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

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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By
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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 (issued under separate cover) entitled, "Phase II - Title I Engineering Assessment of Inactive Uranium Mill Tailings, Riverton Site, Riverton, Wyoming". Both reports are authorized under the U.S. Energy Research and Development Administration (ERDA) Contract No. E(05-1)-1658. These 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, to identify reasonable remedial action options for each site, and to estimate the remedial action costs. If additional data that may alter or have an impact on a final remedial action decision for any site are required, they 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) State of Wyoming; Mr. Edd Johnson, Chief, Radiological Health Services
- (3) Wind River Indian Reservation; Mr. John Meyers, Sanitarian, Indian Health Service; Fort Washaki, Riverton, Wyoming
- (4) Solution Engineering, Inc.; Mr. Tom Fife; Alice, Texas
- (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 Riverton, Wyoming site. The Phase II - Title I services include: the performance of core drillings; soil, water and other sample analyses; radiometric measurements to determine areas with radium-contaminated materials; the evaluation of resulting radiation exposures of individuals and nearby populations; the investigation of site geology, hydrology, and meteorology; and the evaluation and costing of alternative corrective actions.

Radon gas release from the 900,000 tons of tailings at the Riverton site constitutes the main environmental impact. The two alternative actions presented are fencing and maintenance of the site and off-site remedial action (Option I); and, in addition to the items in Option I, decontamination of the millsite and ore storage areas and additional stabilization cover to a minimum of 2 ft (Option II). The cost estimates for the options are \$460,000 and \$1,140,000, respectively.

Estimated costs for moving the tailings and all contaminated materials to unspecified sites 5 and 10 mi from the present location are \$6,000,000 and \$6,400,000, respectively.

Reprocessing the tailings for uranium is not economically attractive at present.

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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 INACTIVE URANIUM MILL TAILINGS

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 Riverton 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 uranium from the tailings

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

- (a) Minimum remedial action, which amounts to fencing, maintenance, and off-site remedial action
- (b) Increase stabilization cover to 2-ft thickness, maintenance, fencing, and off-site remedial action

Costs were estimated for moving the tailings and all contaminated materials 5 and 10 mi from the present site for long-term storage.

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 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

*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.

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 Riverton site was performed from July 27 through July 29, 1976. Radon measurements were made from Oct 14 through Oct 18, 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 Riverton 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 radio-isotopes 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 Riverton millsite and tailings pile are located 2 mi southwest of Riverton in Fremont County, Wyoming, and approximately 120 mi east of Teton National Park. It is in the Wind River Valley at an elevation of 4,950 ft above sea level on the Wind River Indian Reservation. The land around the site is mainly flat and gently sloping ranch land. The site and its relationship to the surrounding area are shown in the aerial photo in Figure 2-1, Chapter 2.*

1.2.2 Ownership and History of Milling Operations and Processing

The site is on the Wind River Indian Reservation, but the millsite has been deeded to others. Susquehanna-Western, Inc., originally known as Fremont Minerals, Inc., was the operational owner of the site beginning in 1958. Solution Engineering Company of Alice, Texas is the current owner of the site. From 1958 until it shut down in 1963, the plant processed approximately 900,000 tons of ore from surrounding areas. Both acid and carbonate circuits were used in the mill processing to provide flexibility in treating the many varieties of ore received. A sulfuric acid plant was a part of the original mill and is still in operation under lease by Western Nuclear Company.

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

1.2.3 Present Conditions of the Site

Figure 2-3, Chapter 2, is a descriptive map of a portion of the site as it now exists. Most of the mill equipment and some of the structures have been removed, including portions of the main mill building. The steel water tower remains and serves the sulfuric acid plant which is still in operation.

The 900,000 tons of tailings occupy a rectangular-shaped area of approximately 72 acres to an average depth of 7.5 ft. They have been stabilized against wind and water erosion by a 1.5 ft cover of pit-run sand and gravel. The surface of the pile slopes to the east, as does the natural slope of the ground. The site including the tailings are fenced with a barbed-wire fence. Figure 2-4, Chapter 2, is a typical cross-section through the pile.

1.2.4 Tailings and Soil Characteristics

The tailings consist of coarse and finely ground sand and slimes. The alluvial material under the tailings is composed of soil, gravel, and cobbles.

1.2.5 Geology, Hydrology, and Meteorology

The Riverton tailings pile is located on approximately 15 to 25 ft of soil and coarse-grained alluvium of the Wind River flood plain, underlain by approximately 2,000 ft of sedimentary Wind River Formation bedrock. The formation consists of an inter-bedded sequence of lenticular fine- to coarse-ground sandstones, siltstones, and shales with lesser amounts of bentonite, tuff, and limestone. These sedimentary beds are nearly horizontal below the site. A simplified well log at the site is shown in Figure 2-5, Chapter 2.

There are flowing surface waters within 0.5 mi in all directions from the pile. The Little Wind River flows northeastward 0.5 mi southeast of the pile. The Wind River flows to the east 1 mi north of the site. Numerous irrigation ditches flow near the site and empty into marshy areas east and southwest of the site. Because of the extensive flood plain, slightly elevated location of the pile, and protection from highway roadgrades, flood waters of the Wind River and Little Wind River cannot reach the tailings pile, although flood waters could rise within the base of the tailings. Overland flow on the pile is limited to the precipitation that actually falls on the site. A ditch and berm protect the pile from off-site runoff onto the site and trap overland runoff from the pile on site. Contamination of surface waters near the site is unlikely to occur from physical transport because the tailings are protected by a soil cover and the ditch and berm trap runoff. Contamination of surface waters near the site could occur by seepage from the pile from waters leaching through the pile and by unconfined ground waters rising within the tailings which later discharge into surface waters.

The confined ground waters in the Wind River Formation occur under very shallow as well as deeper artesian conditions. The shales act as confining layers to water in lenticular sandstone horizons, but the entire sequence behaves somewhat as a single aquifer. Intensive development of the area's ground water, including wells on the millsite, has affected water levels, flow gradients, and artesian pressures in the immediate vicinity of the city of Riverton. The ground water flow gradient is toward the Riverton well field, which is at a considerably greater depth than the potentially affected waters at the site. Recharge to the confined ground water system occurs by the flow of water across permeable bedrock. The tailings site is an area of potential recharge to the underlying aquifers of the Wind River Formation. Ground water from various horizons within this formation are used for domestic water supplies without treatment over much of the rural area. The city's well field consists of 15 wells 500 to 800 ft deep. This supply is barely adequate to supply peak daily pumping requirements during summer months.

The unconfined ground waters consist of waters within terrace deposits, within river alluvium, and waters within the shallow bedrock of the Wind River Formation. These sources are hydraulically interconnected and act as a single system. Due to natural topography and return irrigation flows, much of the area is waterlogged and evaporation results in salt deposits in the soils. The water table at the site is usually less than 6 ft below the original land surface and unconfined ground waters rise within the base of the tailings. Thus, there is a potential for contamination of the unconfined ground water, of the surface waters into which it discharges, and of the unconfined ground water system which is recharged in the area. Unconfined ground waters are not used for domestic water supplies in the Riverton area because of the insufficient quantity or poor chemical quality of the water, but the surface waters are used for irrigation and watering of stock.

The tailings are protected from winds and water erosion by soil and vegetative cover. High-intensity winds and storms are known in the area and limited water erosion of some of the finer cover material is evident on the steeper western boundary of the pile. Coarser material has not been affected.

The climate in the Riverton area is semiarid with an annual precipitation of 10 in./yr. Winds in the area tend to be in an east-west direction. Weather data were recorded at the Riverton airport.

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. No quantitative evaluation of this pathway was performed.
- (d) Ingestion of ground and surface waters 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 ERDA-supplied continuous radon monitors at 6 locations in the vicinity of the Riverton tailings pile. The locations and values of the radon measurements, including background, are shown in Figure 3-3, Chapter 3. Two measurements of atmospheric radon indicated an average background concentration of 1.1 pCi/l for the Riverton area.

1.3.1.2 Direct Gamma Radiation

The range of natural background values in the Riverton area

was between 9 and 13 $\mu\text{R/hr}$, averaging 11 $\mu\text{R/hr}$ 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 84 $\mu\text{R/hr}$. At the former ore stockpile area, gamma radiation reached a maximum of 280 $\mu\text{R/hr}$.

1.3.1.3 Windblown Contaminants

Background gamma radiation rates were reached within 0.2 mi to the south, east, and west of the pile and within 0.3 mi north of the pile. The results of the EPA gamma radiation survey around the tailings pile are shown in Figure 3-9, Chapter 3.

1.3.1.4 Ground and Surface Water Contamination

The Little Wind River flows within 0.5 mi south of the River-ton tailings pile and the Wind River flows within 1 mi north of the pile. Eight surface and ground water samples were taken from the vicinity of the tailings pile. The dissolved ^{226}Ra concentrations for the samples ranged from 0.12 to 0.68 pCi/l.⁽²⁾ Four samples were taken from a stream that flows by the southwest corner of the pile. No significant increase in the ^{226}Ra content of the stream was found as it flowed by the tailings. While radium from the tailings may be entering surrounding ground and surface waters, the level of contamination is considerably below the EPA Interim Drinking Water Regulations for radium, and is not a radium health hazard.

1.3.1.5 Soil Contamination

The leaching of radium into the subsoil beneath the tailings extends from 2 to 5 ft below the tailings-subsoil interface, averaging 3 ft, before reaching the average background level of radium concentration in local soil samples (1.1 pCi/g).

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 on 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 μ 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 μ R/hr above background is used in such circumstances. Average background in the Riverton area was determined in this study to be 11 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 waters should meet applicable state and federal standards.

1.3.3 Potential Health Impacts

Radon gas exhalation from the piles and the subsequent inhalation of radon daughters account for most of the total dose to the population from the Riverton site under present conditions. The gamma radiation exposure from the piles is essentially zero since

there are very few persons who live or work within 0.3 mi of the piles where gamma radiation is above background.

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⁽³⁾ indicate that 13 ft of earth cover theoretically would be required to reduce the radon diffusion from the Riverton 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 results 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, and 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).⁽⁴⁾ 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 is considered to have an uncertainty factor of about 3. The relative risk estimator can be several factors larger than the absolute risk estimator.⁽⁵⁾

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 a best estimate curve of radon concentrations in excess of the background value, it is calculated that the average radon-induced lung cancer risk due to the pile in the area within 3 mi from the Riverton site is 6.0×10^{-6} per person per year, or less than 3% of the average risk due to all causes for Wyoming residents (2.1×10^{-4}).⁽⁶⁾

The 25-yr health effects were calculated for three population projections using a present population of 9,359 assumed to be concentrated at 2.0 mi from the edge of the pile. The health effects from pile-induced Rn and background Rn were as follows:

25-yr Cumulative Effect Within 3 Mi From Edge of Pile

<u>Growth Rate</u>	<u>Pile-Induced RDC</u>	<u>Background RDC</u>
Static	1.4	13
Constant 4.0% growth rate	2.4	21
4% decreasing growth rate ^a	2.1	20

^aThe growth rate is constant for 10 yr, then decreases linearly to 0% at 25 yr.

Pile-induced radon daughter health effects were approximately 11% of the background radon daughter health effects. The exposure and consequent risk will continue as long as the radiation source remains in its present location and condition.

1.3.4 Nonradioactive Pollutants

There are other potentially toxic materials in the tailings. Chemical analyses of samples from auger holes in the Riverton tailings pile showed barium and chromium in concentrations between 20 and 70 ppm. The highest selenium concentration was about 400

ppm and the arsenic concentration ranged as high as 170 ppm. Cadmium was present in concentrations less than 0.5 ppm in the tailings.

Eight surface and ground water samples were taken from the vicinity of the Riverton tailings pile and chemically analyzed. The locations of these samples are shown in Figure 3-10, and the analyses of these samples are presented in Table 3-5, Chapter 3. All of the water samples, both upstream and downstream from the tailings pile, contained selenium above the EPA Interim Drinking Water Standard. In addition, four samples contained cadmium in concentrations above the acceptable drinking water level. The low level of cadmium in the tailings and the fact that high cadmium content was found in waters upstream as well as downstream from the tailings indicate that the tailings were not a major source of cadmium contamination. Selenium contamination in the water was found both upstream and downstream from the tailings; however, the much higher level of selenium in the ground water immediately around the tailings suggests that this higher level of contamination is due to the tailings.

1.4 SOCIOECONOMIC AND LAND USE IMPACTS

The Riverton site is located in an unincorporated rural area surrounded by the Wind River Indian Reservation. There are a number of houses and trailer houses dispersed throughout the area near the many roads that lead to the city of Riverton or to principal highways. South of the site is a school and its associated community, St. Stephens, and on the millsite itself is an operating sulfuric acid plant. The neighboring land is mainly farms and ranches.

Most of the land in the vicinity is owned by the Shoshone Tribe or by individual Indians. Even when individuals desire to sell land in the reservation, the tribe has the right of first refusal. Land use and land values are in large part controlled by the tribe and council and their extensive ownership tends to increase pressure to develop inholdings of nonreservation land for homesites and for industrial growth.

The presence of the tailings has not affected land uses in the area or land values. Land is worth approximately \$1,000 to \$2,000/acre. Continued industrial and residential growth in the area will continue to put pressure on the site and its immediate environs to shift from farmland to residential or industrial land.

1.5 RECOVERY OF RESIDUAL VALUES

Estimates of the uranium content of the Riverton tailings by the AEC indicate an average U_3O_8 concentration of 0.015% for the tailings.

There are five factors that should be employed to evaluate whether reprocessing the Riverton 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 Riverton tailings is not a practical economic consideration at this time, and would not be practical until the market value of U_3O_8 reaches \$92/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.

1.7 OFF-SITE REMEDIAL ACTION

A mobile scanning unit, operated by the AEC under interagency agreement for the EPA, was used to perform a gamma radiation survey of the Riverton, Wyoming area prior to 1972. A subsequent field survey identified 14 off-site locations where tailings use was suspected or confirmed. The cost of remedial action for these locations has been estimated to be \$65,000. Cleanup of the wind-blown tailings surrounding the pile has been estimated to cost a total of \$180,000. The total remedial action cost for off-site structures and for decontamination of off-pile open lands has been estimated to be \$245,000, exclusive of engineering costs and contingency. The locations at which tailings are on vacant lands or are greater than 10 ft from structures could constitute a problem in the future. Costs for this category are not included in this assessment because they are not covered under the Grand Junction remedial action criteria.

1.8 LONG-TERM STORAGE SITE SELECTION

The Riverton site was not included in Phase I; hence, it was not included in the sites for which the moving option was to be considered. However, because of the relative magnitude of the potential health effects, removal options have been provided, and costs have been estimated for removal to distances of 5 and 10 mi.

1.9 REMEDIAL ACTIONS AND COST-BENEFIT ANALYSES

1.9.1 Remedial Action Options

Two remedial actions for the site include security fencing, a maintenance and monitoring program which would include the monitoring of nearby wells and surface waters, and off-site remedial action. Option I would provide fencing around the tailings and around the old mill and ore storage areas, but would take no action on the site in the way of cleanup or decontamination. Rubble and contaminated materials from off-site cleanup activities would be deposited on the surface of the tailings pile and stabilized with 1.5 ft of the same type of material as used in the original stabilization efforts. The cost of this option is \$460,000.

Option II accomplishes the same off-site work as Option I, but provides for demolishing and burying in the tailings all of the on-site contaminated structures, including contaminated portions of the old mill buildings. Also, adjacent areas contaminated by windblown tailings would be cleaned up, as would the old ore storage areas and soil beneath the mill building. All this material would be placed on the pile, over the debris. This area would then be covered with 2 ft of stabilization material and the balance of the pile with another 0.5 ft so that the entire pile would have a 2-ft stabilization cover. The estimated cost of this option is \$1,140,000, which also includes a perpetual care fund and security fencing (for the tailings only).

Although specific long-term storage sites have not been identified, the costs for relocating the tailings and contaminated material to sites at distances of 5 and 10 mi from the present location have been estimated as \$6,000,000 and \$6,400,000, respectively. These costs include preparation at the new site, remedial action, engineering, EIS, contingency, and perpetual care costs.

1.9.2 Cost-Benefit Analyses

As summarized in Table 1-2, the total costs for the remedial actions vary from \$460,000 to \$6,400,000. Each of these costs would yield a distinct health benefit. The number of potential cancer cases avoided per million dollars expended for each remedial action is given in Figure 9-1, Chapter 9. The curves indicate an increase in the benefit/cost ratio with time due to the increasing number of health effects avoided. The potential cancer

cases avoided for each remedial action and the cost per potential cancer case avoided are given in Table 9-2, Chapter 9. The removal alternatives have the largest health benefit/cost ratios because the health effects are eliminated by removing the radiation source.

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

SUMMARY OF REMEDIAL ACTION OPTIONS AND EFFECTS

<u>Option Number</u>	<u>Cost¹ (\$000)</u>	<u>Description of Remedial Action</u>	<u>Benefits</u>	<u>Adverse Effects</u>
I	460	Fencing, maintenance, and remedial action at off-site locations	A,H	W,X,Y
II	1,140	Off- and on-site decontamination, stabilization increased to 2 ft, fencing, and maintenance	A,B,C,D, F,H	W,Z
Removal	6,000 to 6,400	Relocate tailings and contaminated materials to a long-term storage site 5 or 10 mi from the present site, and remedial action at off-site locations	A,B,E,G, H	W

Definition of Benefits

- A. Better security provided for tailings
- B. Better control of wind and water erosion
- C. Further reduction in radon exhalation to 30% of bare tailings flux
- D. Reduction of gamma radiation on tailings to background
- E. Radon source removed
- F. Site available for limited use except tailings area
- G. Entire site available for unrestricted use
- H. Off-site locations decontaminated

Definition of Adverse Effects

- W. Some security and maintenance required
- X. Site unavailable for any use
- Y. No reduction in health effects
- Z. Little reduction in health effects

Notes

¹Costs are in 1977-value dollars

CHAPTER 1 REFERENCES

1. "Summary Report, Phase I Study of Inactive 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 Riverton, Wyoming"; ORNL; (in preparation).
3. 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.
4. "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.
5. "Health Effects of Alpha-Emitting Particles in the Respiratory Tract"; Report of the Advisory Committee on the Biological Effects of Ionizing Radiation; 76-013; EPA; Office of Radiation Programs, Washington D.C.; Oct 1976.
6. 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 in 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 2-3. DESCRIPTIVE MAP

FIGURE 2-4. CROSS-SECTION AT STATION 15+00

FIGURE 2-5. SIMPLIFIED LOG OF WELL AT THE SITE

130-16

FIGURE 3-3. RADON CONCENTRATION IN VICINITY OF PILE

NOTE:
REFERENCE DRAWING: RADIOLOGICAL
SURVEY AT THE INACTIVE URANIUM
MILLSITE; NEAR RIVERTON, WYOMING;
ORP/LV-77-2, USEPA, LAS VEGAS FACILITY;
JUNE 1977.

FIGURE 3-9. EPA GAMMA SURVEY SURROUNDING MILLSITE

FIGURE 3-10. SURFACE AND SUBSURFACE RADIUM CONCENTRATIONS

TABLE 3-5

CHEMICAL ANALYSES OF RIVERTON WATER SAMPLES (mg/l)

<u>Sample^a</u>	<u>As</u>	<u>Ba</u>	<u>Cd</u>	<u>Cr</u>	<u>V</u>	<u>Fe</u>	<u>Pb</u>	<u>Se</u>
A - Stream NW of pile, up-stream from pile	0.013	0.19	<0.001	<0.001	0.030	0.990	<0.001	0.021
B - Stream NW of pile, up-stream from pile	0.010	0.14	0.017	<0.001	0.060	0.740	<0.001	0.024
C - Stream SW corner of pile	<0.001	0.34	<0.001	<0.001	<0.001	0.680	<0.001	0.026
D - Stream SW of pile, down-stream from pile at road bridge	0.022	0.50	0.028	<0.001	<0.001	4.900	<0.001	0.027
E - Irrigation ditch N of pile, standing water	<0.001	0.24	0.032	0.028	0.011	5.700	0.004	0.017
F - Irrigation ditch NE of pile, standing water	<0.001	0.20	0.037	0.021	0.040	4.800	<0.001	0.015
G - Well at Indian home SE of tailings pile	0.039	0.35	<0.001	<0.001	<0.001	1.620	<0.001	0.254
H - Well at millsite furnishes water for site	0.023	0.20	<0.001	<0.001	0.410	0.066	<0.001	0.089
EPA Interim Drinking Water Standards ^b	0.05	1.0	0.01	0.05	--	0.3 ^c	0.05	0.01

^aSee Figure 3-10 for locations^bFederal Register, Dec 24, 1975^cRecommended Limit from Manual for Evaluating Public Drinking Water Supplies, U.S. Public Health Service, 1969

TABLE 9-2

POTENTIAL CANCER CASES AVOIDED AND COST
PER POTENTIAL CANCER CASE AVOIDED
FOR RIVERTON SITE

A. NUMBER OF POTENTIAL CANCER CASES AVOIDED			
<u>Options:</u>	<u>I</u>	<u>II</u>	<u>Removal (5 mi-10 mi)</u>
Option Costs (in million \$)	0.46	1.14	6.0-6.4
Years After Remedial Action			
25	0	0.1	2.1
50	0	0.3	4.8
75	0	0.5	7.5
100	0	0.7	10.2
Potential Cancer Cases After 100 yr	10.2	9.5	0
B. COST PER POTENTIAL CANCER CASE AVOIDED (Million \$)			
<u>Options:</u>	<u>I</u>	<u>II</u>	<u>Removal (5 mi-10 mi)</u>
Option Costs (in million \$)	0.46	1.14	6.0-6.4
Years After Remedial Action			
25	--	11.4	2.9-3.1
50	--	3.8	1.3-1.3
75	--	2.3	0.8-0.9
100	--	1.6	0.6-0.6