A SUMMARY OF THE PHASE II - TITLE I ENGINEERING
ASSESSMENT OF INACTIVE URANIUM MILL TAILINGS
LAKEVIEW SITE, LAKEVIEW, OREGON

MASTER

DECEMBER 1977

PREPARED FOR

UNITED STATES DEPARTMENT OF ENERGY
GRAND JUNCTION, COLORADO, CONTRACT NO. E(05-1)-1658

BY

Ford, Bacon & Davis Utah Inc.

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NOTICE

This Phase II - Title I Engineering Assessment has been performed under ERDA Contract No. E(05-1)-1658 executed on June 23, 1975 between the U.S. Energy Research and Development Administration and Ford, Bacon & Davis Utah Inc. On October 1, 1977, ERDA was incorporated into the U.S. Department of Energy; hence, this engineering assessment is issued for the DOE, the present responsible agency.

FOREWORD

This report is a summary of a parent report entitled, "Phase II - Title I Engineering Assessment of Inactive Uranium Mill Tailings, Lakeview Site, Lakeview, Oregon". Both reports are authorized under the U.S. Energy Research and Development Administration (ERDA) Contract No. E(05-1)-1658. The reports are part of a series of reports on inactive uranium millsites, and address the radiological problems and estimated costs of remedial measures that would reduce exposure of the general public. Title I is not a scientific study but an engineering assessment to determine the relative magnitude of the hazards associated with each site, and to estimate the remedial action costs. If additional information that may alter or have an impact on a final remedial action decision for any site is required, it can be obtained during the Title II Engineering Effort.

Ford, Bacon & Davis Utah Inc. (FB&DU) under supplemental authorization currently is investigating uranium mill tailings stabilization techniques. This research could modify some of the estimated costs in this report.

Also, FB&DU acknowledges the excellent cooperation and assistance given in this engineering assessment. Particular recognition is due the ERDA personnel of both the Germantown, MD and Grand Junction, CO offices and also the Union Carbide Corporation personnel of the Health Physics Division, Oak Ridge National Laboratory, who provided field radiological measurements and radio-metric analyses of samples. The preparation of this report could not have been accomplished without the cooperation and assistance of the following:

- (1) The Environmental Protection Agency; for consultation, data, and information from prior surveys and studies with notable assistance from the Office of Radiation Programs, Las Vegas, Nevada
- (2) Atlantic Richfield Company; Mr. L. R. Selkirk, Mr. H. S. McAlister, and other company personnel
- (3) Mr. G. L. Toombs, Supervisor, Environmental Radiation Surveillance Program, Radiation Control Section, Oregon State Department of Human Resources
- (4) Mr. Allison E. Smith; Lakeview, Oregon; for assistance with site inspection
- (5) EG&G; Las Vegas, Nevada; Mr. Jack Doyle; for aerial photography
- (6) Center for Health and Environmental Studies, Brigham Young University, Provo, Utah; for socioeconomic studies

ABSTRACT

Ford, Bacon & Davis Utah Inc. has performed an engineering assessment of the problems resulting from the existence of radioactive uranium mill tailings at the Lakeview, Oregon site. The Phase II - Title I services include: performance of core drillings; analyses of soil, water, and other samples; radiometric measurements to determine areas with radium-contaminated materials; evaluation of resulting radiation exposures of individuals and nearby populations; investigation of site geology, hydrology, and meteorology; and evaluation and costing of alternative corrective actions.

Radon gas release from the 130,000 tons of tailings at the Lakeview site constitutes the main environmental impact, which is minimal. The two alternative actions presented are maintenance of the site now that the ARCO reclamation program has been completed (Option I); and addition of stabilization cover to a minimum depth of 2 ft, improved fencing, and removal of a few isolated spots of contamination (Option II). The cost estimates for these options are \$40,000 and \$290,000, respectively.

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GLOSSARY

Abbreviations/Terms

Definitions

absorbed dose	Radiation energy absorbed per unit mass.
A-E	Architect-Engineer.
AEC	Atomic Energy Commission.
alpha particle (α)	A positively charged particle emitted from certain radioactive material. It consists of two protons and two neutrons, hence is identical with the nucleus of the helium atom. It is the least penetrating of the common radiation (α , β , γ), hence is not dangerous unless alpha-emitting substances have entered the body.
amenability	The relative ease with which a mineral(s) can be removed from an ore by a particular process.
anomaly (mobile gamma survey)	Any location detected by the mobile gamma survey where the recorded counts per second (c/s) from a large gamma-ray detector exceed the determined background for that area by 50 or more c/s.
aquifer	A water-bearing formation below the surface of the earth; the source of wells. A confined aquifer is overlain by relatively impermeable rock. An unconfined aquifer is one associated with the water table.
atmospheric pressure	Pressure exerted on the earth by the mass of the atmosphere surrounding the earth; expressed in inches of mercury (at sea level and 0°C, standard pressure is 29.921 in. Hg).
background radiation	Naturally occurring low-level radiation to which all life is exposed. Background radiation levels vary from place to place on the earth.
beta particle (β)	A particle emitted from some atoms undergoing radioactive decay. A negatively charged beta particle

	is identical to an electron. A positively charged beta particle is called a positron. Beta radiation can cause skin burns and beta-emitters are harmful if they enter the body.
BEIR	Biological Effects of Ionizing Radiation.
BOM (USBOM)	Bureau of Mines.
CHES	Center for Health and Environmental Studies, Brigham Young University, Provo, Utah.
Ci	Curie (the unit of radioactivity of any nuclide, defined as precisely equal to 3.7×10^{10} disintegrations/second).
daughter product	The nuclide remaining after a radioactive decay. A daughter atom may itself be radioactive, producing further daughter products.
diurnal	Daily, cyclic (happening each day or during the day).
dose equivalent	A term used to express the amount of effective radiation when modifying factors have been considered (the numerical product of absorbed dose and quality factor).
EGR	External gamma radiation (gamma radiation emitted from a source(s) external to the body, as opposed to internal gamma radiation emitted from ingested or inhaled sources).
EPA (USEPA)	Environmental Protection Agency.
ERDA (USERDA)	Energy Research and Development Administration.
ERDA-GJO	Energy Research and Development Administration-Grand Junction Office.
erg	The basic unit of work or energy in the centimeter-gram-second.

	system (1 erg is equal to 7.4×10^8 ft-lb).
exposure	Related to electrical charge produced in air by ionizing radiation per unit mass of air.
exhalation	Emission of radon from earth (usually thought of as coming from a uranium tailings pile, but actually from any location).
FB&DU	Ford, Bacon & Davis Utah Inc.
gamma background	Natural gamma ray activity everywhere present, originating from two sources: (1) cosmic radiation, bombarding the earth's atmosphere continually, and (2) terrestrial radiation. Whole body absorbed dose equivalent in the U.S. due to natural gamma background ranges from about 60 to about 125 mrem/yr.
gamma ray	High energy electromagnetic radiation emitted from the nucleus of a radioactive atom, with specific energies for the atoms of different elements and having high penetrating power.
GJO	Grand Junction Office.
ground water	Subsurface water in the zone of full saturation which supplies wells and springs.
health effect	Adverse physiological response from tailings (in this report, one health effect is defined as one case of cancer from exposure to radioactivity).
heap leaching	A process for removing uranium from ore, tailings, or other material wherein the material is placed on an impermeable pad and wetted with appropriate reagents. The uranium solution is collected for further processing.
HEW (USHEW)	Department of Health, Education, and Welfare.

insult	Negative impact on the environment or the health of individuals.
Interim Drinking Water Standards (EPA)	Title No. 40 of the Code of Federal Regulations, Chapter 1, Part 141, dated Dec 24, 1975; scheduled to become effective Jun 24, 1977.
iso-exposure line	A line drawn on a map to connect all points having the same exposure rate.
isotope	One of two or more atoms with the same atomic numbers (the same chemical element) but with different atomic weights. Isotopes usually have very nearly the same chemical properties, but somewhat different physical properties.
JCAE	Joint Committee on Atomic Energy.
knot	A unit of velocity, approximately equal to 1.15 mi/hr.
μ R/hr	Microroentgen per hour.
mR/hr	Milliroentgen per hour.
MeV	Million electron volts.
MPC	Maximum permissible concentration (the highest concentration in air or water of a particular radionuclide permissible for occupational or general exposure without taking steps to reduce exposure).
NAS	National Academy of Sciences.
NIOSH	National Institute for Occupational Safety and Health.
noble gas	One of the gases, such as helium, neon, radon, etc., with completely filled electron shells which is therefore chemically inert.
NRC	Nuclear Regulatory Commission.

nuclide	A general term applicable to all atomic forms of the elements; nuclides comprise all the isotopic forms of all the elements. Nuclides are distinguished by their atomic number, atomic mass, and energy state.
ORNL	Oak Ridge National Laboratory.
ORP-LVF (EPA)	Office of Radiation Programs, Las Vegas Facility (Environmental Protection Agency).
pCi/l	Picocurie per liter.
PHS (USPHS)	Public Health Service.
QF	Quality factor (an assigned factor which denotes the modification of the effectiveness of a given absorbed dose by the linear energy transfer).
R	Roentgen (a unit of exposure to ionizing radiation. It is that amount of gamma or X-rays required to produce ions carrying 1 electrostatic unit of electrical charge, either positive or negative, in 1 cubic centimeter of dry air under standard conditions, numerically equal to 2.58×10^{-4} coulombs/kg).
rad	The basic unit of absorbed dose of ionizing radiation. A dose of 1 rad means the absorption of 100 ergs of radiation energy per gram of absorbing material.
radioactivity	The spontaneous decay or disintegration of an unstable atomic nucleus, usually accompanied by the emission of ionizing radiation.
radioactive decay chain	A succession of nuclides each of which transforms by radioactive disintegration into the next until a stable nuclide results. The first member is called the parent, the intermediate members are called daughters, and the final stable member is called the end product.

radium	A radioactive element, chemically similar to barium, formed as a daughter product of uranium (^{238}U). The most common isotope of radium, ^{226}Ra , has a half-life of 1,620 yr. Radium is present in all uranium-bearing ores. Trace quantities of both uranium and radium are found in all areas, contributing to the gamma background.
radon	A radioactive, chemically inert gas, having a half-life of 3.8 days (^{222}Rn); formed as a daughter product of radium (^{226}Ra).
radon background	Low levels of radon gas found in an area, due to the presence of radium in the soil.
radon concentration	The amount of radon per unit volume. In this assessment, the average value for a 24-hr period of atmospheric radon concentrations, determined by collecting data for each 30 min period of a 24-hr day and averaging these values.
radon daughter	One of several short-lived radioactive daughter products of radon (several of the daughters emit alpha particles).
RDC	Radon daughter concentration (the concentration in air of short-lived radon daughters, expressed usually in pCi/l; also measured in terms of working level (WL)).
radon flux	The quantity of radon emitted from a surface in a unit time per unit area (typical units are in pCi/cm ² -sec).
raffinate	The liquid part remaining after a product has been extracted in a solvent extraction process.
recharge	The processes by which water is absorbed and added to the zone of saturation of an aquifer, either directly into the formation or indirectly by way of another formation.

rem	(Acronym of roentgen equivalent man) The unit of dose of any ionizing radiation which produces the same biological effect as a unit of absorbed dose of ordinary X-rays, numerically equal to the absorbed dose in rads multiplied by the appropriate quality factor for the type of radiation. The rem is the basic recorded unit of accumulated dose to personnel.
residual value	The value of minerals in tailings material.
riprap	An irregular wall of broken rock, placed as a retaining wall, as a protection for dikes, etc.
sands	Relatively coarse-grained materials produced along with the slimes as waste products of ore processing in uranium mills (see tailings). These sands normally contain less radioactive material than the slimes.
scintillometer	A gamma-ray detection instrument normally utilizing a NaI crystal.
slimes	Extremely fine-grained materials, mixed with small amounts of water, produced along with the sands as waste products of ore processing in uranium mills (see tailings). Most of the radioactive material remaining in tailings is found in the slimes.
tailings	The remaining portion of a metal-bearing ore after the metal, such as uranium, has been extracted. Tailings also may contain other minerals or metals not extracted in the process (e.g. radium).
WL	Working level. A unit of radon daughter exposure, equal to any combination of short-lived radon daughters in 1 liter of air that will result in the ultimate emission of 1.3×10^5 MeV of potential alpha energy. This level is equivalent to the energy produced in the

decay of the daughter products RaA, RaB, RaC, and RaC' that are present under equilibrium conditions in a liter of air containing 100 pCi of Rn-222. It does not include decay of RaD (22 yr half-life) and subsequent daughter products.

WLM

Working level month. One WLM is equal to the exposure received from 170 WL-hours.

CHAPTER 1

A SUMMARY OF THE PHASE II - TITLE I
ENGINEERING ASSESSMENT OF
RADIOACTIVE SANDS AND RESIDUES

CHAPTER 1

A SUMMARY OF THE PHASE II - TITLE I ENGINEERING ASSESSMENT OF INACTIVE URANIUM MILL TAILINGS

1.1 INTRODUCTION

The U.S. Energy Research and Development Administration (ERDA) has contracted with Ford, Bacon & Davis Utah Inc. (FB&DU) of Salt Lake City, Utah, to provide architect-engineering services in the assessment of the problems resulting from the existence of large quantities of radioactive uranium mill tailings at the sites of inactive mills in eight western states.

A preliminary survey (Phase I) was carried out by ERDA in cooperation with the EPA and the affected states and completed in October 1974. In the Summary Report⁽¹⁾, ERDA identified 17 sites in Arizona, Colorado, Idaho, New Mexico, Utah, and Wyoming for which practical remedial measures are to be evaluated. Subsequently, ERDA added five additional sites (Riverton and Converse County, Wyoming; Lakeview, Oregon; Falls City and Ray Point, Texas) to the list for a total of 22 sites. Most of these mills produced by far the greatest part of their output of uranium under contracts with the U.S. Atomic Energy Commission (AEC) during the period 1947 through 1970. After operations ceased, some companies made no attempt to stabilize the tailings, while others did so with varying degrees of success. Recently, concern has increased about the possible adverse effects to the general public from long-term exposure to low-level sources of radiation from the tailings piles and sites.

To date, the studies of radiation levels on and in the vicinity of these sites have been limited in scope. The data available were insufficient to permit assessment of risk to people with any degree of confidence in the conclusions reached. In addition, information on practicable measures to reduce radiation exposures and estimates of their projected costs are limited. The purpose of this study is to develop the necessary information to provide a basis for decision-making for appropriate remedial actions for each of these sites.

In assessing the significance of the conditions existing at the Lakeview site, evaluations of the following factors were included:

- (a) Exhalation of radon gas from the tailings
- (b) On-site and off-site direct radiation
- (c) Land contamination from windblown tailings

(1) See end of chapter for references

- (d) Hydrology and contamination by water pathways
- (e) Potential health impact
- (f) Potential for extraction of additional metals from the tailings

Investigation of these and other factors led to the detailed evaluation of two potential practical options:

- (a) Maintenance of the site after the decontamination and stabilization program of ARCO.
- (b) Stabilization with additional cover, upgrading the fencing and removal of small areas of contaminated soil.

The estimated costs of carrying out the remedial action options depend on such parameters as the degree of decontamination to be achieved, and the degree of stabilization necessary.

1.1.1 Background

On March 12, 1974, the Subcommittee on Raw Materials of the Joint Committee on Atomic Energy (JCAE), Congress of the United States, held hearings on S. 2566 and H.R. 11378, identical bills submitted by Senator Frank E. Moss and Representative Wayne Owens of Utah. The bills provided for a cooperative arrangement between the AEC and the State of Utah in the area of the Vitro tailings site in Salt Lake City.* The bills also provided for the assessment of and appropriate remedial action to limit the exposure of individuals to radiation from uranium mill tailings.

Dr. William D. Rowe, testifying in behalf of the Environmental Protection Agency (EPA), pointed out that there are other sites with similar problems. He recommended the problem be approached as a generic one, structured to address the most critical problem first.

Dr. James L. Liverman, testifying for the AEC, proposed that a comprehensive study should be made of all such piles, rather than treating the potential problem on a piecemeal basis. He proposed that the study be a cooperative two-phase undertaking by the states concerned and the appropriate federal agencies, such as the

*The proceedings of these hearings and the Summary Report on the Phase I Study were published by the JCAE as Appendix 3 to ERDA Authorizing Legislation for Fiscal Year 1976. Hearings before the Subcommittee on Legislation, JCAE, on Fusion Power, Biomedical and Environmental Research; Operational Safety; Waste Management and Transportation, Feb 18 and 27, 1975, Part 2.

AEC and EPA. Phase I would involve site visits to determine such aspects as their condition, ownership, proximity to populated areas, prospects for increased population near the site, and need for corrective action. A preliminary report then would be prepared which would serve as a basis for determining if a detailed engineering assessment (Phase II) were necessary for each millsite. The Phase II study, if necessary, would include evaluation of the problems, examination of alternative solutions, preparation of cost estimates and of detailed plans and specifications for alternative remedial action measures. This part of the study would include physical measurements to determine exposure or potential exposure to the public.

The Phase I assessment began in May 1974, with teams consisting of representatives of the AEC, the EPA, and the states involved visiting 21 of the inactive sites. The Phase I report was presented to the JCAE in October 1974. Table 1-1 summarizes the conditions at the time of the Phase I visits.⁽¹⁾ Based on the findings presented in the report, the decision was made to proceed with Phase II.

On May 5, 1975, ERDA, the successor to AEC, announced that Ford, Bacon & Davis Utah Inc. of Salt Lake City had been selected to provide the architect-engineering (A-E) services for Phase II. ERDA's Grand Junction, Colorado, office (GJO) was authorized to negotiate and administer the terms of a contract with FB&DU. The contract was effective on June 23, 1975. The Salt Lake City Vitro site was assigned as the initial task, and work began immediately. Field work on the Lakeview site was performed from September 15 through September 19, 1976.

1.1.2 Scope of Phase II Engineering Assessment

Phase II A-E Services are divided into two stages: Title I and Title II.

Title I services include the engineering assessment of existing conditions and the identification, evaluation and costing of alternative remedial actions for each site. Following the selection and funding of a specific remedial action plan, Title II services will be performed. These services will include the preparation of detailed plans and specifications for implementation of the selected remedial action.

This report is the assessment made for Title I requirements and was prepared by FB&DU. The Oak Ridge National Laboratory (ORNL) at Oak Ridge, Tennessee, under separate agreement with ERDA, provided measurements of the radioactivity concentrations in the soil and water samples and gamma surveys. The EPA staff provided the results of radiation surveys they previously had made at the Lakeview site.

The specific scope requirements of the Title I assessment as given in the contract may include but are not limited to the

following:

- (a) Preparation of an engineering assessment report for each site, and preparation of a comprehensive report suitable for submission to the Congress on reasonable remedial action alternatives and their estimated costs.
- (b) Determination of property ownership in order to obtain release of federal government and A-E liability for performance of engineering assessment work at both inactive millsites and privately owned structures.
- (c) Preparation of topographic maps of millsites and other sites to which tailings and other radioactive materials might be moved.
- (d) Performance of core drillings and radiometric measurements ample to determine volumes of tailings and other radium-contaminated materials.
- (e) Performance of radiometric surveys, as required, to determine areas and structures requiring cleanup or decontamination.
- (f) Determination of the adequacy and the environmental suitability of sites to which mill tailings containing radium can be moved for long-term (>50 yr) storage; and once such sites are identified, perform evaluation and estimate the costs involved.
- (g) Performance of engineering assessments of structures where uranium mill tailings have been used in off-site construction to arrive at recommendations and estimated costs of performing remedial action.
- (h) Evaluation of various methods, techniques and materials for stabilizing uranium mill tailings to prevent wind and water erosion, to inhibit or eliminate radon exhalation, and to minimize maintenance and control costs.
- (i) Evaluation of availability of suitable fill and stabilization cover materials that could be used.
- (j) Evaluation of radiation exposures of individuals and nearby populations resulting from the inactive uranium millsite, with specific attention to:
 - (1) Gamma radiation
 - (2) Radon

- (3) Radon daughter concentrations
- (4) Radium and other naturally occurring radioisotopes in the tailings
- (k) Investigation of site hydrology and meteorology.
- (l) Evaluation of recovering residual values, such as uranium and vanadium in the tailings and other residues on the sites.
- (m) Performance of demographic and land use studies. Investigation of community and area planning, and industrial and growth projections.
- (n) Evaluation of the alternative corrective actions for each site in order to arrive at recommendations, estimated costs, and socioeconomic impact based on population and land use projections.
- (o) Preparation of preliminary plans, specifications, and cost estimates for alternative corrective actions for each site.

Not all of these items received attention at this site.

1.2 SITE DESCRIPTION

1.2.1 Location and Topography

The Lakeview millsite and tailings pile are located approximately 16 mi north of the Oregon-California border in south-central Oregon. It is 96 mi east of Klamath Falls, Oregon in Goose Lake Valley at an elevation of 4,750 ft above sea level. Mountains surround the site on the east and west and reach elevations of 8,000 ft. The site and its relationship to the surroundings are shown in the aerial photo in Figure 2-1, Chapter 2.

1.2.2 Ownership and History of Milling Operations and Processing

The mill was built and operated by the Lakeview Mining Company in 1958. The same people owned the Gunnison Mining Company at Gunnison, Colorado. Between 1960 and 1968, the property had five different owners. Atlantic Richfield acquired the site in 1968, and is the current owner. The plant processed a total of 130,000 tons of ore with a grade of 0.15% U_3O_8 , and a total of 171 tons of the uranium oxide was sold to the AEC. The ore was obtained from mines in southern Lake County. An acid leach process was utilized to process the ore.

*All figures and tables referenced in this summary are from the parent report and are included in the Addendum.

1.2.3 Present Condition of the Site

Figure 2-2, Chapter 2, is a descriptive map of a portion of the site as it now exists. With the exception of the old mill building and the office building, the structures and machinery are being or have been removed. The old mill building and the site are being decontaminated by the owner. The tailings pile, which occupies some 30 acres of the 258-acre site, has been stabilized with earth cover varying in thickness from 18 to 24 in. A dense growth of grasses covers the pile which is surrounded by a hog-style fence.

A seasonal stream which drains a canyon east of the site passes through the site north of the tailings, then between the tailings and the evaporation ponds on the west. The six evaporation ponds occupy 64 acres and are still in their original shapes and are sustaining a healthy weed growth. The entire site is fenced with barbed-wire fencing. Atlantic Richfield has completed its reclamation program and the mill building and other structures have been decontaminated and the machinery and other salvageable items have been removed.

1.2.4 Tailings and Soil Characteristics

The uranium tailings are a fine sand, brown in color resting on a compacted clay liner which overlies a rich dark brown-to-black loam.

1.2.5 Geology, Hydrology, and Meteorology

The Lakeview site is located in an unconsolidated valley fill consisting of clays, sands and gravels which overlie sedimentary rocks of lacustrine and fluvial origin. The site is at the eastern boundary of the Goose Lake Graben, which is block-faulted by northerly and northeasterly normal faults. A simplified stratigraphic column is shown in Figure 2-3, Chapter 2.

The surface waters near the site consist of drainage ditches, ponded water after rains, and an unnamed stream from Hammersley Canyon which is routed between the tailings pile and the adjacent evaporation ponds. There is no evidence that the stream flow has eroded the tailings pile or the embankments surrounding the evaporation ponds.

Ground water occurs under confined and unconfined conditions. There is a strong upward flow gradient from leaky artesian aquifers in the thin unconsolidated lacustrine sediments. Contamination of the ground water is unlikely. A known geothermal area is located adjacent to Warner Mountain and surface water temperature at Hunters Hot Springs 1 mi northwest of the site is 212°F.

The mean annual precipitation of 16 in. occurs fairly uniformly throughout 9 mo of the yr. The other 3 mo, July through September, receive less than 6% of the total precipitation. The average

annual evaporation rate is 45 in.

Prevailing winds blow from the south with windspeeds less than 15 mph about 85% of the time.

1.3 RADIOACTIVITY AND POLLUTANT IMPACTS ON THE ENVIRONMENT

About 85% of the total radioactivity originally in uranium ore remained in the tailings after removal of the uranium because the radium and thorium, principal contributors to radioactive emissions, were not normally removed from the uranium ores during milling. The principal environmental radiological impact and associated health effects arise from the ^{230}Th , ^{226}Ra , ^{222}Rn , and ^{222}Rn daughters contained in the uranium tailings. Although these radionuclides occur in nature, their concentrations in the tailings material are several orders of magnitude greater than their average concentrations in the earth's crust.

1.3.1 Radiation Exposure Pathways, Contamination Mechanisms, and Background Levels

The major potential environmental routes of exposure to man are:

- (a) Inhalation of ^{222}Rn and its daughter products, resulting from the continuous radioactive decay of ^{226}Ra in the tailings. Radon is a gas which diffuses from the pile. The principal exposure results from inhalation of the ^{222}Rn and Rn daughters. This exposure affects the lungs. For this assessment, no criteria have been established for radon concentrations in air. However, the pathway for radon and radon daughters accounts for the major portion of the exposure to the population.
- (b) External whole-body gamma exposure directly from radionuclides in the pile.
- (c) Inhalation and ingestion of windblown tailings. The primary health effect relates to the alpha emitters ^{230}Th and ^{226}Ra , each of which causes exposure to the bones and lungs.
- (d) Ingestion of ground and surface water contaminated with radioactive elements (primarily ^{226}Ra) and other toxic materials.
- (e) Contamination of food through uptake and concentration of radioactive elements by plants and animals is another pathway which can occur; however, this pathway was not considered in this study.

1.3.1.1 Radon Gas Diffusion and Transport

Short-term radon measurements were performed with the ERDA-supplied continuous radon monitors at eight locations in the vicinity of the Lakeview tailings pile. The locations and values of the radon measurements, including background, are shown in Figure 3-3, Chapter 3. No correlation was found between radon concentration and distance from the pile. The lowest concentration off the pile was 0.6 pCi/l at a distance of 0.3 mi, while the highest concentration was 0.8 pCi/l measured at 3 different locations.

Eight 24-hr measurements of atmospheric radon indicated an average background concentration of 0.7 pCi/l for the Lakeview area.

1.3.1.2 Direct Gamma Radiation

The range of natural background values in the Lakeview area was between 5 and 10 μ R/hr, averaging 8 μ R/hr as measured with an energy-compensated Geiger Mueller detector.⁽²⁾ Above the surface of the tailings pile, gamma radiation rates were measured as high as 53 μ R/hr. At the former ore stockpile area, gamma radiation reached a maximum of 340 μ R/hr; however, since the field survey this situation has been remedied as part of the ARCO reclamation program.

1.3.1.3 Windblown Contaminants

Background gamma radiation rates were reached within 0.05 mi from the tailings pile.

Surface soil samples obtained around the site contained only background levels of ^{226}Ra , except for one sample taken from the evaporation pond north of the tailings pile. This sample did not appear to be due to windblown contamination.

1.3.1.4 Ground and Surface Water Contamination

The East Fork of Thomas Creek flows within 0.25 mi from the Lakeview tailings pile. The stream from Hammersley Canyon flows along the edge of the tailings pile. An analysis of all water samples downstream from the tailings pile showed ^{226}Ra concentrations to be significantly less than the EPA Interim Drinking Water Standards.

1.3.1.5 Soil Contamination

The amount of ^{226}Ra leaching from the tailings into the soil was determined by drilling auger holes around the tailings pile. The radioactivity profile was measured in these holes with a Geiger probe in a lead shield that collimates the radiation. These auger holes were drilled 2 to 2.5 ft deep and no radioactive contamination was observed. Analyses of soil samples⁽³⁾ obtained

previously from a trench dug through the pile indicated ^{226}Ra was being trapped in the clay liner under the tailings.

1.3.2 Remedial Action Criteria

Radiological criteria established for this engineering assessment are divided into two general categories:

- (a) Criteria applicable to structures with tailings underneath them or within 10 ft
- (b) Criteria pertaining to the mill tailings site and open land

The criteria utilized for habitable structures are the guidelines published by the Surgeon General of the United States for use in the Grand Junction, Colorado, remedial program. These guidelines recommend graded levels (based on yearly average values) for remedial action in terms of the external gamma radiation (EGR) levels and of the indoor radon daughter concentration (RDC) levels above background found within dwellings constructed on or near uranium mill tailings. (In this usage, the word "external" refers to gamma radiation from sources outside the human body to which an individual may be exposed.)

The recommended graded levels are as follows:

<u>EGR</u>	<u>RDC^a</u>	<u>Recommendations</u>
Greater than 0.1 mR/hr ^b	Greater than 0.05 WL ^c	Remedial action indicated
From 0.05 to 0.1 mR/hr	From 0.01 to 0.05 WL	Remedial action may be suggested
Less than 0.05 mR/hr	Less than 0.01 WL	No remedial action indicated

^aBased upon yearly average values from 6 air samples of at least 100-hr duration taken at a minimum of 4-wk intervals throughout the year.

^bmR/hr = milliroentgen per hour, a measure of gamma radiation;
1 mR/hr = 1,000 $\mu\text{R/hr}$.

^cWL = working level, a measure of alpha radiation from short-lived radon daughter elements.

The criteria for land decontamination have the objective of reducing residual gamma radiation to levels which are as low as practicable. However, topographic and economic considerations frequently preclude complete decontamination. A provisional maximum of 40 $\mu\text{R/hr}$ above background is used in such circumstances. Average background in the Lakeview area was determined in this

study to be 8 μ R/hr. As a guideline for the land beyond the site, if residual gamma levels are less than 10 μ R/hr above background, the land may be released for unrestricted use. Where cleanup is necessary the radium content of the soil should be reduced to no more than twice the radium background in the area. If the radioactive tailings material is stabilized in place, the same criteria apply but control of gamma radiation would be by an earth covering. However, the area should be designated a controlled area, be fenced to limit access, and be restricted as to human occupancy. The numerical guidelines provide a basis for the engineering assessment, but are subject to review based on the overall findings of Phase II.

The radium and gross alpha content of ground and surface water should meet the applicable state and federal standards.

1.3.3 Potential Health Impact

Radon gas exhalation from the pile and the subsequent inhalation of radon daughters account for most of the total dose to the population from the Lakeview site under present conditions. The gamma radiation exposure from the pile is essentially zero since the gamma radiation levels are in the background range within 0.05 mi from the pile.

Gamma radiation can be reduced effectively by shielding with any dense material. However, experience has shown that it is very difficult to control the movement of radon gas through porous solid materials. Once released from the radium-bearing minerals in the tailings, the gaseous radon diffuses by the path of least resistance to the surface. The radon has a half-life of about 4 days, and its daughter products are solids. Therefore, part of the radon decays en route to the surface and leaves daughter products within the tailings piles. If the diffusion path can be made long enough, then, theoretically, substantially all the radon and its daughter products can be made to decay before escaping to the atmosphere. Calculations using the techniques of Kraner, Schroeder, and Evans⁽⁴⁾ indicate that 13 ft of earth cover theoretically would be required to reduce the radon diffusion from the Lakeview tailings by 95%.

The health significance to man of long-term exposure to radiation is a subject that has been studied extensively for many years. The end result of long-term exposure to low-level radiation is increased susceptibility to diseases such as lung cancer or leukemia, which also are attributable to many other causes. Thus, the determination of specific cause in any given case becomes very difficult. Therefore, the usual approach to evaluation of the health impact of low-level radiation exposures is to make projections from observed effects of high exposures on the premise that the effects are linear. A considerable amount of information has been accumulated on the high incidence of lung cancer in uranium miners exposed to radon and its daughters in mine air. This provides a basis for calculating the probable health effects of low-level

exposure to large populations. (The term "health effect" refers to an incidence of disease; for radon daughter exposure, 1 health effect = 1 case of lung cancer.) This is the basis of the health effects calculations in this report. It should be recognized, however, that there is a large degree of uncertainty in such projections. Among the complicating factors is the combined effect of radon daughters with other carcinogens. As an example, the incidence of lung cancer among uranium miners who smoke is far higher than can be explained on the basis of either smoking or the radiation alone.

The risk estimators used in this report are given in the report of the National Academy of Sciences Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR report).⁽⁵⁾ This report presents risk estimators for lung cancer derived from epidemiological studies of both uranium miners and fluorspar miners. The average of the absolute risk estimator for these two groups is: 6 cancers per year per 10^6 person-WLM exposure. The term WLM means working level month, or an exposure to a concentration of one working level of radon daughter products in air for 170 hr, which is a work-month. A working level (WL) is a unit of measure of radon daughter products which recognizes that the several daughter elements are frequently not in equilibrium with each other nor with the parent radon. Because of the many factors which contribute to natural biological variability, and of the many differences between exposure conditions in mines and residences, this estimator (6 cancer cases per year per 10^6 person-WLM) is considered to have an uncertainty factor of about 3. The relative risk estimator can be several factors larger than the absolute risk estimator.⁽⁶⁾

For the purpose of the mill tailings assessment, it was assumed that about 50% equilibrium exists inside structures between radon and its daughter elements resulting in the following conversion factors:

$$1 \text{ pCi/l of } ^{222}\text{Rn} = 0.005 \text{ WL}$$

For continuous exposure:

$$0.005 \text{ WL} = 0.25 \text{ WLM/yr}$$

On the basis of measurements of radon concentrations in excess of background values, it is estimated that the average pile radon-induced lung cancer risk to individuals within 5 mi from the tailings site is 1.9×10^{-6} per person per year. The health effect rate for background radon is approximately 17 times that attributable to pile radon. The average lung cancer risk due to all causes for Oregon residents is 3.4×10^{-4} per person per year.⁽⁷⁾ At 0.2 mi from the edge of the tailings pile, which is the distance to the nearest occupied dwellings, the lung cancer risk due to pile radon is about 6% of the average risk to residents of Oregon from all causes.

As a result of the low population density, the low radiation levels of the tailings at the Lakeview site, and the relatively high background radon levels, the potential health impact of the pile is minimal. The cumulative number of health effects after 100 yr is estimated to be 0.82 using a 4.3% declining growth rate. In 100 yr the background radon is calculated to cause 14 health effects for the same population growth.

1.3.4 Nonradioactive Pollutants

Six water samples were taken from the vicinity of the Lakeview site and chemically analyzed. Two of these samples were taken from a pond northwest of the pile. The third sample was taken from a stream under a road 900 yd north of the pile. The remaining three water samples were taken south of the pile: one sample from the Hammersley Canyon stream, one from a ditch, and one from a well. The three samples obtained north of the tailings contained arsenic and selenium above the EPA Interim Drinking Water Standards. However, these samples are upstream from the tailings pile and the evaporation ponds. It is not likely that the tailings contributed to their contamination. In addition, the Hammersley Canyon stream that flows along the edge of the tailings pile was sampled south of the pile (downstream) and no significant contamination was found.

1.4 SOCIOECONOMIC AND LAND USE IMPACTS

The mill and tailings site are located about 2 mi northeast from Lakeview, a city with about 2,900 inhabitants. Farmers and farm laborers are the largest employment sector; however, Lakeview enjoys a healthy, stable economy with a diversified base of agriculture, forestry, local recreation, manufacturing, retailing, and government employment.

The land usage near the site is diverse and consists of numerous small and large holdings, a lumber mill is on the south of the site, and additional commercial development could occur along U.S. Highway 395 which is adjacent to the millsite. There is interest in using the millsite for other industrial activities; however, there are no strong pressures to use the tailings area for other purposes. Market value of land in the area varies from \$1,000/acre to \$2,500/acre.

1.5 RECOVERY OF RESIDUAL VALUES

Estimates of the uranium content of the Lakeview tailings by the AEC indicate an average U_3O_8 concentration of 0.018%.

There are five factors that should be employed to evaluate whether reprocessing the Lakeview tailings to extract residual uranium and other mineral values would be practicable:

- (a) The amount of tailings present

- (b) Concentrations of residual values
- (c) Projected recovery
- (d) Current market price of recovered values
- (e) Proximity to processing mills

Based on the aforementioned criteria, reprocessing of the Lakeview tailings is not a practical economic consideration at this time and would not be practical until the market value of U₃O₈ reaches \$300/lb in present dollars.

1.6 MILL TAILINGS STABILIZATION

Present practices and technology of mill tailings stabilization are being examined. This investigation indicates that much research and development remains to be performed before complete and permanent stabilization of radioactive mill tailings can be realized.

Reasonably effective means of wind and water erosion control are available, although they will involve continued maintenance costs. Lining of containment areas or chemical solidification of the tailings are possible methods for control of leaching.

Up to this time, no attempt has been made to contain radon in a tailings pile. Although a thick earth cover is theoretically effective, it has not actually been tried. The observed variability of radon exhalation rates indicates that with better understanding of the mechanism involved, control may be possible.

The tailings pile is presently covered with a nominal 2 ft of earth. This cover greatly reduces the wind and water erosion. Gamma radiation generally has been reduced to twice background levels but radon exhalation has been reduced by an estimated 30% due to this thickness of cover material.

1.7 REMEDIAL ACTIONS AND BENEFITS

The remedial actions take into consideration the decontamination and stabilization efforts of the owner and of the remoteness of the site from areas of large population.

There are no known off-site locations where tailings have been used and, therefore, there are no such areas to decontaminate.

No alternative disposal site has been considered for the Lakeview tailings. In their present condition, or with the implementation of either of the two remedial action options, the tailings meet the criteria for long-term storage.

1.7.1 Remedial Options

Option I includes provisions for a continuing maintenance program. No additional decontamination or stabilization work is proposed for the site except the completion of the ARCO program. The cost for this option is \$40,000 and would provide approximately \$2,800/yr for monitoring and physical maintenance.

In addition to the action of Option I, Option II provides for: decontaminating of additional on-site, but off-pile areas; straightening portions of the stream as it passes through the site in order to reduce the residence time of surface water on the site; improving security in the form of a 6-ft-high chainlink fence; and adding sufficient material to the pile to have a minimum cover of 2 ft. The cost of this option is \$290,000. If additional cover is desired it would add approximately \$193,600/ft of cover to the option cost.

1.7.2 Cost-Benefit Analyses

The principal reasons for the remedial options are to provide maintenance or better site decontamination and security. Population and off-pile radiation levels are so small that health benefits associated with the remedial actions are negligible. The costs for Options I and II are summarized in Table 1-2.

TABLE 1-1
SUMMARY OF CONDITIONS NOTED AT TIME OF PHASE I SITE VISITS ^a

	Cond. of Tailings	Cond. of Structures on Site	Mill Housing	Adequate Fencing, Posting, Security	Property Close by River or Stream	Houses- Industry w/in 1/2 Mile	Evidence of Wind Water Erosion	Possible Water Contami- nation	Tailings Removed for Pri- vate Use	Other Hazards On-site
<u>ARIZONA</u>										
Monument	U	R	N	No	No	Yes	No	No	No	No
Tuba City	U	PR-UO	E-O	No	No	Yes	Yes	No	No	Yes
<u>COLORADO</u>										
Durango	P	PR-UO	N	Yes	Yes	Yes	Yes	No	Yes	Yes
Grand Junction	S	PR-O	N	Yes	Yes	Yes	No	No	Yes	No
Gunnison	S	B-O	N	Yes	No	Yes	No	Yes	No	No
Maybell	S	R	N	Yes	No	No	No	No	No	No
Naturita	S	PR-O	E-P	Yes	Yes	No	Yes	Yes	No	No
New Rifle	P	M-O	N	Yes	Yes	Yes	Yes	Yes	No	No
Old Rifle	S	PR-UO	N	Yes	Yes	Yes	No	Yes	Yes	No
Slick Rock (NC)	S	R	N	No	Yes	Yes	Yes	No	No	No
Slick Rock (UCC)	S	R	E-P	Yes	Yes	Yes	No	No	No	No
<u>IDAHO</u>										
Lowman	U	R	N	No	Yes	Yes	No	No	Yes	No
<u>NEW MEXICO</u>										
Ambrosia Lake	U	PR-O	N	Yes	No	No	Yes	No	No	No
Shiprock	P	PR-O	E-O	Yes	Yes	Yes	No	No	Yes	Yes
<u>OREGON</u>										
Lakeview	U	M-UO	N	Yes	No	Yes	Yes	No	No	No
<u>TEXAS</u>										
Falls City	P	M-UO	N	Yes	No	No	No	No	No	No
Ray Point	P	M-UO	N	Yes	No	No	No	No	No	No

TABLE 1-1 (Cont)

	Cond. of Tailings	Cond. of Structures on Site	Mill Housing	Adequate Fencing, Posting, Security	Property Close by River or Stream	Houses- Industry w/in 1/2 Mile	Evidence of Wind Water Erosion	Possible Water Contami- nation	Tailings Removed for Pri- vate Use	Other Hazards On-site
<u>UTAH</u>										
Green River	S	B-O	N	Yes	No	Yes	Yes	Yes	No	No
Mexican Hat	U	B-O	E-O	No	No	Yes	Yes	Yes	No	No
Salt Lake City	U	R	N	No	Yes	Yes	Yes	Yes	Yes	Yes
<u>WYOMING</u>										
Converse County	U	R	N	No	No	No	No	No	No	No

(1) S - Stabilized but requires improvement

P - Partially stabilized

U - Unstabilized.

(2) M - Mill intact

B - Building(s) intact

R - Mill and/or buildings removed

PR- Mill and/or buildings
partially removed

O - Occupied or used

UO- Unoccupied or unused.

(3) N - None

E - Existing

O - Occupied

P - Part occupied.

^aThis table does not necessarily represent conditions at the present time.

TABLE 1-2
COST ESTIMATE SUMMARY

<u>Option No.</u>	<u>Description</u>	<u>Estimated Cost (\$) *</u>
I	Maintenance and monitoring	40,000
II	Additional site decontamination and stabilization, drainage improvements, security, monitoring, and maintenance	290,000

*Costs are in thousands of dollars, based on 1977 value

CHAPTER 1 REFERENCES

1. "Summary Report, Phase I Study of Inactive Uranium Mill Sites and Tailings Piles"; AEC; Grand Junction, Colorado; Oct 1974.
2. F. F. Haywood, et al; "Assessment of Radiological Impact of the Inactive Uranium Mill Tailings Pile at Lakeview, Oregon"; ORNL; (in preparation).
3. "Radiological Survey of Inactive Uranium Mill Site, Lakeview, Oregon for Atlantic Richfield Company" NHPQ Inc.; Grand Junction, Colorado; Jul 23, 1974.
4. H. W. Kraner, G. L. Schroeder, and R. D. Evans, "Measurements of the Effects of Atmospheric Variables on Radon-222 Flux and Soil-Gas Concentrations"; The Natural Radiation Environment; J. A. S. Adams and W. M. Lowder, eds; University of Chicago Press; 1964.
5. "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation"; Report of Advisory Committee on Biological Effects of Ionizing Radiation; NAS, National Research Council; Nov 1972.
6. "Health Effects of Alpha-Emitting Particles in the Respiratory Tract"; Report of the Advisory Committee on the Biological Effects of Ionizing Radiation; EPA-520/4-76-013; EPA; Office of Radiation Programs; Washington, D.C.; Oct 1976.
7. Vital Statistics of the U.S.; Vol II; Mortality; National Center for Health Statistics; HEW; 1968.

ADDENDUM

FIGURES AND TABLES

(The figures and tables contained on the following pages have been extracted from chapters of the parent report.)

LIST OF FIGURES

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FIGURE 2-1, AERIAL PHOTOGRAPH OF SITE

FIGURE 2-2. DESCRIPTIVE MAP

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