 100 pCi of Ra-222.

Appendix II. Uranium Decay Series

In the figures below, Figure AII.1. for the uranium-238 radioactive decay series, and Figure AII.2. for the uranium-23 radioactive decay series, each radioactive element is shown in a box with its mass number (^{226}Ra for example) along with its half life in µseconds (µsec), minutes (m), days (d), and years (y). The principal type of radiation given off as the radionuclide decays is shown alongside the box: alpha (α), beta (β).

Figure AII.1. Uranium–238 Radioactive Decay Series

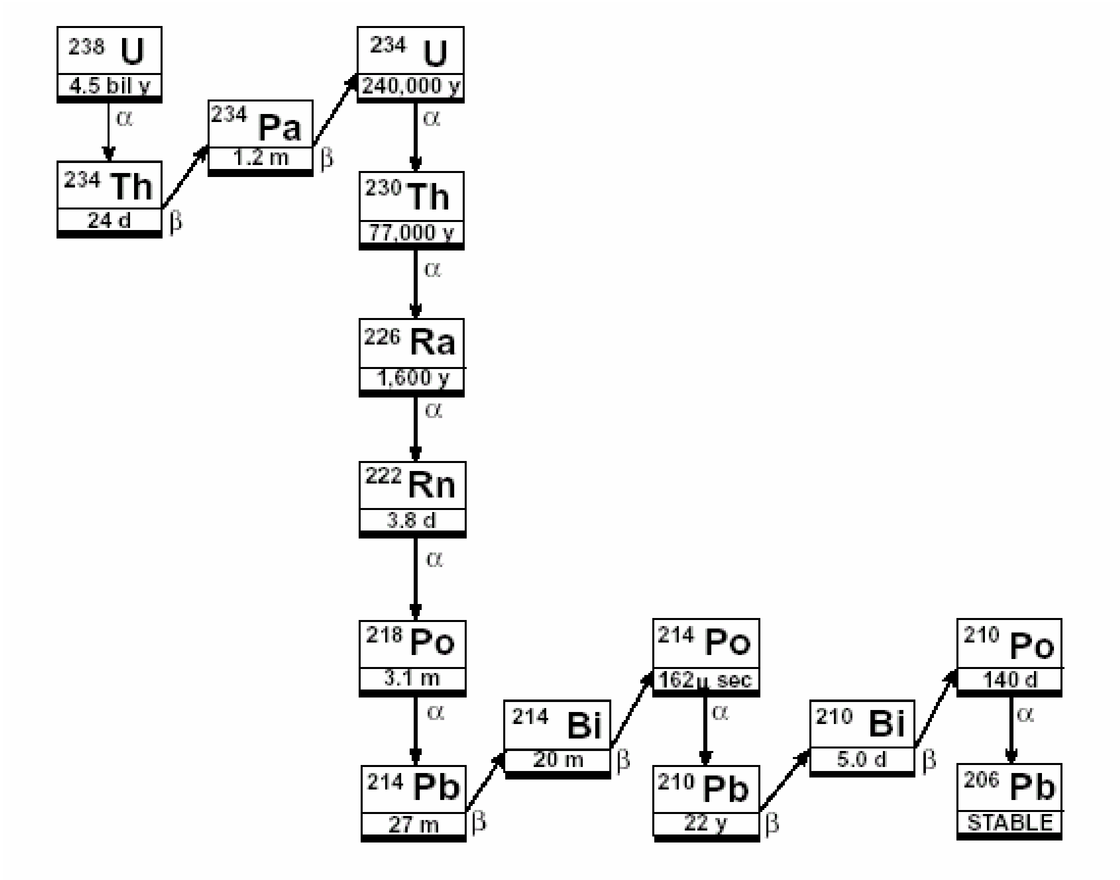
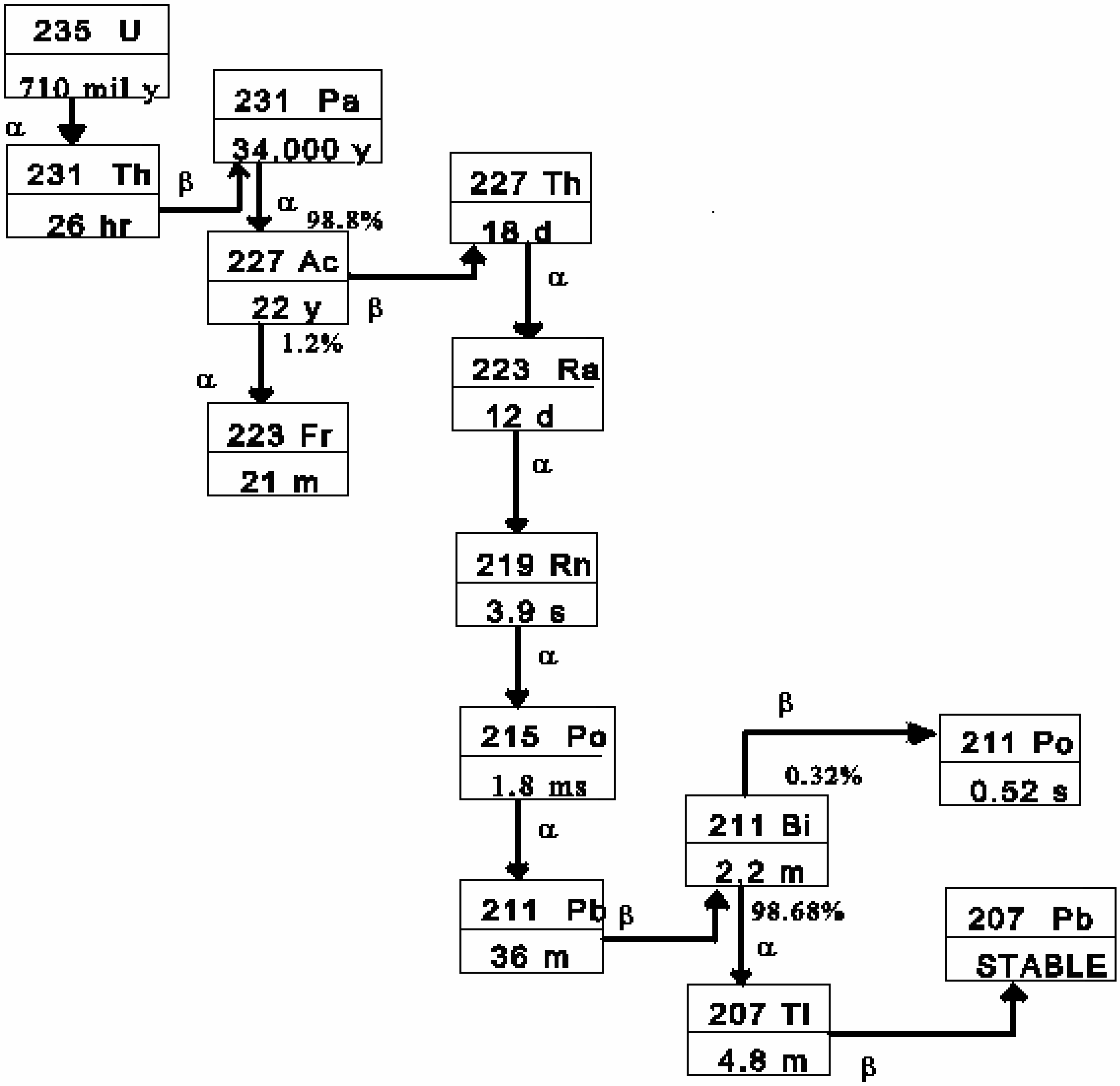


Figure AII.2. Uranium-235 (Actinium) Decay Series



Appendix III. Overview of Uranium Mines and *In Situ* Leach Operations Case Studies

In the main body of this report, mention is made of a number of conventional uranium mines and ISL leach operations which were studied in detail by EPA in order to better understand the environmental conditions associated uranium extraction. Portions, though not all, of the data collected in the course of those studies were included in the report in order to illustrate points made in the text. The conventional mine sites listed in this appendix are abandoned, idle, or in reclamation status, and the descriptions which follow provide information on their location, size, and production status. ISL sites described were licensed facilities under the environmental oversight of and regulation of the NRC or its Agreement States. The wastes from those facilities are considered byproduct materials and not TENORM. As such, the information presented in this Appendix is for information purposes only. For a description of how new ISL operations are carried out, see Chapter 2.

A decision will be made in the near future about whether or not more detailed information on the conventional mine and ISL sites which was assembled as case studies for this report will be issued separately.

Canyonlands Uranium Mines, Lathrop Canyon, Utah

This is a group of 12 abandoned mines in sandstone deposits of southeastern Utah in a semi-arid region of the country. The mines are remotely located in Lathrop Canyon of the Canyonlands National Park near Moab, Utah, about 1½ hour hike from the nearest visitor's center at the park. Mine waste rock is found in piles inside and outside the mines, with contaminated water located below the mines. Contaminated water does not directly feed into any major bodies of water. Total waste amounts are estimated at 1,750 m^3 (2,322 yd^3). A study done by Burghardt et al. (2000) provides most of the data on the site contamination. Data are available on metals concentrations, pH, radiation levels, and electrical conductivity for the waste rock piles. Similar information is available for the Lathrop Canyon water and drainage. Based on this information, as well as population proximity information, the National Park Service and Utah Abandoned Mine Lands Reclamation Program maintain that Lathrop Canyon Mines now pose minimal risk to human safety and health.

Orphan Uranium Mine, Arizona

The Orphan Uranium mine is located at the Grand Canyon National Park in northern Arizona and is being assessed by the National Park Service for cleanup under CERCLA. The deposit is in sandstone and claystone, but occurs as a breccia pipe deposit. The mine's buildings, hoisting headframe, and ore loadout area are located a short walk from the south rim visitor's center, although the area has been fenced to deter visitors. Mining activities were conducted mainly between 1956 and 1969 for uranium, copper, silver, and vanadium. Radioactive rock and soil have been found at the loading area, and at the mine itself, which is located below the canyon rim. The mine still contains significant amounts of unmined uranium. Horn Creek, which lies beneath the Orphan Mine and along a major hiking trail of the park was found to discharge "hostile" effluent containing uranium and exceeding the maximum contaminant level for gross alpha radiation in drinking water. Uranium contamination of Horn Creek may be derived from: surface runoff from the upper mine site and tailing debris at the lower mine site; groundwater and surface water that have percolated through the Orphan Mine, including the open glory hole; and ore and waste rock debris containing uranium that has eroded and has been swept into the drainage basin of Horn Creek. The case study includes results of Horn Spring sampling for uranium, as well as radiation levels recorded for the upper and lower mine sites. Approximately two million people visit the vicinity of the mine annually; however, relatively few individuals are directly exposed to radiation.

Further evaluation of the site in accordance with CERCLA is underway to evaluate the extent of contamination and cleanup alternatives. According to the National Park Service (U.S. NPS 2006), an Engineering Evaluation/Cost Analysis (EE/CA) should commence for the upper mine area in 2006. This study would analyze cleanup action and the effectiveness, feasibility, and cost of a number of cleanup alternatives. Upon completion, the EE/CA (including any recommended cleanup) and supporting documents would be made available to the public for review and comment. An EE/CA for the lower and middle mine areas was also being planned.

Midnite Uranium Mine, Washington

The Midnite Mine is an inactive open-pit uranium mine located within the boundaries of the Spokane Indian Reservation in eastern Washington State, and is a disseminated deposit in igneous rocks. It was operated by Dawn Mining Company between 1955 and 1981, and the disturbed area covers approximately 320 acres (129.6 hectares). The initial series of open-pits were backfilled with waste rock as mining progressed, and additional overburden and waste rock is on the surface, as well as a number of ore/protore stockpiles. Two large pits remain open and accumulate water from multiple sources, including seep water collected at the base of the largest waste rock pile. The pile was graded and partly reclaimed by the mining company, which also operates an ongoing seep collection system and $BaCl_2$ treatment facility. Midnite Mine was listed as a Superfund site in 2000, and an EPA-funded study is under way. In addition to the seeps and impounded surface water contaminated with heavy metals and radionuclides, contamination has spread to areas outside the mined area in surface water and sediments, groundwater, and road dust. Most runoff from the mined area flows to three streams (called "drainages"). The drainages meet south of the mine and flow into Blue Creek. Blue Creek travels an additional 3.5 miles to the Spokane River Arm of Lake Roosevelt. Shallow groundwater also flows from the mined area along the three drainages and emerges south of the mined area. Collection and treatment of contaminated water has reduced the amount of contamination entering surface water. However, the drainages and Blue Creek still show ongoing contamination from the mine. A proposed cleanup plan was issued by EPA in September of 2005.

Bluewater Uranium Mines, New Mexico

The Bluewater Uranium mines are a series of three sandstone mine sites located in north Central Cibola County in west-central New Mexico. Portions of the site had a semi-agricultural rural setting where approximately 65 persons lived in 1990. The mines were operated primarily between 1952 and 1966. Reclamation activities were conducted by EPA, ATSDR, and the Navajo Superfund Program to reduce potential radiological hazards associated with the mines. As a result of previous mining activities and the absence of reclamation action, the sites contained large open-pits with exposed uranium-bearing overburden, waste rock, and protore. A contaminated water well and houses constructed with uranium mine wastes were closed and removed. Radiological contaminants of concern were uranium and its daughter products of radium, thorium, bismuth, lead, and radon gas. Heavy metal species suspected to be present in the mining waste were arsenic, barium, manganese, molybdenum, selenium, strontium, and vanadium, Analytical data on uranium and radium were collected prior to and after the completion of reclamation activities.

White King/Lucky Lass Uranium Mine Sites, Oregon

Also known as the Fremont National Forest Superfund Site, the site is located in south-central Oregon, and includes two former uranium mining areas encompassing about 140 acres (about 57 hectares). The site is located in a mountainous semi-arid setting on National Forest Service lands, with the closest residences and drinking water wells more than 10 miles (16 kilometers) from the site. The mines are located within the northwest terminus of the Basin and Range province. This area is characterized by north-trending fault-block mountains and basins of internal drainage. Geologic units in the region are characterized by a thick sequence of volcanic flows and volcaniclastic rocks which have been extensively faulted and fractured. The major features include a water-filled excavation pit (pond); a protore stockpile; an overburden stockpile; areas where overburden and ore were dumped or spilled; and Augur Creek, which flows adjacent to the two White King stockpiles. Mining operations were conducted between 1955 and 1965, with exploratory drilling conducted until 1979. The area has been extensively sampled for arsenic, uranium-234/238, radium, and radon. A baseline risk assessment was conducted and serves as part of the record of decision (ROD). Construction for remediation of the sites began in 2005.

Yazzie--312 Mine, Cameron, Arizona

The Yazzie-312 Uranium Mine is located on the Navajo Indian Reservation located in the Painted Desert section of the Black Mesa basin area near Cameron, Arizona. The site was operated between 1956 and 1961 and contained a large, water-filled open-pit lake; the water had been used for recreational swimming and livestock watering. The water standing in the Yazzie-312 pit was the result of an artesian flow from an underlying aquifer. The mine was in the Petrified Forest Member of the Chinle Formation. The mine operator drilled a hole in the bottom of the pit looking for a deeper ore horizon. The drill hole encountered artesian water in the Shinarump Member, which filled the pit.

The EPA studied the mine to determine: the presence of metals and radionuclides in water within the mine pit, in underlying water, and in the Little Colorado River; assessing metals and radionuclides in subsurface soil and sediments; determining infiltration in the water-filled mine pit; and assessing communication into other aquifers at the site. Analytical data were collected on several borings for soil samples, as well as several water samples. The area has several hard impermeable substrates located between 50 and 130 feet (15.2 and 39.6 meters) below ground surface. Elevated levels of uranium and thorium were found at soil depths that were above the groundwater table (110 to 210 feet) (33.5 to 64 meters-below ground surface), with significantly lower levels found at deeper depths. No metal levels exceeded EPA Region 9's Preliminary Remediation Goals. In the overburden and protore piles, the most significant contaminants were the uranium and thorium concentrations. Groundwater samples indicated contamination for uranium, radium, arsenic, beryllium, chromium, and manganese. Pit water tested similarly high for the same contaminants and for iron and lead. Testing also indicated that the Little Colorado River contained measureable uranium, arsenic, beryllium, and chromium, although not at significant levels. The mine site was remediated by the Navajo Abandoned Mine Land agency in 2002.

Uranium In Situ *Fields*

Crow Butte, Nebraska

Cameco's facility and associated wellfields are located in west-central Dawes County, Nebraska, just north of the Pine Ridge, five miles southeast of Crawford, Nebraska. The total surface area of the project site is approximately 2,800 acres (1,134 hectares), with about 500 acres (202 hectares) that will be disturbed during the life of the project. The uranium deposit at the Crow Butte site is a roll-front deposit, similar to those in the Wyoming basins. Liquid wastes from operations are generated from three sources: (1) wellfield development, (2) processing plant operations, and (3) aquifer restoration activities. Currently, Cameco has three options approved by the NRC for the disposal of liquid wastes: (1) solar evaporation ponds, (2) land application, or (3) deep-well injection. At this time, land application has not been used. The study contains results for lead, polonium, radium, radon, thorium, and uranium, taken from both the ponds located at the site and surface waters.

Holiday/El Mesquite, Texas

The Combined Holiday and El Mesquite ISL fields are located in Duval and Webb counties, Texas, and they cover a permit area of approximately 4,500 acres (1,822 hectares). They are owned by COGEMA which cited its total wellfield area as 335 acres (135 hectares) in two combined leases, with 1,750 injection wells and 1,450 production wells. Production commenced in 1977, with the expectation of 17 years of production and the fields' producing an ore grade of 0.07% using a sodium bicarbonate-injected lixiviant. Production from the fields averaged 750 tons of uranium per year, with an estimated extraction efficiency of 93 to 95%. Wastewater was collected at two storage ponds at the El Mesquite project before injection into deep disposal wells. The El Mesquite project lease area comprises 2,900 acres (1174 hectares) including five wellfields, three satellite locations, a processing plant, a yellowcake dryer, administrative buildings, a laboratory, a warehouse, and a maintenance shop. The Holiday lease covers 1,483 acres (600 hectares), including 10 wellfields and two satellite locations. Uranium production at the Holiday and El Mesquite project areas has ceased, and negative pressure in producing wells of the field is maintained to prevent excursions of pollutants (or plume migration) beyond mine lease boundaries. Areas that were depleted at an early point in the operations history were subjects of groundwater restoration activities. At Holiday and El Mesquite, the groundwater prior to extraction was usable for livestock watering, (with some localized exceptions, due to elevated radium-226, which is present in the groundwater within the uranium ore body). Therefore, COGEMA's goal after extraction is to clean up the groundwater to as close to background conditions as possible.

Irigaray and Christensen Ranch, Wyoming

The Irigaray and Christensen Ranch projects are two separate ISL operations that are located about 51 to 55 miles (82 to 88 kilometers) southeast of Buffalo in the Powder River Basin in northeast Wyoming. The Irigaray property is 21,100 acres (8,545 hectares) and contains the central plant for both projects, though the actual disturbed area for Irigaray is only 133 acres. COGEMA purchased both properties in April 1993, and all mining activities (at both sites) ceased in June 2000. The ore mineralization is one of many roll-front type uranium deposits located in the Wasatch formation. Water treatment processes, such as reverse osmosis, were used to clean wellfield bleed water for use in restoration. Uranium-laden resin from the ion exchange columns was transferred to a tanker trailer and trucked to the Irigaray central plant for elution, final uranium precipitation, and drying. Wastewater disposal capability included evaporation in lined ponds, storage of clean water (reverse osmosis permeate) in clay-lined ponds, treatment and disposal via surface discharge under a Wyoming National Pollutant Discharge Elimination System permit, and deep-well injection. The lined solar evaporation ponds were initially designed to provide a surface area and capacity capable of evaporating a 5 gallons per minute (about 19 liters per minute) process effluent stream. The four lined solar evaporation ponds were designed to meet the requirements of the NRC. Samples of the wastewater effluents were taken and tested for uranium and radium concentrations. Restoration of the Irigaray well fields was complete in August 2002 and was expected to be complete at Christensen Ranch in 2006. Surface decommissioning and reclamation are underway (as approved by NRC) and should be complete in 2007.

Crownpoint Uranium, New Mexico

The proposed Crownpoint Uranium ISL project consists of three properties located near Church Rock, New Mexico. Operations at the Crownpoint site would include a central processing facility where yellowcake will be dried and packaged. Generally, the uranium deposits are a few feet thick and several hundred to a thousand feet (305 meters) long, and may be stacked, usually parallel to the strike of the host rock. Uranium was proposed to be extracted from the ore bodies by leachate mining, using a sodium bicarbonate lixiviant, and is then extracted from the solution and concentrated. Uranium to be produced at the Church Rock and Unit 1 sites, uranium concentrate, in the form of either uranium-loaded resin beads or yellowcake slurry, would be shipped by truck to the central processing facility and packaged into a final yellowcake product. Before the waste would be disposed of, barium chloride would be added to effectively remove radium, thus lowering the radionuclide concentrations of the waste. HRI, the site's owner and operator, is currently considering up to five different final disposal options for wastewaters (both process-generated and restoration waters): (1) surface discharge, (2) land application, (3) brine concentration, (4) waste-retention ponds, and (5) deep-well disposal. At present, HRI is limited to using surface discharge (with appropriate state or federal permits/licenses), brine concentration, waste-retention ponds, or a combination of the three options to dispose of process wastewater. In July 2005, NRC required that HRI reduce its secondary groundwater restoration standard for uranium from 0.44 mg/L to 0.03 mg/L.

Highlands Uranium, Wyoming

Operated by Power Resources, Inc., Highlands is a 15,000-acre (6,073 hectare) ISL facility, located in the Southern Powder River Basin of east-central Wyoming, in central Converse County, Wyoming. The land has been used for seasonal sheep and cattle grazing. The uranium production process uses a lixiviant comprised of native groundwater with gaseous carbon dioxide and oxygen, which is injected into the ore zone through a series of well patterns. Uranium becomes dissolved within the lixiviant, which is pumped from the ground, treated to remove the uranium, then re-injected into the ore zone. Liquid wastes from the operation consist of two types of wastewater: (1) freshwater streams and (2) a saltwater stream. The freshwater streams consist of restoration wastewaters and well field/process purge. Together, the process purge and restoration fluids make up the irrigation water source. Power Resources disposes of its freshwater waste stream by using radium settling basins, purge storage reservoirs, and irrigation areas. Due to erosion problems encountered with the original clay liner of the ponds, a geotextile fabric was installed in September 1988 to protect against future erosion concerns. Data was obtained for radium and uranium in the settling ponds. Saltwater waste is disposed of in a waste disposal injection well. The saltwater waste is produced from several sources in the uranium recovery and yellowcake production process. The sources that make up this waste stream include analytical laboratory liquid wastes, elution agents decanted from the precipitation circuit, yellowcake wash water, reject solutions from the water treatment process, and washdown water from the Central Processing Facility.

Smith Ranch, Wyoming

This Power Resources project acquired from Rio Algom, is a 16,000-acre (6,480 hectare) site at the Smith Ranch, located in the North Platte River drainage in Converse County, approximately 17 miles (27.2 kilometers) northeast of Glenrock, Wyoming. Power Resources proposed to extract uranium at depths of 450 to 1,000 feet (137 to 305 meters). The project involves approximately 25 individual mining units. When the project was to be fully operational, about two years after licensing, approximately five mining units would be in production at a time. Extraction would proceed approximately three years in each unit, followed by an equivalent period of unit restoration and surveillance monitoring. The proposed schedule covers a total of about 20 years. Liquid effluents from the operation include the production bleed stream, excess fluids from the elution and precipitation process, regeneration of the water softener system (calcium control), yellowcake rinse water, plant washdown water, restoration equipment waste, restoration bleed, and facility sanitary waste. If the water quality was acceptable, the water would then be routed through a separate radium removal and solids settling system prior to evaporation and/or land application (surface irrigation). Excess liquids from the elution and precipitation circuit and water softener regeneration were expected to average about 60 gallons per minute (227 liters per minute) and would be routed to lined evaporation ponds or to a disposal injection well. In 2005, Power Resources applied for an amendment to the Smith Ranch/Highland license to include the adjacent planned Reynolds Ranch ISL project as a satellite facility. Sample data on radium and uranium concentrations in evaporation ponds from the pilot projects were obtained by EPA.

Appendix IV. Calculations of Volumes of Uranium Overburden and Waste Rock

Conventional mining techniques produce large amounts of solid waste materials. Open-pit mining in particular produces large quantities of overburden, while underground mining produces lesser, but still significant amounts of waste rock. Overburden and weakly mineralized waste rock that have not been used for reclamation have usually been stored in piles on site and are usually unsaturated, given that most conventional mining occurs in arid regions (U.S. DOE/EIA 1997). In general in this Appendix overburden and waste rock have been included together in estimating total waste rock at the mine sites.

The density of mine wastes varies, depending on the type of ore body with which they are associated and the geology of the enclosing rock formations. Standard weight per volume figures used in mine waste calculations are 1.68 tons/y^3 or 2 MT/m^3.

The approach used here is to estimate the ratio of waste rock production to ore production by mining category (open-pit and underground); calculate the amount of waste generated from annual production statistics (also given by mining category); and compare these numbers to waste volumes known or calculated for various mines.

When the uranium mining industry first started, most of the ores were recovered from deposits located at or near the surface. Ores were often exposed at the surface and shallow open-pit and underground mines often followed mineralized zones directly into the subsurface. The open-pit mines would remove thin overburden from buried parts of the ore body adjacent to the surface exposure. As easily accessible ore deposits became depleted, mining had to be performed at increasing depths by either open-pit or underground methods. In addition, lower grade ore deposits, once ignored, were later mined by using improved mining methods and more efficient ore extraction techniques. In the early mining years, an ore grade of 0.15% was often ignored; more recent mining practices target ore grades as low as 0.03%. Accordingly, over the years, the mining industry was required to move larger quantities of topsoil, overburden, and other waste rock in order to reach deeper deposits.

The amount of overburden that can be economically removed during open-pit mining is a complex function of the depth to the orebody, the grade and thickness of the ore-bearing zone, the price of uranium, and the costs of moving the overburden. The costs of processing ore at mills also influence the economics. Those processing costs, which apply to both underground and surface mines, have steadily declined and have lowered the ore grade that is economic to mine.

Information about the ratio of waste rock to ore can be derived from Abandoned Mine Land survey reports written since the mid-1980s, production statistics in files of the U.S. Geological Survey, from mining journal articles, from detailed descriptions of uranium mining operations in statewide compilations, and from interviews with mining engineers at selected properties. Such data are available for mines in Wyoming, Texas, Arizona, and New Mexico (Table AIV.1).

The ratio of waste rock to ore for mines of varying sizes shows that small open-pit mines are highly variable, but the ratios for the largest mines (greater than 900,000 MTs of ore) tend to range from 8:1 to 20:1. For example, the largest open-pit mine in the United States, the Jackpile-Paguate mine in New Mexico, was in the 12:1 range through the first 21 years of production (1953–73) but finished with an overall 16:1 ratio before production ceased in early 1982. The nearby St. Anthony open-pit mine had a stripping ratio of 10:1. The Shirley basin open-pit complex in Wyoming had an 8:1 waste to ore ratio.

Open-pits in Texas seem to have variable waste to ore ratios ranging from 2:1 to 20:1 for the smaller older pits on shallow ore bodies to relatively high values of 20:1 to 50:1 for the deeper deposits. Large open-pits dominate production in Wyoming and New Mexico, whereas smaller open-pits occur in Colorado, Utah, and Arizona. The Moonlight and Monument #2 open-pits in Arizona are thought to have had a 5:1 stripping ratio based on the depth to ore and ore thickness (Chenoweth 1998). Smaller open-pit operations in the range of 900 MTs to 900,000 MTs of ore have waste to ore ratios that generally range from 10:1 to 30:1.

The Jackpile-Paguate open-pit mine began production in 1953. Between 1953 and early 1963, 70 MMTs of overburden and associated waste and subore material had been removed to acquire 6.0 MMTs of ore (a ratio of about 11.8:1, Kittel 1963). By mid-1974, about 110 MMTs of overburden were removed and 9 MMTs of ore were recovered at an average grade of 0.25% (a 12:1 ratio, Graves 1974). Production ceased in early 1982, with a total of 364 MMTs of overburden and related materials removed from the ore body and 23 MMTs of ore produced (U.S. BLM 1986), a ratio of 16:1. The mine site contained 32 waste dumps and 23 protore dumps segregated according to grade. About 10.5 MMTs of protore were stored outside of the pits, and another 4.5 MMTs in dumps within pits. The ratio of all waste to protore was about 24:1. About 92 MMTs of backfill, comprised of ore-associated waste and some overburden, were returned to the pits during operations.

Throughout the 1950s, 1960s, and 1970s, open-pit mining was characterized by numerous small to moderate-sized open-pit operations with highly variable waste to ore ratios on the Colorado Plateau, by large open-pit mines in Wyoming and New Mexico with variable but usually lower waste to ore ratios, and by moderate to large open-pit operations in Texas with generally high waste to ore ratios. In the late 1970s and early 1980s waste to ore ratios for the largest mines appear to have peaked at an average of about 30:1 (Bohert and Gerity 1978; Facer et al. 1978). As the price of uranium dropped in the early 1980s, only the more efficient open-pit operations remained in production and the waste to ore ratios probably dropped significantly for the period 1984 to 1992.

Underground mining operations result in much smaller spoil storage piles than those generated by surface mines. Consequently, the waste to ore ratio generally ranges from 20:1 to 1:1 for underground mines, with an average ratio of about 9:1 (U.S. EPA 1983b). As with surface mining, this ratio has also increased over the years from a range of 5:1 until the early 1970s to about 1:1 by the late 1970s.

Table AIV.1 Waste to Ore Relation for Mines in Texas, Wyoming, Arizona, and New Mexico

State	Waste in tons	Ore in tons	Ratio
TX	37,300,000	1,945,366	19.2
	6,720,000	264,660	25.4
	2,040,000	52,390	38.9
	220,000	29,000	7.6
	138,600	7,899	17.5
	168,000	35,495	4.7
	5,980,000	117,709	50.8
	1,025,000	575,000	1.8
	1,610,000	117,775	13.7
	5,300,000	148,294	35.7
WY	121,106,000	14,687,480	8.2
	405,350,000	10,350,000	39.2
	69,050	10,900	6.3
	28,900	2,347	12.3
	25,200	1,000	25.2
	29,700	4,343	6.8
	7,728	201	38.4
	59,500	1,761	33.8
	15,900	256	62.1
	34,340	259	132.6
	6,540	67	97.6
	30,100	153	196.7
	42,700	54	790.7
	21,190	11	1926.4
	27,330	1,056	25.9
	9,160	358	25.6
	134,160	2,175	61.7
	3,440	61	56.4
	16,300	95	171.6
	72,996	2,341	31.2
	91,140	3,800	24.0
	154,812	4,000	38.7
	4,032	975	4.1
	25,450	22	1156.8
	10,350	63	164.3

Table AIV.1 Waste to Ore Relation for Mines in Texas, Wyoming, Arizona, and New Mexico (cont.)

State	Waste in tons	Ore in tons	Ratio
WY (cont.)	20,160	62	325.2
	7,190	7,130	1.0
	18,600	134	138.8
	37,800	1,270	29.8
	16,180	284	57.0
	22,390	1,345	16.6
	7,140	462	15.5
	18,300	1,471	12.4
	46,940	485	96.8
	3,090	387	8.0
AZ	758	3	252.7
	42,000	926	45.4
	202	7	28.8
	3,920	109	36.0
	61	6	10.1
	55,200	1,363	40.5
	706	123	5.7
	12,440	586	21.2
	4,200	305	13.8
	15,750	794	19.8
	958,220	33,821	28.3
	7,390	563	13.1
	226,800	1,264	179.4
	294,000	1,128	260.6
	19,320	218	88.6
	14,950	1,042	14.3
	2,100	23	91.3
	196,560	2,829	69.5
	22,340	343	65.1
	31,080	1,610	19.3
NM	364,000,000	23,000,000	15.8
	St. Anthony Pit		10.0
	50,000	10,400	4.8

Sources: AVI 1986, HE 1987, RCT 1994, Kittel 1963, SRB 1981, Chenoweth 1998, McLenore 1983, Finch 1998.

Uranium ore production rates since 1948 for conventional mining techniques and related production amounts of overburden are given in Table AIV.2. As shown in the table, the estimates for surface mine ratios (overburden to ore) are based on a factor of 30 for the entire period. This approach is believed to arrive at a total waste number for open-pit mines that seems reasonable (i.e. should not significantly over- or underestimate the number), considering the waste volumes associated with the largest mines (see discussion below).

For underground mines, a ratio of 3:1 was used for the years 1948–1970, and 1:1 was used for 1971 and later on. Despite the earlier EPA estimate mentioned previously, it is believed that applying a single ratio of 9:1 for all years would significantly underestimate the amount of waste generated during the last two decades.

Based on the preceding discussion, the total overburden produced by open-pit mines is estimated to range from 1 billion metric tons to 8 billion metric tons, with an average of 3 billion metric tons. For underground mines, the estimate ranges from 5 MMTs to 1 hundred MMTs, averaging 67 MMTs. Waste produced by open-pit mining is a factor of 45 greater than that for underground mining, based on their respective averages. For the range between the low and high estimates, the factor is 190 for the low estimate and 80 for the higher one. Thus, the amount of overburden generated from open-pit mines far exceeds that from underground mines.

The four largest mines in Table AIV.1 yield about 30% of the surface mine total; however, the size of mines drops dramatically as the rest of the inventory is considered. More than 1,000 of the 1,300 surface mines that have been operated in the past 50 years have produced less than 900 MTs of ore. These mines total less than 30 MMTs of waste, or less than 1% of the median estimate. Accordingly, the waste inventory produced by this industry is primarily the result of past operations at some 300 surface mines (SC&A 1989).

Table AIV.2. Uranium Ore Production Rates and Overburden 1948—1996

Year	Open-Pit Mining				Underground Mining			
	Ore (MTs)	Overburden (MTs)			Ore (MTs)	Overburden (MTs)		
		Low	Avg.	High		Low	Avg.	High
1948	<9.0E+02	9.1E+03	2.7E+04	7.3E+04	3.4E+04	1.7E+03	1.1E+04	3.4E+04
1949	9.1E+02	9.1E+03	2.7E+04	7.3E+04	1.6E+05	7.8E+03	5.2E+04	1.6E+05
1950	2.1E+04	2.1E+05	6.3E+05	1.7E+06	2.1E+05	1.0E+04	6.9E+04	2.1E+05
1951	2.5E+04	2.5E+05	7.6E+05	2.0E+06	2.9E+05	1.4E+04	9.6E+04	2.9E+05
1952	5.9E+04	5.9E+05	1.8E+06	4.7E+06	3.4E+05	1.7E+04	1.1E+05	3.4E+05
1953	1.6E+05	1.6E+06	4.9E+06	1.3E+07	5.0E+05	2.5E+04	1.7E+05	5.0E+05
1954	2.4E+05	2.4E+06	7.2E+06	1.9E+07	7.6E+05	3.8E+04	2.5E+05	7.6E+05
1955	3.4E+05	3.4E+06	1.0E+07	2.7E+07	1.0E+06	5.2E+04	3.5E+05	1.0E+06
1956	1.1E+06	1.1E+07	3.4E+07	9.1E+07	1.6E+06	8.0E+04	5.3E+05	1.6E+06
1957	1.5E+06	1.5E+07	4.4E+07	1.2E+08	1.9E+06	9.4E+04	6.3E+05	1.9E+06
1958	2.1E+06	2.1E+07	6.4E+07	1.7E+08	2.6E+06	1.3E+05	8.5E+05	2.6E+06
1959	2.0E+06	2.0E+07	6.0E+07	1.6E+08	4.3E+06	2.2E+05	1.4E+06	4.3E+06
1960	2.2E+06	2.2E+07	6.5E+07	1.7E+08	5.1E+06	2.5E+05	1.7E+06	5.1E+06
1961	2.3E+06	2.3E+07	6.8E+07	1.8E+08	5.0E+06	2.5E+05	1.7E+06	5.0E+06
1962	1.6E+06	1.6E+07	4.8E+07	1.3E+08	4.8E+06	2.4E+05	1.6E+06	4.8E+06
1963	1.7E+06	1.7E+07	5.1E+07	1.4E+08	3.7E+06	1.8E+05	1.2E+06	3.7E+06
1964	1.4E+06	1.4E+07	4.2E+07	1.1E+08	3.4E+06	1.7E+05	1.1E+06	3.4E+06
1965	1.1E+06	1.1E+07	3.4E+07	9.0E+07	2.8E+06	1.4E+05	9.5E+05	2.8E+06
1966	1.2E+06	1.2E+07	3.6E+07	9.7E+07	2.7E+06	1.4E+05	9.1E+05	2.7E+06
1967	1.4E+06	1.4E+07	4.3E+07	1.2E+08	3.4E+06	1.7E+05	1.1E+06	3.4E+06
1968	2.1E+06	2.1E+07	6.4E+07	1.7E+08	3.7E+06	1.9E+05	1.2E+06	3.7E+06
1969	2.0E+06	2.0E+07	5.9E+07	1.6E+08	3.4E+06	1.7E+05	1.1E+06	3.4E+06
1970	2.5E+06	2.5E+07	7.6E+07	2.0E+08	3.2E+06	1.6E+05	1.1E+06	3.2E+06
1971	3.0E+06	3.0E+07	8.9E+07	2.4E+08	2.7E+06	1.4E+05	2.7E+06	2.7E+06
1972	3.5E+06	3.5E+07	1.1E+08	2.8E+08	2.3E+06	1.1E+05	2.3E+06	2.3E+06
1973	4.1E+06	4.1E+07	1.2E+08	3.3E+08	1.8E+06	9.0E+04	1.8E+06	1.8E+06
1974	3.8E+06	3.8E+07	1.1E+08	3.1E+08	2.6E+06	1.3E+05	2.6E+06	2.6E+06
1975	3.9E+06	3.9E+07	1.2E+08	3.1E+08	2.5E+06	1.3E+05	2.5E+06	2.5E+06
1976	4.2E+06	4.2E+07	1.3E+08	3.4E+08	3.6E+06	1.8E+05	3.6E+06	3.6E+06
1977	5.1E+06	5.1E+07	1.5E+08	4.0E+08	4.3E+06	2.2E+05	4.3E+06	4.3E+06
1978	7.5E+06	7.5E+07	2.2E+08	6.0E+08	5.5E+06	2.8E+05	5.5E+06	5.5E+06
1979	8.8E+06	8.8E+07	2.6E+08	7.0E+08	4.9E+06	2.4E+05	4.9E+06	4.9E+06
1980	9.4E+06	9.4E+07	2.8E+08	7.5E+08	5.8E+06	2.9E+05	5.8E+06	5.8E+06
1981	7.7E+06	7.7E+07	2.3E+08	6.1E+08	4.7E+06	2.4E+05	4.7E+06	4.7E+06
1982	5.0E+06	5.0E+07	1.5E+08	4.0E+08	2.5E+06	1.3E+05	2.5E+06	2.5E+06
1983	4.4E+06	4.4E+07	1.3E+08	3.6E+08	2.3E+06	1.1E+05	2.3E+06	2.3E+06

Table AIV.2. Uranium Ore Production Rates and Overburden 1948—1996 (cont.)

Year	Open-Pit Mining				Underground Mining			
	Ore (MTs)	Overburden (MTs)			Ore (MTs)	Overburden (MTs)		
		Low	Avg.	High		Low	Avg.	High
1984	1.8E+06	1.8E+07	5.4E+07	1.4E+08	9.3E+05	4.7E+04	9.3E+05	9.3E+05
1985	8.5E+05	8.5E+06	2.5E+07	6.8E+07	5.2E+05	2.6E+04	5.2E+05	5.2E+05
1986	1.3E+05	1.3E+06	3.8E+06	1.0E+07	6.0E+05	3.0E+04	6.0E+05	6.0E+05
1987[a]	1.7E+05	1.7E+06	5.1E+06	1.4E+06	7.8E+05	3.9E+04	4.6E+05	4.6E+05
1988[a]	6.5E+05	6.5E+06	2.0E+07	5.2E+07	8.5E+05	4.3E+04	4.7E+05	4.7E+05
1989[a]	6.2E+05	6.2E+06	1.9E+07	5.0E+07	7.3E+05	3.7E+04	7.3E+05	7.3E+05
1990[a]	2.9E+05	2.9E+06	8.7E+06	2.3E+07	2.8E+05	1.4E+04	2.8E+05	2.8E+05
1991[a]	6.0E+05	6.0E+06	1.8E+07	4.8E+07	6.0E+05	3.0E+04	6.0E+05	6.0E+05
1992	<9.0E+02	--	--	--	<9.0E+02	--	--	--
1993	none	--	--	--	none	--	--	--
1994	none	--	--	--	none	--	--	--
1995	none	--	--	--	none	--	--	--
1996	none	--	--	--	<9.0E+02	--	--	--
Total	**1.03E+08**	**1.03E+09**	**3.08E+09**	**8.21E+09**	**1.06E+08**	**5.29E+06**	**6.91E+7**	**1.06E+08**
1948–1987		1.0E+09	3.0E+09	8.0E+09		5.2E+06	6.7E+07	1.0E+08
1987–1996		2.3E+07	6.7E+07	1.7E+08		1.6E+05	2.5E+06	2.5E+06

[a] *Ore volumes not reported by mining category; volumes based on annual average uranium content of ore.*

Appendix V. Radiochemical Data for Uranium Overburden and Waste Rock, Pit Lakes and Streams, and *In Situ* Leach Operations

Introduction

The following tables present radionuclide concentration data on solid and liquid wastes at conventional mines, pit lakes and streams, and from *in situ* leach operations. The data compiled has come from a wide variety of sources, many or most without uncertainty limits on the data provided. However, the information is instructive in providing a range of values for these wastes from numerous mines and facilities throughout the west.

In several of the sources, measurements were reported for samples taken from conventional mine "waste" or "spoils" or "dumps" without distinguishing between overburden, soil, or waste rock, or potentially protore. Nevertheless, those studies provide a sense of how radioactive the wastes may be at those sites.

Table AV.1 Radiochemical, Exposure, and Radon Flux Data for Uranium Mine Waste

DataSource	Type of Data	U(nat) pCi/g[1] (Bq/g)	Ra-226 pCi/g[1] (Bq/g)	MicroR/hr	Radon Flux
AVI 1991	Avg. of 54 analyses	30.7 (1.14)	15.2 (0.56)		
Bullrush spoils, drill hole data	Range of 54 analyses	2–299 (0.07–3.7)	2-140 (0.07–5.18)		
Whitworth 1996	Mine waste, avg.	24.4 (0.9)	28.2 (1.04)		
La Bajada Mine, NM	Protore, avg.	75 (2.78)	613.5 (2.28)		
PEDCO 1983	Protore, NM	59 (2.18)	78.4 (0.259)		
	Protore	71.4 (2.64)	51.4 (1.9)		
	Protore	112 (4.14)	88.9 (3.29)		
	Protore	122 (4.51)	55.8 (2.06)		
	Protore	63.7 (2.36)	66.4 (2.46)		
	Waste	1.47 (0.05)	1.71 (0.06)		
	Waste	9.3 (0.34)	7.8 (0.29)		
	Waste	4.2 (0.16)	3.5 (0.13)		
	Waste	34.5 (12.77)	30 (1.11)		
	Protore, WY	8.55 (0.32)	37.4 (1.38)		
	Waste	17.6 (0.65)	1.17 (0.04)		
	Waste	1.35 (0.05)	10.8 (0.4)		
	Soil	0.51 (0.02)	0.71 (0.02)		
	Protore	129 (4.77)	82.2 (0.3)		
	Waste		1.23 (0.05)		
	Waste		0.81 (0.03)		
	Waste	0.61 (0.02)	3.2 (0.12)		
	Waste	1.17 (0.04)	1.06 (0.04)		
	Protore	54.4 (2.0)	67.9 (2.51)		

Table AV.1 Radiochemical, Exposure, and Radon Flux Data for Uranium Mine Waste (cont.)

DataSource	Type of Data	U(nat) pCi/g[1] (Bq/g)	Ra-226 pCi/g[1] (Bq/g)	MicroR/hr	Radon Flux
PEDCO 1983 (cont.)	Waste	0.93 (0.03)	2.15 (0.08)		
	Waste	0.18 (0.01)	2.74 (0.1)		
	Soil	1.55 (0.11)	1 (0.04)		
	Protore	97.1 (3.59)	148 (0.67)		
	Waste	7.1 (0.26)	5 (0.19)		
	Waste	4.9 (0.19)	6.3 (0.23)		
	Soil	4 (0.15)	3.9 (0.14)		
	Waste, µg	26.4	32.4		
	Waste, µg	5.8	6.1		
	Waste, µg	15.7	11.6		
	Waste, µg	24	16.4		
	Waste, µg	58.3	31.9		
	Waste, µg	58.7	39.4		
	Waste	6.2 (0.23)	4.4 (0.16)		
	Protore	137 (5.07)	118 (4.37)		
	Waste	30.5 (1.13)	25.8 0.95)		
	Protore	215 (7.96)	76.5 (2.83)		
	Waste	30.8 (1.14)	27.9 (1.03)		
	Waste	23.9 (0.88)	17.2 (0.04)		
	Waste, µg	54.3	40		
	Waste, µg	12.4	8		
EPA 1983	Boulder sites			40–100	
	Uravan			50–220	
	S.M., waste			35–275	
	ore			100–350	
	overburden			20–120	
	below ground			10–13	

Table AV.1 Radiochemical, Exposure, and Radon Flux Data for Uranium Mine Waste (cont.)

DataSource	Type of Data	U(nat) pCi/g[1] (Bq/g)	Ra-226 pCi/g[1] (Bq/g)	MicroR/hr	Radon Flux
EPA 1983 (cont.)	Mesa Top, waste			25–290	
	Barb Jo, waste			2–170	
	Poison C.,waste			65–250	
	overburden			25–65	
	Morton R., protore			200	
	overburden			59–138	
Burghardt 1998 Various surveys	Orphan (µg), AZ median			250	
	San Mateo (µg) spoils			10–450	
	San M., NM avg.			200	
	Lathrop mine (µg), waste			270–400	
				250	
				170–180	
		212 (7.84)	54 (2.0)		
		57 (2.11)	81 (3.0)		
		2.7 (0.1)	6.3 (0.23)		
		40 (1.48)	47 (1.74)		
	Muss		4.3 (0.16)		
			1.28 (0.05)		
			4.3 (0.16)		
	Jomac	163 (6.03)	110 (4.1)		
		35 (1.3)	206 (7.62)		
	Cath. Butte	17 (0.63)	25 (0.93)		
	Blue N.	7.3 (0.28)	8.5 (0.31)		
		22 (0.81)	26 (0.96)		
	W. Rk. Cn.	15.3 (0.57)	18 (0.67)		
		32 (0.67)	21 (0.78)		
	Terry	188 (6.96)	170 (6.29)		

Table AV.1 Radiochemical, Exposure, and Radon Flux Data for Uranium Mine Waste (cont.)

DataSource	Type of Data	U(nat) pCi/g[1] (Bq/g)	Ra-226 pCi/g[1] (Bq/g)	MicroR/hr	Radon Flux
Burghardt 1998 Various surveys (cont.)		2.3 (0.09)	3.2 0.12)		
	Rainy Day	70 (2.59)	48 (1.78)		
		56.7 (2.1)	1.5 (0.06)		
		1.7 (0.06)	3.8 (0.14)		
		3.1 (0.11)	12 (0.44)		
Longsworth 1994	Monument Valley	Cameron area	AZ/UT		
	Moonlight Mine			18–22	
				43–630	
				185–320	
	Jeepster			18–23	
				19–20	
				5–20	
				47–150	
	Jack Daniels			70–190	
				35–220	
				27–85	
				33–75	
Moore et al. 1996	South spoil, drill hole avg.	85 ppm			
Midnite Mine, WA	Hillside spoil, drill hole avg.	82 ppm			
AVI 1986	Shirley Basin, WY				
	all piles, avg.		11.5 (0.43)		
LAI 1996	Rox ore pile, avg.			400	
	GV area, avg.			120	
	H&I, avg.			150	
	G spoils, avg.			150	
	Stan claims, avg.			500	
	B/R spoils, avg.			150	
	2States/Bl, avg.			250	
	Umetco, spoils, E			120	
	S			280	
	Sunset sp, avg.			200	
	max.			2,000	
	S-T spoils			50–150	
	Bullrush, avg.			90	
	P73 av			300	
	Classic/Bar protore			300–500	
	North Rex, avg.			40	

Table AV.1 Radiochemical, Exposure, and Radon Flux Data for Uranium Mine Waste (cont.)

DataSource	Type of Data	U(nat) pCi/g[1] (Bq/g)	Ra-226 pCi/g[1] (Bq/g)	MicroR/hr	Radon Flux
HE 1989	Pix-Veca pile, drill hole avg.		11.4 (0.42)		
	P-V, avg. 1,200 meas.			113 (4.2)	
	P-V surface avg.		27.2 (1.0)		
AVI 1990	Poison Basin-protore		55–140 (2.04–5.18)	250–600	
HE 1987	Pump Bts. Smpls	35 (1.3)	87 (3.22)	170	
		52 (1.92)	126 (0.44)	300	
		27 (1.0)	45 (1.67)	105	
		2.1 (0.08)	9 (0.33)	70	
	Jean-avg. ore piles			140	
	Key- below ground	22.1 (0.82)	12.7 (0.47)	40	
	waste	20.9 (0.77)	32.8 (1.21)	70	
	ore	688 (25.46)	185.6 (68.67)	300	
FPE 1988	Gas Hills-Jgpile, avg.		33.8		
	Jpile, avg.		15.5 (0.57)		
	Kpile, avg.		7.2 (0.27)		
WY AML Project 15	Converse County, WY				
	Avg. of 677,482 yds				
	of protore	170 ppm			
	Site II-avg.		51 (1.89)	74	30.7 (1.14)
	range		17–180 (0.63-6.67)	3.4-160	
	Average all drill hole in waste/protore piles 11 sites	93.6ppm	49.6 (1.84)		
RCT 1994	Range of 82 smpls of soil/spoil from 10 sites	<.85–668 ppm			

Table AV.1 Radiochemical, Exposure, and Radon Flux Data for Uranium Mine Waste (cont.)

DataSource	Type of Data	U(nat) pCi/g[1] (Bq/g)	Ra-226 pCi/g[1] (Bq/g)	MicroR/hr	Radon Flux
U.S. BLM 1986	Jackpile-Paguate, NM				
	Dump A waste	4.5 ppm		11 (0.41)	
	B waste	2.7 ppm		10 (0.37)	
	C waste	2.7 ppm		5 (0.19)	
	D waste	4.05 ppm		5 (0.19)	
	E waste	1.5 ppm		5 (0.19)	
	F waste	4.03 ppm		5 (0.19)	1.1 (0.04)
	G waste	5.82 ppm		5 (0.19)	4.15 (0.15)
	H waste	146.8 ppm		29 (1.07)	
	I waste	10.0 ppm		5 (0.19)	
	J waste	10.66 ppm		75 (2.78)	
	K waste	20.30 ppm		7 (0.26)	2.7 (0.10)
	L waste	5.5 ppm		5 (0.19)	2.57 (0.1)
	N waste	42.0 ppm		9 (0.33)	
	N2 waste	200.0 ppm		30 (1.11)	
	O, P, P1, P2 waste	3.12 ppm		12 (0.44)	
	Q waste	160.0 ppm		68 (2.52)	
	R waste	11.0 ppm		24 (0.89)	
	S waste	2.79 ppm		10 (0.37)	
	T waste	3.9 ppm		9 (0.33)	
	U waste	34.3 ppm		52 (1.92)	
	V waste	13.9 ppm		34 (1.26)	
	W waste	2.5 ppm		10 (0.37)	
	X waste	18.0 ppm		5	
	Y waste	33.4 ppm		13	

Table AV.1 Radiochemical, Exposure, and Radon Flux Data for Uranium Mine Waste (cont.)

DataSource	**Type of Data**	**U(nat) pCi/g[1] (Bq/g)**	**Ra-226 pCi/g[1] (Bq/g)**	**MicroR/hr**	**Radon Flux**
U.S. BLM 1986 (cont.)	Y2 waste	4.2 ppm		5	
	South waste	4.9 ppm		8	
	FD-1 waste	2.7 ppm		10	
	FD-2 waste	45.0 ppm		3	
	FD-3 waste	14.0 ppm		28	
	17BC protore	220.0 ppm		581	
	6A protore	200.0 ppm		388	
	6B protore	130.0 ppm		383	
	J1 protore	94.0 ppm		155	
	J2 protore	490.0 ppm		606	
	17D protore	520.0 ppm		198	
	1B protore	140.0 ppm		237	
	2C protore	110.0 ppm		422	
	10 protore	390.0 ppm		506	
	2D protore	180.0 ppm		419	
	1C protore	61.0 ppm		227	
	1A protore	31.0 ppm		161	
	2E protore	220.0 ppm		451	
	SP-1 protore	130.0 ppm		354	
	PLG protore	5.0 ppm		210	
	4-1 protore	77.0 ppm		266	
	SP-2 protore	180.0 ppm		300	
	SP-2B protore	610.0 ppm		164	
	TS-1 soil pile	4.9 ppm		8	
	TS-2A soil pile	4.9 ppm		18	
	TS-2B soil pile	2.9 ppm		6	
	TS-3 soil pile	3.6 ppm		11	
	Topsoil borrow	4.1 ppm		17	
Otton 1998	Ascensión mine	Front Range of CO			
	Waste/prot avg. 41 sites		45.7 (1.69)		
	Protore range		294–421 (10.88–15.58)	680–1,100	

Table AV.2 Radionuclide Concentrations in Ponds and Streams Associated with Open-pit Mines in Arizona, Texas, Utah and New Mexico

Data Source	Type of Data	U-238 ppb	U-235 pCi/L	Ra-226 pCi/L
Longsworth 1994	Monument Valley area, AZ–UT			
	Moonlight Mine—shallow well	11000	440 (1.63)	44 (1.63)
AZ-UT deposits	Moonlight Mine—shallow well	14000	530 (19.61)	110 (4.07)
	Moonlight Mine—pit water	-	-	8.6 (0.32)
	Radium Hill—drillhole water	210	12 (0.04)	19 (0.7)
	Radium Hill—shallow well	0.5	<0.1	0.16 (0.01)
	Cameron area, AZ			
	Jeepster Mine—pit water	22	0.8 (0.03)	0.25 (0.01)
	Jack Daniels Mine—ground water	150	5.7 (0.21)	0.1
	Jack Daniels Mine—pit water	11	0.4 (0.01)	0.07
	Manuel-Denetsone—drillhole water	180	8.9 (0.33)	0.52 (0.02)
	Ramco No. 20—small pit water	15	0.6 (0.02)	0.09
		U ppb		
RCT 1994 Texas mines.	Open-pit mine water samples			
	Stoeltje	600		
		700		
	Manka	250		
		200		
		300		
		220		
	I.M. Brysch	12		
		<1		
		14		
	Galen	<1		
	Butler	180		
		180		
		42		
		45		
		<1		
		<1		
		65		

Table AV.2 Radionuclide Concentrations in Ponds and Streams Associated with Open-pit Mines in Arizona, Texas, Utah and New Mexico (cont.)

Data Source	Type of Data	U-238 ppb	U-235 pCi/L	Ra-226 pCi/L
RCT 1994 Texas mines. (cont.)	Wright-McCrady	49		
		49		
	Esse	49		
		49		
	Sickenius	240		
		230		
	Kopplin	72		
		82		
	Smith	4,500		
		4,500		
	Pfeil	57		
		25		
	Weddington South	25		
		49		
	Kellner-Tenneco Weddington	220		
		170		
		200		
		300		
	Franklin	18		
		7		
U.S. BLM 1986	South Paguate—pit pond, N.M.			21.1 (0.78)
	North Paguate—pit pond			36 (1.33)
	South Jackpile—pit pond			18 (0.67)
	North Jackpile—pit pond			16.1 (0.60)
	Rio Paguate—upstream from mine	6		0.35 (0.01)
	Rio Moquino—upstream from mine	8		0.28 (0.01)
	Below confluence—down from mine	239		3.73 (0.14)
	Paguate Reservoir—down from mine	236		1.03 (0.04)

The following licensed ISL facilities are under the environmental oversight and regulation of the NRC and its Agreement States. The wastes from these facilities are considered byproduct materials and not TENORM. The information presented here is for information purposes only.

Table AV.3. In Situ Leach Operation Evaporation Pond Radionuclides, Crow Butte, Nebraska

Radionuclides	Pond Liquids (uCi/ml)
Lead-210	0.66 x 10-9
Polonium-210	0.70 x 10-9
Radium	0.65 x 10-9
Radon	0.70 x 10-4
Thorium-230	2.28 x 10-9
Uranium	5.24 x 10-9

Source: NRC License Application Supporting Materials.

Table AV.4.1 *In Situ* Leach Operation Evaporation Pond Radionuclides COGEMA, Irigaray Field, Wyoming

Sample Loc. /Date	Total U mg/L	Ra 226 pCi/L +/- Precision	Ra 226 Bq/L +/- Precision
IR-1 01/21/99	7.0	3.9/ 0.3	0.14/0.01
IR-1 04/16/99	18.3	8.1/0.5	0.30/0.02
IR-2A 01/21/99	15.1	46.3/1.9	1.71/0.07
IR-2A 04/16/99	1.90	68.9/2.4	2.55/0.9
IR-2B 01/21/99	6.0	29.1/1.5	1.08/0.07
IR-2B 04/16/99	3.96	50.5/2.0	1.87/0.07
IR-3 01/21/99	1.9	17.3/1.3	0.64/0.05
IR-3 04/16/99	0.746	8.4/0.5	0.31/0.02
IR-A 01/21/99	39.8	135/4.2	5.0/0.16
IR-A 04/16/99	36.0	151/4.7	5.59/0.17
IR-B 01/21/99	11.5	471/7.8	17.43/0.29
IR-B 04/16/99	11.8	439/7.9	16.24/0.29
IR-C 01/21/99	3.2	439/7.4	16.24/0.3
IR-C 04/16/99	3.0	325/5.4	12.03/0.2
IR-D 01/21/99	6.6	580/8.6	21.46/0.32
IR-D 04/16/99	6.0	529/6.6	19.57/0.24
IR-E 01/21/99	13.6	1,716/14.6	63.49/0.54
IR-E 04/16/99	13.4	1,760/12.3	65.12/0.46
IR-RA 01/21/99	3.0	16.9/1.2	0.63/0.04
IR-RA 04/16/99	31.0	39.0/1.9	1.44/0.07
IR-RB 01/21/99	46.5	5.1/0.4	0.19/0.01
IR-RB 04/16/99	86.0	11.5/1	0.43/0.04

Source: Quarterly Environmental Reports to the Nuclear Regulatory Commission.

Table V.4.2. *In Situ* Leach Operation Evaporation Pond Radionuclides COGEMA, Christensen Ranch Field, Wyoming

Sample Loc. /Date	Total U	Ra 226 pCi/L	Ra 226 Bq/L
CR-1 01/21/99	8.6	107/2.9	3.96/0.11
CR-1 04/16/99	6.6	97.5/2.8	3.61/0.1
CR-2 01/21/99	1.10	1.5/0.2	0.06/0.01
CR-2 04/16/99	18.10	3.1/0.3	0.11/0.01
CR-3 01/21/99	0.443	1.4/0.2	0.05/0.007
CR-3 04/16/99	2.00	37.8/1.8	1.4/0.07
CR-4 01/21/99	0.07	1.5/0.2	0.06/0.007
CR-4 04/16/99	0.3160	23.7/1.4	0.88/0.05
CR-P1 01/21/99	0.021	0.8/0.2	0.03/0.007
CR-P1 04/16/99	0.0166	6.0/0.4	0.22/0.15

Source: Quarterly Environmental Reports to the Nuclear Regulatory Commission.

Table AV.5. *In Situ* Leach Operation Evaporation Pond Radionuclides, Power Resources, Inc. Highlands Uranium Project, Wyoming

Purge Storage Reservoir PSR-1			Purge Storage Reservoir PSR-2		
	Ra-226			Ra-226	
Date	pCi/L	Bq/L	Date	pCi/L	Bq/L
01/10/97	3.14	0.12	01/09/97	5.50	0.20
02/03/97	1.36	0.05	02/07/97	2.47	0.09
03/05/97	2.26	0.08	03/05/97	3.70	0.14
04/01/97	2.10	0.07	04/03/97	9.50	0.35
05/05/97	2.00	0.07	05/08/97	7.45	0.27
06/03/97	2.10	0.07	06/18/97	1.20	0.04
07/02/97	2.24	0.08	07/03/97	2.15	0.08
08/04/97	1.50	0.06	08/01/98	4.50	0.17
09/03/97	5.60	0.21	09/05/97	4.20	0.16
10/02/97	1.34	0.05	10/16/97	1.38	0.05
11/06/97	4.13	0.15	11/13/97	5.60	0.21
10/01/97	2.36	0.09	12/03/97	8.10	0.30
01/05/98	6.70	0.25	01/06/98	2.30	0.09
02/02/98	2.68	0.10	02/10/98	3.60	0.13
03/02/99	2.99	0.11	03/10/99	3.10	0.11
04/07/98	1.21	0.04	04/06/98	1.71	0.06
05/04/98	3.60	0.13	05/07/98	2.10	0.08
06/03/98	4.10	0.15	06/09/98	4.00	0.15

Source: Quarterly Environmental Reports to the Nuclear Regulatory Commission.

Table AV.5. *In Situ* Leach Operation Evaporation Pond Radionuclides, Power Resources, Inc. Highlands Uranium Project, Wyoming (cont.)

E Radium Settling Basin					**W Radium Settling Basin**			
	U Total		**Ra-226**		**U Total**		**Ra-226**	
Date	**pCi/L**	**Bq/L**	**pCi/L**	**Bq/L**	**pCi/L**	**Bq/L**	**pCi/L**	**Bq/L**
03/20/97	4.60	0.17	1.30	0.05	5.30	0.20	8.30	0.31
06/30/97	3.00	0.11	5.10	0.19	3.00	0.11	5.10	0.19
09/03/97	2.26	0.08	8.00	0.30	2.18	0.08	1.20	0.04
12/30/97	5.96	0.22	7.00	0.26	4.29	0.16	1.10	0.04
03/24/98	4.80	0.18	1.20	0.04	3.61	0.13	2.80	0.10
06/22/98	4.85	0.18	1.30	0.05	2.26	0.08	9.00	0.33

Source: Quarterly Environmental Reports to the Nuclear Regulatory Commission.

Table AV.6. *In Situ* Leach Operation Evaporation Pond Radionuclides Rio Algom Mining Corp. (Now owned by Power Resources) Smith Ranch Project, Wyoming

Evaporation Pond Water Analyses Q&S Sand *In Situ* Leaching						
Location Date	**East Cell**			**West Cell**		
	U mg/L	**Ra226 pCi/L (Bq/L)**	**Th230 pCi/L (Bq/L)**	**U mg/L**	**Ra226 pCi/L (Bq/L)**	**Th230 pCi/L (Bq/L)**
1st Qtr. 1982	1,100	2,378 (87.99)		16	172 (6.36)	
2nd Qtr. 1982	784	456 (16.88)		49	1,804 (66.75)	
3rd Qtr. 1982	38	100 (3.7)		132	2,119 (78.4)	
4th Qtr. 1982	275	315 (11.66)		131	1,779 (65.82)	
1st Qtr. 1983	4	86 (0.15)		2	22 (0.81)	
2nd Qtr. 1983	79	216 (0.96)		1	36 (1.33)	
3rd Qtr. 1983	13	108 (0.07)		14	44 (1.63)	
4th Qtr. 1983	103	483 (17.87)		100	553 (20.46)	
1st Qtr. 1984	22	42(1.55)		1	34 (1.26)	
2nd Qtr. 1984	55	183 (6.77)		121	224 (8.29)	
3rd Qtr. 1984	105	21 (0.78)		105	7 (0.26)	
4th Qtr. 1984	141	5,095 (188.52)		--	--	
1st Qtr. 1985	12	3,030 (112.11)		--	--	
2nd Qtr. 1985	.20	643 (23.79)		.17	1,149 (42.51)	
3rd Qtr. 1985	.23	510 (18.87)		.23	490 (18.13)	
4th Qtr. 1985	.21	754 (27.90)		.22	552 (20.42)	
1st Qtr. 1986	.33	184 (6.8)		.14	423 (15.65)	
2nd Qtr. 1986	.25	1,366 (50.54)		.20	923 (34.15)	
3rd Qtr. 1986	.39	3,253 (120.36)		.38	2,081 (77.0)	
4th Qtr. 1986	.32	4 (0.15)		.27	41 (1.52)	
1st Qtr. 1987	.24	772 (2.86)		.25	755 (27.94)	
2nd Qtr. 1987	.25	1912 (70.74)		.23	560 (20.72)	
1st Half 1997	69.7	3,230 (119.51)	15.4 (0.57)	137	74.6 (2.76)	1.1 (0.04)
2nd Half 1997	27.8	57.1 (2.11)	0			
2nd Half 1999	92.4	945 (34.97)	6.2 (0.23)	70.8	203 (0.1)	0.7 (0.03)

Source: Quarterly Environmental Reports to the Nuclear Regulatory Commission.

The evaporation ponds were being sampled semiannually. Gamma radiation was measured quarterly at the evaporation ponds. The measurements obtained during the 1st & 2nd quarters of 1999 were 71 and 27 uR/hr, respectively.

Table AV.7. Evaporation Pond Leaks, Smith Ranch Project, Wyoming

Location	Date	U (nat) mg/L
East Pond	01/13/99	6.19
East Pond Stand Pipe	01/13/99	6.89
East Pond Stand Pipe	02/08/99	25.8
East Pond Sump	05/04/99	28
West Pond Sump	05/04/99	65
West Pond Sump	06/25/99	166
West Pond	10/23/99	75
West Pond Sump	10/23/99	193
West Pond Sump	10/29/99	150

Source: Quarterly Environmental Reports to the Nuclear Regulatory Commission.

Table AV.8. Deep-well Injection, Smith Ranch *In Situ* Leach Facility, Wyoming

The following is a table of the amounts and concentration of U Nat & Ra-226 disposed by UIC injection in 1998, 1999.

Date	Gals./month (liters/month)	Nat. Uranium mg/L *	Radium-226 pCi/L* (Bq/L)
June 1998		27.5	1,250 (46.25)
Sept. 1998		5.0	1,300 (48.10)
Dec. 1998		17.5	1,550 (57.35)
Jan. 1999	1,869,362 (7,076,095.9)		
Feb. 1999	1,832,431 (6,936,722.5)		
Mar. 1999	1,867,385 (7,068,612.4)	10.0	1,450 (53.65)
April 1999	1,906,162 (7,215,395.0)		
May 1999	1,952,301 (7,390,044.9)		
June 1999	1,713,467 (6,485,960.1)	19.0	1,050 (38.85)

** = Values estimated from graph.*
Source: Quarterly Environmental Reports to the Nuclear Regulatory Commission.

Appendix VI. Legal Authorities Concerning Uranium, Uranium Mines and Extraction Facilities

Introduction

This section presents information on the authorities under which major federal, state and Tribal agencies operate. These authorities have been used to establish regulatory standards and requirements, and could potentially be used to develop additional guidances, or take other actions for the control of uranium TENORM, uranium mining, and uranium extraction facilities.

U.S. EPA

More than a dozen major statutes or laws form the legal basis for the programs of the EPA. EPA authority to develop radiation protection standards and to regulate radioactive materials including TENORM is derived from a number of those federal laws, plus Executive Orders.

The authority to develop Federal guidance for radiation protection was originally given to the Federal Radiation Council (FRC) by Executive Order in 1959 as an offshoot of authorities of the Atomic Energy Act (42 U.S.C. 2011 et seq.)(1954). Over the next decade the FRC developed federal guidance ranging from guidance for exposure of the general public, to estimates of fallout from nuclear weapons testing. Federal guidance developed by the FRC provided the basis for most regulation of radiation exposure by federal and state agencies, prior to the establishment of the EPA.

In 1970, the responsibility for developing Federal guidance for radiation protection was transferred from the FRC to the newly formed EPA under Executive Order 10831 and Reorganization Plan No. 3. Federal Guidance Documents are signed by the President and issued by EPA. By signing these, the President provides a framework for federal and state agencies to develop regulations that ensure the public is protected from the harmful effects of ionizing radiation. Federal Guidance is also an opportunity for the President to promote national consistency in radiation protection regulations. For example, the guidance document *Radiation Protection Guidance to Federal Agencies for Occupational Exposure*, issued by EPA in 52 CFR 2822 January 27, 1987, established general principles, and specifies the numerical primary guides for limiting worker exposure to radiation.

Clean Air Act (CAA)

EPA regulates radon and radioisotope emissions through its authority under the Clean Air Act (42 USC 7401 et seq.) (1970). Regulations promulgated by the Agency which control radioactive facilities and sites include 40 CFR 61:

- Subpart B, Underground Uranium Mines
- Subpart H, Department of Energy Facilities
- Subpart I, Certain non-DOE Facilities
- Subpart K, Elemental Phosphorous Plants
- Subpart R, Radon from Phosphogypsum Stacks
- Subpart W, Operating Uranium Mill Tailings

Under Subpart B, emissions of radon-222 to the ambient air from an underground uranium mine may not exceed amounts that would cause any member of the public to receive in any year an effective dose equivalent of 10 mrem/y. Operators must provide a report to EPA annually on their compliance with the standard.

Under Subpart W, operating uranium mills must comply with the radon emission requirements of 20 pCi/(m2-sec)(1.9 pCi/(ft2-sec)) of radon-222, and other provisions under EPA's UMTRCA requirements in 40 CFR 192.32(a). Operators must provide a report to EPA annually on their compliance with the standard.

Under the Radon Gas and Indoor Air Quality Research Act (USC 42 et seq.)(1986) and Indoor Radon Abatement Act (1988), as well as authorities of the CAA, EPA has developed guidance for control of radon in homes, buildings and schools, and more recently for drinking water treatment and wastewater treatment facilities (U.S. EPA 2005, ISCORS 2005). The CAA gives EPA the authority to regulate emissions of both "conventional" pollutants, like PM_{10} (particulate matter less than 10 microns), and hazardous pollutants, such as radon. Both of these air pollutants are emitted by uranium extraction and beneficiation activities.

Clean Water Act (CWA)

The Clean Water Act's (33 USC 121 et seq., 1977) primary objective is to restore and maintain the integrity of the nation's waters. This objective translates into two fundamental national goals: eliminate the discharge of pollutants into the nation's waters, and achieve water quality levels that are fishable and swimmable. Under this law, EPA is given the authority to establish water quality standards and regulate the discharge of pollutants into waters of the United States, and this is performed under EPA's National Pollutant Discharge Elimination System (NPDES). A point source is defined as any discrete conveyance, natural or man made, including pipes, ditches, and channels, and NPDES permits are issued by EPA or delegated States.

Section 502(6) of the CWA includes “radioactive materials” in the definition of pollutants. EPA's implementing regulations at 40 CFR 122.2, which defines the term “pollutants” includes radioactive materials except those regulated under the AEA. The law also gives EPA the authority to regulate, through permits, storm water discharges from both inactive and active mine sites. Mines and mills that discharge must obtain a permit, and must monitor twice a year for specific pollutants determined by the type of ore they mine or process. EPA regulations in 40 CFR 440, Part C, are applicable to discharges from (a) mines either open-pit or underground (ISL operations are excluded), from which uranium, radium and vanadium ores are produced; and (b) mills using the acid leach, alkaline leach, or combined acid and alkaline leach process for the extraction of uranium, radium and vanadium.

These regulations provide effluent limitations based upon best practicable control technology (BPT) and best achievable technology (BAT) for uranium mills and open-pit and underground uranium mines, including mines using ISL methods. Discharges from regulated operations must meet best available technology/best practicable technology (BAT/BPCT) standards for zinc, arsenic, ammonia, dissolved radium-226, total radium, uranium, total suspended solids (TSS), chemical oxygen demand (COD), and pH. A summary of the standards is included in Chapter 1, as well as in more detail in U.S. EPA (1995a), and 40 CFR 440 Subpart C: 440.32, 440.33, and 440.34. Individual states are required to adopt water quality criteria at least as stringent as federal levels. The application of these criteria is based on the designated use of a specific receiving water (drinking water supply, aquatic life, and/or recreational use).

Except as provided in cases of unusually high storm water events, EPA has regulated that there shall be no discharge of process wastewater to navigable waters from mills using the acid leach, alkaline leach or combined acid and alkaline leach process for the extraction of uranium or from mines and mills using ISL methods. The only exception occurs if annual precipitation falling on the treatment facility and the drainage area contributing surface runoff to the mine or mill's water treatment facility exceeds the annual evaporation. In such cases, the volume of water exceeding annual evaporation may be discharged subject to the numerical limitations for uranium and radium discharge mentioned above.

Some discharges from mine sites do not meet the definition of a "point source discharge." These discharges are nonpoint source discharges. Under Section 319 of the CWA, States are required to prepare nonpoint source assessment reports and to develop programs to address nonpoint sources, including active and inactive/abandoned mine sites, on a watershed-by-watershed basis. Each state must report to EPA annually on program implementation and resulting water quality improvements.

Safe Drinking Water Act (SDWA)

The Safe Drinking Water Act (42 USC 300f et seq., 1974), is the main federal law that ensures the quality of Americans' drinking water. Under the SDWA, EPA sets standards for drinking water quality and oversees the states, localities, and water suppliers who implement those standards. Implementing regulations for 40 CFR 141 include the establishment of national primary drinking water standards which currently include maximum contaminant level goals and maximum contaminant levels (MCLs) for radiation and radionuclides. The standards also include combined Ra-226 and Ra-228, Uranium, gross alpha excluding uranium and radon, man-made beta and photon emitters. A draft MCL has also been proposed for Radon. EPA established a UIC program under the authority of the SDWA. Through this program, the Agency has a permit system to ensure underground sources of drinking water are protected from the injection of process fluids and liquid wastes, including those produced during uranium extraction and beneficiation, into the subsurface via wells.

EPA's UIC regulations protect underground sources of drinking water (USDWs) by prohibiting the direct injection or migration of foreign fluids into these aquifers. A USDW is defined as any aquifer or its portion that supplies a public water system or contains fewer than 10,000 mg/l total dissolved solids (TDS). An aquifer may be exempted from UIC regulation if it is shown to be completely isolated with no possible future uses. In general, federal regulations prohibit any underground injection unless authorized by permit or by rule. In addition, no owner/operator of a well may construct, operate, maintain, convert, plug, or abandon an injection well in a manner which allows the movement of contaminated fluid into underground sources of drinking water. The program establishes requirements for five injection well categories. Regulations vary according to the class of well. These categories are outlined below:

Class I: Injection wells for hazardous, industrial, non-hazardous, and municipal wastewater disposal below the lower most formation, within 1/4 mile of the wellbore, containing an underground source of groundwater.

Class II: Injection wells for fluids related to oil and gas production such as salt water disposal wells, enhanced oil recovery wells and hydrocarbon storage wells.

Class III: Injection wells related to mineral extraction such as ISL production of uranium, only for ore bodies which have not been conventionally mined.

Class IV: Disposal of radioactive or hazardous waste into or above a formation which contains an underground source of drinking water within 1/4 mile. Section 3020(a) of RCRA prohibits the construction and operation of Class IV wells.

Class V: Injection wells not included in the other classes. This includes solution mining of conventional mines, such as isotope leaching and low-level radioactive waste wells.

Classes I, III and V are potentially applicable to the uranium extraction and beneficiation industry. Enforcement of the requirements of the SDWA may be delegated by EPA to states. Under the regulations, EPA may permit injection wells for uranium ISL operations. EPA's regulations issued under UMTRCA authority provide the principal standards for uranium ISL operations and groundwater protection, while the UIC regulations are considered additional requirements for ISL operations. Under UIC permits, the Agency usually exempts that portion of an aquifer constituting the well field from meeting drinking water standards. However, under EPA standards established under UMTRCA authority, the operator of the ISL restores the well field to either background conditions or EPA drinking water maximum contaminant limit levels where possible or practical. When this can not be accomplished, Alternate Concentration Limits (ACLs), in terms of the presence of metals, organics, pH level, and radioactivity, may be approved by the NRC or its Agreement States, with EPA concurrence.

CERCLA (Superfund)

The Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) (42 USC 9601 et seq.,1980) and the Superfund Amendments and Reauthorization Act (SARA) (42 USC 9601 et seq., 1986) provided broad Federal authority to respond directly to releases or threatened releases of hazardous substances that may endanger public health or the environment. CERCLA established prohibitions and requirements concerning closed and abandoned hazardous waste sites; provided for liability of persons responsible for releases of hazardous waste at these sites; and established a trust fund to provide for cleanup when no responsible party could be identified. EPA has determined that radiation is a carcinogen and thus a hazardous substance. Under the National Oil and Hazardous Substances Contingency Plan (NCP), EPA has issued guidance on removals and cleanup of radioactively contaminated sites, including those contaminated with the TENORM radionuclides radium, thorium and uranium. Implementing regulations for the NCP are found at 40 CFR 300.

The Toxic Substances Control Act (TSCA)

The Toxic Substances Control Act (TSCA) (15 USC 2601 et seq., 1976) was enacted by Congress to give EPA the ability to track the 75,000 industrial chemicals currently produced or imported into the United States. EPA repeatedly screens these chemicals and can require reporting or testing of those that may pose an environmental or human health hazard. EPA can ban the manufacture and import of those chemicals that pose an unreasonable risk. While radionuclides are considered toxic substances under the Act, source material, special nuclear material, or byproduct material (as such terms are defined in the AEA, and regulations issued under such Act) are excluded from coverage. Consequently, TENORM radionuclides may be subject to this law, though EPA has not previously applied it in this way.

The Resource Conservation and Recovery Act (RCRA)

The Resource Conservation and Recovery Act (RCRA) (42 USC 321 et seq., 1976) gave EPA the authority to control hazardous waste. This includes the generation, transportation, treatment, storage, and disposal of hazardous waste. RCRA also set forth a framework for the management of non-hazardous wastes. The 1986 amendments to RCRA enabled EPA to address environmental problems that could result from underground tanks storing petroleum and other hazardous substances. RCRA focuses only on active and future facilities and does not address abandoned or historical sites (see CERCLA). HSWA (the Federal Hazardous and Solid Waste Amendments) are the 1984 amendments to RCRA that required phasing out land disposal of hazardous waste. Some of the other mandates of this strict law include increased enforcement authority for EPA, more stringent hazardous waste management standards, and a comprehensive underground storage tank program. EPA's implementing regulations for RCRA do not address disposal of radioactively contaminated substances in landfills, however nuclear accelerator wastes (a form of waste previously classified as part of the TENORM waste class) has been disposed of in such facilities, depending on the permitting authority.

Uranium Mill Tailings Radiation Control Act (UMTRCA)

EPA does not license uranium mills or ISL facilities. However, it does establish certain environmental standards which must be adopted by the NRC and its Agreement States and DOE for uranium processing facilities. Current regulations applicable to remediation of both inactive uranium mill tailings and uranium extraction facilities, including vicinity properties and ISL operations, active uranium and thorium mills, and ISL operations, have been issued by the EPA under the Uranium Mill Tailings Radiation Control Act (UMTRCA) (42 USC 2022 et seq.) of 1978, as amended. EPA's regulations in 40 CFR 192 apply to remediation of such properties and address emissions of radon, as well as radionuclides, metals, and other contaminants into surface and groundwater.

Under UMTRCA, EPA has the responsibility to establish standards for exposure of the public to radioactive materials originating from mill tailings, and for cleanup and control standards for inactive uranium processing sites and associated vicinity areas, as well as for active uranium extraction facilities licensed by the NRC or its Agreement States. To the maximum extent possible, those standards were required to reflect the requirements issued by EPA under the Solid Waste Disposal Act (now RCRA), and do so by referencing 30 CFR Part 261 regulations.

Tailings or wastes produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material content is defined by Section 11e.(2) of the Atomic Energy Act as byproduct material. That material is not considered to be TENORM in the U.S., and is regulated by the NRC or its Agreement States. Under UMTRCA, the NRC must utilize EPA environmental protection standards to develop its regulations for active and inactive uranium milling and extraction facilities. The NRC does not have regulatory authority over conventional type uranium mine wastes (see NRC discussion below).

U.S. Nuclear Regulatory Commission

The mission of the NRC is to ensure adequate protection of the public health and safety, the common defense and security, and the environment in the use of nuclear materials in the United States. The NRC's scope of responsibility includes regulation of commercial nuclear power reactors; research, test, and training reactors; fuel cycle facilities; medical, academic, and industrial uses of nuclear materials; and the transport, storage, and disposal of nuclear materials and waste.

The NRC was created as an independent agency by the Energy Reorganization Act of 1974, which abolished the AEC and moved the AEC's regulatory function to NRC. This act provides the foundation for regulation of the nation's commercial nuclear power industry.

NRC regulations are issued under the United States Code of Federal Regulations (CFR) Title 10, Chapter 1. Principal statutory authorities that govern NRC's work are:

- Atomic Energy Act of 1954, as amended
- Energy Reorganization Act of 1974, as amended
- Uranium Mill Tailings Radiation Control Act of 1978, as amended
- Nuclear Non-Proliferation Act of 1978
- Low-Level Radioactive Waste Policy Act of 1980
- West Valley Demonstration Project Act of 1980
- Nuclear Waste Policy Act of 1982
- Low-Level Radioactive Waste Policy Amendments Act of 1985
- Diplomatic Security and Anti-Terrorism Act of 1986
- Nuclear Waste Policy Amendments Act of 1987
- Solar, Wind, Waste and Geothermal Power Production Incentives Act of 1990
- Energy Policy Act of 1992

The NRC and its licensees share a common responsibility to protect the public health and safety. Federal regulations and the NRC regulatory program are important elements in the protection of the public. NRC licensees, however, have the primary responsibility for the safe use of nuclear materials.

The NRC fulfills its responsibilities through a system of licensing and regulatory activities that include:

1) Licensing the construction and operation of nuclear reactors and other nuclear facilities, such as nuclear fuel cycle facilities and test and research reactors, and overseeing their decommissioning;
2) Licensing the possession, use, processing, handling, and export of nuclear material;
3) Licensing the siting, design, construction, operation, and closure of low-level radioactive waste disposal sites under NRC jurisdiction and the construction, operation, and closure of the geologic repository for high-level radioactive waste;
4) Licensing the operators of nuclear power and non-power test and research reactors; inspecting licensed facilities and activities;
5) Conducting the principal U.S. Government research program on light-water reactor safety;
6) Conducting research to provide independent expertise and information for making timely regulatory judgments and for anticipating problems of potential safety significance;

7) Developing and implementing rules and regulations that govern licensed nuclear activities;
8) Investigating nuclear incidents and allegations concerning any matter regulated by the NRC;
9) Enforcing NRC regulations and the conditions of NRC licenses;
10) Conducting public hearings on matters of nuclear and radiological safety, environmental concern, common defense and security, and antitrust matters;
11) Developing effective working relationships with the States regarding reactor operations and the regulation of nuclear material;
12) Maintaining the NRC Incident Response Program, including the NRC Operations Center; and
13) Collecting, analyzing, and disseminating information about the operational safety of commercial nuclear power reactors and certain non-reactor activities.

Atomic Energy Act – Regulation of Source Material

Under the AEA, the AEC, now the NRC, was given responsibility for regulation of "source material". Source material includes either the element thorium or the element uranium, provided that the uranium has not been enriched in U-235. Source material also includes any combination of thorium and uranium, in any physical or chemical form, or ores that contain by weight 0.05 percent or more of uranium, thorium, or any combination thereof. Depleted uranium (left over from uranium enrichment) is considered source material. Source material can result from the milling and concentration of uranium contained in ore mined for its uranium content. As the chemical refining processes are generally the same, the NRC also regulates source material generated from ISL operations. It can also be generated in the process of refining ores mined for other precious metals. In addition, source material can arise from the reprocessing of spent nuclear fuel (no commercial reprocessing is currently licensed in the U.S.) and also, as depleted uranium (contains lower levels of U-235 than natural uranium), from the process of enriching uranium in the isotope U-235. However, the NRC does not regulate conventional (open-pit and underground) mining of uranium or thorium ore. NRC's regulations for source material facility licensing are found at 10 CFR 40.

Guidance for applications for ISL operation licenses are contained in NUREG 1569 (U.S. NRC 2003). An applicant for a new operating license, or for the renewal or amendment of an existing license, is required to provide detailed information on the facilities, equipment, and procedures to be used and to submit an environmental report that discusses the effect of proposed operations on public health and safety and the impact on the environment. This information is used by NRC staff to determine whether the proposed activities will be protective of public health and safety and will be environmentally acceptable.

Regulations in 10 CFR Part 51, provide for environmental protection regulations for domestic licensing and related regulatory functions, while those in 10 CFR Part 20 cover radiation protection standards. Fuel cycle facility inspections which enforce these regulations focus on the areas that are most important to safety and safeguards, using objective measures of performance called "performance indicators." Inspections at fuel cycle facilities occur several times a year and typically cover activities such as chemical process, emergency preparedness, fire safety, and radiation safety. Uranium mill facilities in standby status (non-operational) are inspected every three years. Also, specialized inspections are conducted using personnel from NRC headquarters in Maryland and the Region II office in Atlanta, Georgia. Inspectors follow guidance in the NRC Inspection Manual that contains objectives and procedures to use for each type of inspection. The inspection program for fuel cycle facilities is being revised to accommodate the use of risk insights to focus the NRC and its licensees on matters that are most important to safety and safeguards.

Atomic Energy Act-- Regulation of Byproduct Material

Section 11e.(2) byproduct material, as defined by the AEA, is regulated by the NRC under 10 CFR Part 40. In Part 40, the NRC clarified the definition of byproduct material by adding the clause "including discrete surface wastes resulting from uranium solution extraction processes." In simpler terms, it is the waste and tailings generated by the processing of ore for its uranium or thorium content. Most of this material is created by uranium milling and is primarily mill tailings. Examples of milling wastes are broken pipe from ISL facilities and contaminated mill equipment that is to be discarded. Byproduct material from uranium mining and milling is disposed of in uranium mill tailings impoundments.

Under the Energy Policy Act of 2005, the Atomic Energy Act was amended to place additional “discrete sources of naturally occurring radioactive material” under NRC jurisdiction. The primary focus of this provision is on security and the potential misuse of such materials. This suggests that the materials of concern will be those that are highly radioactive in small quantities, though “discrete” in this context will be defined further after consultation between NRC and the EPA, and the states, as well as through the regulatory process. These wastes are not those resulting from uranium or thorium processing.

The definition of byproduct materials was modified by the Act to include: “Any discrete source of Ra-226 that is produced, extracted or converted after extraction, before, on or after the date of enactment of this paragraph *(August 8, 2005)* for use for a commercial, medical, or research activity, or (B) any material that (i) has been made radioactive by use of a particle accelerator, and (ii) is produced, extracted, or converted after extraction, before, on, or after the date of enactment of this paragraph for use for a commercial, medical or research activity;

and

any discrete source of naturally occurring radioactive material, other than source material, that: (A) the Commission, in consultation with the Administrator of the Environmental Protection Agency, the Secretary of Energy, the Secretary of Homeland Security, and the head of any other appropriate Federal agency, determines would pose a threat similar to the threat posed by a discrete source of radium-226 to the public health and safety or the common defense and security, and (B) before, on, or after the date of enactment of this paragraph *(August 8, 2005)* is extracted, or converted after extraction for use in a commercial, medical or research activity.”

Waste disposal for this new class of byproduct material must be in a disposal facility that: (a) is adequate to protect public health and safety, and (b)(i) is licensed by the Commission; or(ii) is licensed by a state that has entered into an agreement with the Commission under section, if the licensing requirements of the state are compatible with the licensing requirements of the Commission. The Act also included provisions to allow disposal in a non-NRC licensed facility.

States with Agreement State status can receive authority over byproduct material. However, in states without Agreement State status, the NRC retains authority over byproduct material.

Uranium Mill Tailings Radiation Control Act

The U.S. Government began to purchase uranium for defense purposes in the early 1940's. Since that time, large quantities of tailings have been generated by the uranium milling industry. In many cases, these tailings were dispersed from impoundments and piles by natural forces and by humans for construction use in or around buildings, or for roads. UMTRCA, which in 1978 amended the AEA, established two programs to protect the public health, safety and the environment from uranium mill tailings.

Title I of UMTRCA addresses 22 Congressionally designated sites (to which DOE added 2 more) that were inactive (e.g., all milling had stopped and the site was not licensed by the NRC). Title II of UMTRCA addresses active sites (those with NRC or Agreement State licenses) (48 FR 45926). UMTRCA requires the NRC to concur with remedies DOE selects for cleaning up and controlling inactive sites. Under UMTRCA, the NRC is also responsible for licensing inactive uranium tailings sites that have undergone remediation. Inspection, reporting, and record-keeping requirements are defined in 10 CFR 40.27 under which mill tailings impoundment and some adjoining land will be turned over to the DOE, another federal agency designated by the President, or the state in which the site is located for long-term care. License termination usually involves a confirmation that all applicable reclamation requirements have been met. This includes ensuring completion of stabilization work for the tailings consistent with the accepted reclamation plan and a determination that the licensee has complied with all standards applicable to land structures, and groundwater cleanup.

U.S. Department of Energy

In the 1970s, the Atomic Energy Commission was abolished and the Energy Reorganization Act of 1974 (42 USC. Sec. 5813, 5817, et seq.) created two new agencies: the Nuclear Regulatory Commission to regulate the nuclear power industry and the Energy Research and Development Administration to manage the nuclear weapon, naval reactor, and energy development programs. However, the extended energy crisis of the 1970s soon demonstrated the need for unified energy organization and planning. The Department of Energy Organization Act (42 USC Sec. 5916, 7112, et seq.) brought the Federal Government's energy agencies and programs into a single agency. Established on October 1, 1977, the Department of Energy assumed the responsibilities of the Federal Energy Administration, the Energy Research and Development Administration, and parts and programs from several other agencies.

The Department of Energy's overarching mission is to advance the national, economic and energy security of the United States; to promote scientific and technological innovation in support of that mission; and to ensure the environmental cleanup of the national nuclear weapons complex.

Uranium Mill Tailings Radiation Control Act

Principal responsibility for management of uranium mill tailings facilities under UMTRCA is handled by DOE’s Office of Legacy Management. The office's primary functions include: management of the land and associated resources as a federal trustee, surveillance and maintenance associated with environmental remedies, records and information management, and the management of post-closure liabilities. Sites transferred to the Office include UMTRCA sites, where remediation is complete. As more sites are successfully remediated and closed, the site surveillance and maintenance functions, and worker benefits as appropriate, will be transferred for long-term management.

For UMTRCA Title I disposal sites managed by the Office, DOE becomes a licensee to the NRC. The general license for long-term custody is indefinite in duration, and the land is administratively withdrawn from unrestricted public use. Sites located on Tribal land revert to Tribal control, and DOE obtains a site access agreement with the Tribe that allows DOE to fulfill its custodial responsibilities.

Title I of UMTRCA provided for the remediation and reclamation of 24 uranium mill processing sites and approximately 5,200 associated vicinity properties by the DOE. Remediation of these sites under DOE’s UMTRA resulted in the creation of disposal cells that contain encapsulated uranium mill tailings and associated contaminated material. The stated goals of the UMTRA Program were to: (1) address immediate risk concerns and prevent further increases in relative risk at all sites; (2) complete surface remedial action work at all 24 mill tailings sites and related vicinity properties; and (3) complete ground-water activities in compliance with Environment Protection Agency standards no later than FY 2014.

Residual radioactive material was removed from some of the Title I processing sites to off-site disposal locations. NRC does not require a license for remediated processing sites that do not have disposal cells, but NRC is the regulator if contaminated ground water remains. Ground water compliance action plans, with compliance strategies that range from natural flushing to active remediation, have been or are being developed by DOE for processing sites that have contaminated ground water. These plans require approval by NRC and concurrence by the state and Native American Tribe (when applicable). To date, ground water remedies have been approved and implemented at several former uranium ore-processing sites.

The facilities regulated under Title II of the Act are both conventional uranium mill and in-situ leach facilities that were privately owned and operated under an existing license by the NRC or the Agreement States at the time of the passage of UMTRCA. Both Title I and Title II facilities are subject to NRC regulations in 10 CFR Part 40 and EPA regulations in 40 CFR Part 192. Five Title II facilities have completed reclamation and remediation, and have transitioned under the NRC general license, and are also currently under the management of the DOE Office of Legacy Management.

Office of Surface Mining

Congress passed the Surface Mining Control and Reclamation Act (SMCRA) (30 USC 1300, et seq.) in 1977; the law created the Office of Surface Mining (OSM) in the Department of the Interior. Title IV of SMCRA established the Abandoned Mine Land (AML) program, which provides for the restoration of eligible lands and waters mined and abandoned, or left inadequately restored. The act provides a major source of funding for reclamation of all abandoned mine lands. SMCRA also required a fee be assessed on mined coal and allowed for the use of these funds for abandoned mine reclamation. The funds were set aside for reclamation of coal mines and for the closure of hazardous mine openings (adits and shafts) in other types of mining operations.

Once a state certifies that its coal mine operations were reclaimed, these funds can be used for reclamation at other types of mines where the properties are judged to be abandoned, or had become inactive prior to August 3, 1977. States can use these funds only for properties where there is no company obligation for cleanup and the property is not listed as a National Priority List site under CERCLA. In 1990, changes to SMCRA extended eligibility to limited sites mined after August 3, 1977. The OSM has established guidelines to be considered when developing plans for abandoned mine land programs and projects. They were issued to provide general guidance to states, Indian Tribes, USDA, and OSM on the administration of reclamation activities carried out under SMCRA. While OSM provides guidelines on reclamation requirements, the states/Indian Tribes use their discretion on the caliber or quality of the work done at each site. Significant use has been made of these funds for reclamation of uranium mines in the state of Wyoming, and on the Navajo Reservation. The Hopi and Crow have also made use of these funds for AML reclamation.

Federal Land Management Agencies

In addition to the Department of Energy, certain agencies of the U.S. Department of the Interior and U.S. Department of Agriculture play important roles in uranium development, and remediation of abandoned mines and mills on lands they administer. Principal among them are Interior's Bureau of Land Management and National Park Service, and Agriculture's National Forest Service. Each of these agencies are responsible for implementing on their lands the various environmental laws which are administered by EPA; these include (among others) the CAA, SDWA, CWA, TSCA, RCRA and CERCLA.

U.S. Bureau of Land Management

The BLM, an agency within the U.S. Department of the Interior, administers over 260 million acres of America's public lands, and about 300 million additional acres of subsurface mineral resources, located primarily in 12 Western States. The BLM's mission is to sustain the health, diversity, and productivity of the public lands for the use and enjoyment of present and future generations. BLM administers public lands within a framework of numerous laws. The most comprehensive of these is the Federal Land Policy and Management Act of 1976 (FLPMA) (43 USC 1744, et seq.), though of importance for uranium extraction is its administration of mineral development under the General Mining Law of 1872, as amended (30 USC 29 and 43 CFR 3860. That law provides the successful mining claimant the right to patent (acquire absolute title to the land) mining claims or sites, including uranium locations, if they meet the statutory requirements. To meet this requirement, the successful claimant must:

a. For mining claims, demonstrate a physical exposure of a valuable (commercial) mineral deposit (the discovery) as defined by meeting the Department's Prudent Man Rule[1] and Marketability Test[2]
b. For mill sites, show proper use or occupancy for uses to support a mining operation and be located on non-mineral land.
c. Have clear title to the mining claim (lode or placer) or mill site.

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[1] Where minerals have been found and the evidence is of such a character that a person of ordinary prudence would be justified in the further expenditure of his labor and means, with a reasonable prospect of success, in developing a valuable mine, the requirements of the statute have been met.

[2] A mineral locator or applicant, to justify his possession must show by reason of accessibility, bona fides in development, proximity to market, existence of present demand, and other factors, the deposit is of such value that it can be mined, removed, and disposed of at a profit.

d. Have assessment work and/or maintenance fees current and performed at least $500 worth of improvements (not labor) for each claim (not required for mill sites).
e. Meet the requirements of the Department's regulations for mineral patenting as shown in the Code of Federal Regulations at 43 CFR 3861, 3862, 3863, and 3864.
f. Pay the required processing fees and purchase price for the land applied for.

The BLM administers this program through its 12 State Offices and the Headquarters office. The program has two essential components, adjudication and mineral examination. A staff of land law examiners in each State Office adjudicates applications for completeness and compliance with the law and regulations. All aspects, except the mineral examination, are handled here. Once the application has successfully passed through the adjudication process, the case is assigned to the BLM field office for a formal mineral examination to verify the discovery of a valuable (commercially viable) mineral deposit on the mining claims and proper use or occupancy for any mill sites. If the Agency's mineral report confirms the discovery of a valuable mineral deposit and/or proper use and occupancy for any associated mill sites, BLM will send the application to the Secretary of the Interior for final review and action. If the applicant is successful on all points, BLM issues a mineral patent for the land applied for. However, since October 1, 1994, Congress has imposed a budget moratorium on BLM acceptance of any new mineral patent applications. Until the moratorium is lifted, the BLM will not accept any new applications.

BLM is attempting to identify, prioritize, and take appropriate actions on those historic mine sites that pose safety risks to the public or present serious threats to the environment. Using the approach outlined in the Interdepartmental Abandoned Mine Lands Watershed Initiative, BLM will work in partnership with EPA, state agencies, tribes, private parties, and other interested groups to accelerate the rate of cleanup of watersheds affected by abandoned hard rock mines. With special emphasis on ensuring that viable responsible parties contribute their share of cleanup costs, federal land managers will add three to five watersheds or major mine cleanup actions to the program each year from 1999 through 2005. Within the selected watersheds, cooperative efforts and available resources will be concentrated first on AML sites and features causing serious environmental impacts, then on mitigation and removal of physical safety hazards.

National Park Service

The NPS operates under authority of the 1916 National Park Service Organic Act (16 USC 1, et seq.*)* as well as host of other federal statutes. According to U.S. NPS Policy Manual (2000) mineral exploration and development may be allowed in parks only when prospective operators demonstrate that they hold rights to valid mining claims, federal mineral leases, or non-federally-owned minerals. If this right is not clearly demonstrated, the National Park Service will inform the prospective operator that, until proof of a property right is shown, the Service will not further consider the proposed activity. If the Service determines that the proposed mineral development would impair park resources, values, or purposes, or does not meet approval standards under applicable NPS regulations and cannot be sufficiently modified to meet those standards, the Service will seek to extinguish the associated mineral right through acquisition, unless otherwise directed by Congress.

In some parks, all or certain types of mineral development are specifically prohibited by law. Persons may not use or occupy surface lands in a park for purposes of removing minerals outside the park unless provided for in law. General management plans, land protection plans, and other planning documents for parks with mining claims, federal mineral leases, or non-federally-owned mineral interests will address these non-federal property interests as appropriate. Lands with mineral interests will be zoned according to their anticipated management and use, based on their resource values, park management objectives, and park-specific legislative provisions relating to mineral interests. The location of new mining claims pursuant to the General Mining Act of 1872 is prohibited in all park areas.

NPS has its own AML program and is an active participant with broader interdepartmental and national AML program associations. The goals of the program are an inventory of all abandoned mineral land sites in the NPS, the elimination of public safety hazards in such sites, the elimination or reduction of adverse effects from such sites on resources in the parks, education and awareness of the public from the preservation and interpretation of historic and cultural artifacts, and the maintenance of specific abandoned mineral lands for critical wildlife habitat, particularly for threatened and endangered species. Remediation of AML sites on NPS lands is an ongoing effort and its focus has been on above-ground sites and remediation.

National Forest Service

The NFS was established in 1905 and is an agency of the USDA. The Transfer Act of 1905 (16 U.S.C. § 472, 476, 495, 551, 554, 615(b), et seq.) transferred administration of the forest reserves to the Department of Agriculture under the Bureau of Forestry, which became the Forest Service. The forest reserves were subsequently renamed national forests. The NFS manages public lands in national forests and grasslands, which encompass 193 million acres. The mission of the FS is to sustain the health, diversity, and productivity of the Nation’s forests and grasslands to meet the needs of present and future generations. Exploration, development, and production of mineral and energy resources and reclamation of activities are part of the Forest Service ecosystem management responsibility. All NFS lands which (1) were formerly public domain lands subject to location and entry under the U.S. mining laws, (2) have not been appropriated, withdrawn, or segregated from location and entry, and (3) have been or may be shown to be mineral lands, are open to prospecting for locatable, or hardrock, minerals (16 U.S.C. 482). Claims are filed and processed by agreement by the BLM.

The NFS established its combined Environmental Compliance and Protection (ECAP) and Abandoned Mine Lands (AML) programs to reclaim the several thousand abandoned underground and open-pit hard rock, placer, and coal mine sites and related mine and mill waste sites on NFS lands that are causing damage to the environment or risks to public health and safety. The NFS began receiving funds to clean up abandoned mines and other sites contaminated with hazardous materials following the passage of CERCLA. Current funding for AML remediation resulted from an agreement among the NFS, EPA, and the states to focus resources on cleaning up abandoned mines using the watershed (“basin-wide”) approach rather than attempting to place each mine site under an individual NPDES water discharge permit. In 1995, USDA and the NFS set an AML program goal: To reclaim by the year 2045 all abandoned mine sites on National Forest System lands that have the potential to release hazardous substances or sediment.

Tribes

Uranium mines were produced on lands of many western Tribes. Principal among them are the Navajo of Arizona and New Mexico, which had the most mines produced of any Tribe. The largest uranium mine in the U.S., the Jackpile Mine, was operated on lands of the Laguna Pueblo in New Mexico. The Spokane Tribe in Washington state had a uranium mill and mines on their land, including the Midnite Mine which is now an EPA Superfund site. Others whose lands hosted uranium mine operations include several Tribes of the Sioux of South Dakota, Hopi in Arizona, Yavapai-Apache in Arizona, Eastern Shoshone and Northern Arapaho in Wyoming, and Ute Tribes in Colorado and Utah. All of these Indian Tribes have had very specific environmental, health, and other concerns related to uranium production facilities on their lands.

As a result of the large number of uranium mines on their Reservation, specialized governmental agencies were created by the Navajo Nation to deal with reclamation and remediation activities, as well as environmental protection on their Tribal lands. Due to that level of effort, the following section provides a brief discussion of their organization.

Navajo Nation

The Navajo Nation occupies approximately 25,000 square miles of land in the Four Corners area of Arizona, New Mexico, Utah, and California. The Navajo AMLRP/Uranium Mill Tailings Reclamation Act Department, within the Navajo Nation Division of Natural Resources, has the authority and responsibility to reclaim abandoned uranium mines. The program operates in coordination with the U.S. Office of Surface Mining, within the jurisdiction of the Navajo Nation pursuant to SMCRA, and the approved Navajo Reclamation Plan and Code.

The Navajo Abandoned Mine Lands Reclamation Program (NAMLRP) identified more than 1,032 abandoned uranium mine sites. As of 2005, 913 sites have been reclaimed. This Navajo agency is also responsible for reclamation and administration of uranium mill sites on Navajo lands under DOE UMTRCA program. To guide cleanup actions NAMLRP developed the Health Physics and Instrumentation Monitoring Plan. The plan specifies that the ALARA principal has been adopted such that every attempt will be made to prevent or minimize project related radiation exposure to the general public.

In 1995, legislation made the NNEPA a separate regulatory branch of the Navajo National government and charged it with protecting human health, welfare, and the environment of the Navajo Nation. In April of that year, the Navajo Nation Council passed a resolution establishing the NNEPA and approved adoption of the Navajo Nation Environmental Policy Act. This Act provides guidance for the NNEPA in addition to recognizing that a clean environment contributes to maintaining harmony and balance on the Navajo Nation. The mission of the NNEPA is as follows: `With respect for Dine' values, protect, preserve, and enhance public health, welfare and the environment for present and future generations by developing, implementing, and enforcing strong environmental laws; to foster public awareness and cooperation through education and motivation." Numerous departments in the NNEPA are responsible for the environmental protection programs across Tribal lands, including radiation protection, disposition of hazardous wastes including those from uranium mines, and protection of water resources.

The U.S. EPA headquarters and Region IX offices have provided assistance as part of the Agency’s trust responsibilities to the Navajo Nation concerning uranium mine remediation and other related radiation hazards.

States

State authority to regulate radioactive materials is based on the Constitutional law tenet that any authority or responsibility not specifically assigned to the federal government may be exercised by the states. Many states actively regulate radioactive material through radiation control and other state programs. Control under state law includes naturally occurring and accelerator-produced radioactive materials and other sources of ionizing radiation. As of January 2006, thirty-three states have entered into agreements with the NRC, under which the Commission has delegated regulatory authority over most radioactive materials used in non-federal facilities, as long as the state program is compatible with NRC requirements. Most states also control radioactivity through programs implementing the federal clean air, clean water and other environmental laws authorized by EPA.

A model state radiation control statute, last amended in 1983, has been developed by the Council of State Governments. A comprehensive model state code for all types of radioactivity-containing material and radiation-producing machines has been developed by the CRCPD. For example, Part N of the Suggested State Regulations for Control of Radiation (SSRCR) is specific to TENORM.

As an example from one of the 33 members of the Organization of Agreement States, the Colorado Radiation Control Act designates a state radiation control agency and grants board authority to evaluate and control “...hazards associated with the use of any and all radioactive materials and other sources of ionizing radiation.” In the Colorado Act radioactive material means *any* material, solid, liquid or gas, which emits ionizing radiation spontaneously. Ionizing radiation means gamma rays and x-ray and alpha particles, beta particles, high-speed electrons, neutrons, protons, and other high-speed nuclear particles. The Colorado Act requires the Colorado Board of Health to promulgate regulations (for licenses and for exemption from licensing), which are modeled after those proposed by the Conference of Radiation Control Program Directors. Colorado regulates uranium mining, milling, and mill tailings impoundments within its borders.

Whether or not an individual state has assumed regulatory authority from the NRC under an Agreement, each state has explicit statutory authority for regulating sources of ionizing radiation not otherwise regulated by the federal government. Several non-Agreement states (for example, Michigan and New Jersey) have asserted specific authority over TENORM, especially cleanup approaches and disposal. Thirteen have developed regulations specifically for TENORM. The exercise of state authorities is reasonably consistent nationwide, but does vary in some respects. For example, Colorado's statute requires Colorado's rules to be neither more nor less stringent than the CRCPD SSRCR and also authorizes TENORM rules only after their promulgation by the EPA. By contrast, the Illinois Division of Nuclear Safety, now under the Illinois Emergency Management Agency, has no such constraints. Agreement State regulation of AEA materials is to be uniform, consistent, and compatible with that of the NRC.