PHASE II - TITLE I ENGINEERING ASSESSMENT OF INACTIVE URANIUM MILL TAILINGS LOWMAN SITE, LOWMAN, IDAHO

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.

FB&DU 130-17

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GJT-17

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

LOWMAN SITE
LOWMAN, IDAHO
DECEMBER 1977

Prepared For

U.S. DEPARTMENT OF ENERGY
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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 entitled, "Phase II - Title I Engineering Assessment of Radioactive Sands and Residues, Lowman Site, Lowman, Idaho", was prepared under the U.S. Energy Research and Development Administration (ERDA) Contract No. E(05-1)-1658. It is one of a series of reports on inactive uranium millsites, and addresses 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. Chapter 1 of this report is a summary and is published under separate cover for those not requiring all of the details of this report.

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 radiometric 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 studies with notable assistance from the Office of Radiation Programs, Las Vegas, Nevada

(2) Michigan Chemical Corporation

(3) EG&G; Las Vegas, Nevada; Mr. Jack Doyle; for aerial photography

(4) Center for Health and Environmental Studies, Brigham Young University, Provo, Utah; for socioeconomic studies

(5) Mr. Gary Boothe, formerly with Idaho Department of Health and Welfare

ABSTRACT

Ford, Bacon & Davis Utah Inc. has performed an engineering assessment of the problems resulting from the existence of radioactive uranium sand residues at the Lowman, Idaho site. The Phase II - Title I services normally include the preparation of topographic maps, the performance of core drillings and radiometric measurements sufficient to determine areas and volumes of tailings and other radium-contaminated materials, the evaluation of resulting investigation of site hydrology and meteorology, and the evaluation and costing of alternative corrective actions.

Radon gas release from the 90,000 tons of sand residues at the Lowman site constitutes the most significant environmental impact, although external gamma radiation is also a factor. The two alternative actions presented are dike construction, fencing, and maintenance (Option I); and consolidation of the piles, addition of a 2-ft-thick stabilization cover, and on-site cleanup (Option II). Both options include remedial action at off-site structures. Cost estimates for the two options are $393,000 and $590,000.

Reprocessing the sand residues for uranium recovery 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 $0^{o}C$, 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 x 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 x 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.
μR/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 x 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 x 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

SUMMARY

CHAPTER 1

SUMMARY

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 Lowman site, evaluations of the following factors were included:

(a) Exhalation of radon gas from the residues

(b) On-site and off-site direct radiation

(c) Land contamination from windblown residues

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(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 sand residues

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

(a) Minimum remedial action, which amounts to construction of a dike and fencing, maintenance, and off-site remedial action

(b) Consolidation of the sand residue piles, stabilization with 2-ft of cover, fencing, and off-site remedial action

The estimated costs of carrying out the remedial work to implement each option 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 Sale 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

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*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.

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 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 summarized 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 at the Lowman site was performed from September 20 through September 23, 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 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 Lowman millsite is located in Boise County approximately 75 mi northeast of Boise, Idaho in the Boise National Forest. The site is in a pine-covered mountain valley on the western slope of the Sawtooth Mountain range at an elevation of 4,000 ft above sea level. It rests on a west-facing mountain terrace. Drainage from the site is into Clear Creek just above the junction of Clear Creek and the South Fork Payette River. 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 original owner, and only operator, was the Porter Brothers Corporation of Boise, Idaho. The site now is owned by Velsicol Chemical Corporation, the successor to the former owner, Michigan Chemical Corporation. The plant became operational in 1955 and operated until 1960. During that time approximately

200,000 tons of dredge product obtained from Bear Valley, 20 mi north of Lowman, were processed. The process used was mechanical rather than a chemical process. Columbite-euxenite and monazite concentrates and other by-products such as magnetite, ilmenite, zircon, and garnet were extracted from the ore.

1.2.3 Present Condition of the Site

Figure 2-3, Chapter 2, is a descriptive map of the site today. Some concrete foundations, a few small sheds, and some debris are all that remain of the mill structures. The just over 90,000 tons of sand residues remaining on the site are in several piles. All of these sands are radioactive to varying degrees. The radioactive sands and residues are scattered throughout the 37-acre site in 10 locations covering about 5 acres. None of these materials have been stabilized. Some of the more radioactive sands have been eroded by water down a steep slope on the west side of the site and into an old settling pond adjacent to Clear Creek.

The site is about 80% covered with native grasses and trees, but there is no vegetation on the piles of sand. There is no fencing around the site, although some remnants of a barbed-wire fence are evident. Since the field survey work, a locked and posted gate has been installed to control vehicle access to the site.

1.2.4 Residues and Soil Characteristics

The residues are angular, dense, coarse-grained sand of several colors. Black sands are dense material, primarily magnetite; the red sands are garnet. Grey and white sands are also residues of the mechanical separation process and were deposited along the upper edge of the slope above Clear Creek. Table 2-1, Chapter 2 is a listing of the amounts of these materials on the site.

The soil beneath the sand residues is mountain loam, nearly black in color, with gravely aggregates resulting from glacial deposits in some locations.

1.2.5 Geology, Hydrology, and Meteorology

The Lowman millsite is located on a glacial terrace, which has been incised by Clear Creek to the west of the site and is bordered by a ridge to the east. A lower river-laid terrace, on which a settling pond area was constructed, is adjacent to the higher millsite terrace. The glacial terrace material is composed of deep sandy and loamy soils, gravels, sands, boulders, and cobbles. The lower alluvial terrace is river-run material primarily of granitic origin. Igneous granite bedrock (granodiorite) of the Idaho batholith underlies the site. This granite is fractured and weathered. Bedrock is exposed in the stream bed and forms the escarpment to the east of the site. Figure 2-4, Chapter 2 is a simplified stratigraphic section of the area.

The flowing surface waters near the site consist of Clear Creek, the South Fork Payette River, and the intermittent flow in ditches on the site. Clear Creek is a swiftly flowing stream that intersects the South Fork Payette River approximately 0.5 mi south of the site. It is possible that the lower terrace which borders the creek could be eroded by flood waters of Clear Creek, with resulting undercutting and erosion of the residue piles. However, there is no evidence that such flooding has occurred.

Contamination of the surface waters could occur by physical transport of the sands as a result of overland runoff and by seepage through the pile into the waters. Placement of the pile parallel to the slopes, which tends to trap water behind the pile, has encouraged seepage into the surface waters. The degree of physical transport from the site has been aggravated by the steep banks of the sparsely vegetated piles, where some slopes have gullies up to 10 ft deep. Rill erosion is occurring on the cut behind and adjacent to the mill foundations. The ridge east of the pile limits the catchment area near the site; however, a substantial trench was constructed to convey process water from the eastern slope to the mill during operations. This ditch continues to channel runoff, and this concentration of flow aggravates erosion.

Shallow unconfined aquifers characterize the hydrology of the area. Clear Creek and the South Fork Payette River are gaining streams fed by flows from unconfined ground waters. The terrace materials tend to filter sediments from the waters and act as buffers to regulate overland and subsurface flow. The interface between the unconsolidated surficial materials and bedrock acts as the surface for lateral ground water flow. Seeps and springs are common in the area, particularly at the exposure of this interface. One such spring lies at the southern margin of the pile relatively near the source of domestic water for a trailer home. Three wells in the area are federal government wells, but they have not been monitored. There is no problem associated with confined ground waters at the site because there are no confined ground waters associated with the igneous bedrock of the Idaho batholith.

Average annual precipitation at the site ranges between 20 to 25 in., much of which comes as snow pack. High-intensity rainstorms are infrequent, but such a storm at the site could result in serious erosion of the more susceptible areas of the pile. The strongest winds blow up and down the valley in a north-south direction, but the local land relief and the forest canopy tend to act as windbreaks and protect the sands from wind erosion.

1.3 RADIOACTIVITY AND POLLUTANT IMPACTS ON THE ENVIRONMENT

A significant fraction of the total radioactivity originally in the ore remained in the residue sands after processing. 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 residue sands. Although these radionuclides occur in nature, their concentrations in the residue sands 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 six locations in the vicinity of the Lowman piles. The locations and values of the radon measurements are shown in Figure 3-3, Chapter 3. The one 24-hr on-site measurement averaged only 1.8 pCi/l of radon. Four 24-hr measurements of atmospheric radon indicated an average background concentration of 1.2 pCi/l for the Lowman area.

1.3.1.2 Direct Gamma Radiation

The range of natural background values in the Lowman area was between 10 and 12 μR/hr, averaging 11 μR/hr as measured with an energy-compensated Geiger Mueller detector.(2) Above the surface of the ore piles, gamma rates were measured as high as 2,450 μR/hr and 1,220 μR/hr over the residue piles.

1.3.1.3 Windblown Contaminants

Background gamma radiation rates were reached within 0.2 mi to the north and 0.1 mi in the other directions from the site. The results of the EPA gamma radiation survey around the site are shown in Figure 3-9, Chapter 3. The background line closely follows the area where the piles are located.

A surface soil sample taken 0.1 mi north of the site contained 4 times background levels of ^{226}Ra (1.1 pCi/g). On-site soil samples had radium concentrations from background to 15 times average radium background concentration. However, one sample near Clear Creek and near the base of the grey sand pile contained 200 pCi/g of radium. This sample probably contained sand eroded from the pile by surface run-off.

1.3.1.4 Ground and Surface Water Contamination

Two surface water samples from Clear Creek upstream and downstream from the Lowman site were analyzed for ^{226}Ra. The upstream sample contained 0.16 pCi/l of radium; only a trace of radium was found in the downstream sample. The radium content of water from a spring south of the site was 0.12 pCi/l. These results indicate no contamination of ground and surface water from radium leached from the piles.

1.3.1.5 Soil Contamination

The transport of radium into the subsoil beneath the piles extends to 2 to 3 ft below the pile-subsoil interface before reaching twice the average background level of radium concentration in local soil samples (1.1 pCi/g). A few isolated locations were found where deeper contamination exists.

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:

EGR	RDC[a]	Recommendations
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

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[a] Based 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.

[b] mR/hr = milliroentgen per hour, a measure of gamma radiation; 1 mR/hr = 1,000 μR/hr.

[c] WL = 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 μR/hr above background is used in such circumstances. Average background in the Lowman area was determined in this study to be 11 μR/hr. As a guideline for the land beyond the site, if residual gamma levels are less than 10 μR/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 ^{226}Ra content of ground and surface water should meet applicable state and federal standards.

1.3.3 Potential Health Impact

Radon gas exhalation from the sands and residue piles and the subsequent inhalation of radon daughters account for most of the total dose to the population from the Lowman 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 0.2 mi of the piles where gamma radiations are 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 cover 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 Lowman 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).(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 (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.(5)

For the purpose of the Lowman sand residue 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 predictions of radon concentrations in excess of background values, it is estimated that the pile radon-induced lung cancer risk to individuals 0.5 mi from the site is 2.2×10^{-6} per person per year. The health effect rate for background radon is approximately 5.2×10^{-5} per person per year, or about 24 times that attributable to pile radon. The average lung cancer risk due to all causes for Idaho residents is 1.0×10^{-4} per person per year.(6)

As a result of the low population density and the low radiation levels of the sand residues at the Lowman site, the potential health impact of the piles is minimal.

1.3.4 Nonradioactive Pollutants

Four water samples were taken from the vicinity of the Lowman site and analyzed for heavy metal content. Two samples were from Clear Creek upstream and downstream from the site, and two samples were from a well and a spring downgradient from the site. None of the samples indicated leaching of nonradioactive heavy metals from the site.

1.4 SOCIOECONOMIC AND LAND USE IMPACTS

The area near the site is used as forest land or for recreation. Much of the land is administered by the U.S. Forest Service. There are no population concentrations near the site, although the community of Lowman has a general store, a service station, a lodge, and a motel. Some of the private tracts near the site have been subdivided into 1-acre lots for summer homes. One such tract is located across the river from the site. Projected land uses are similar to present land uses, with increased development of lots for year-round as well as for vacation purposes.

Single 1-acre lots sell for approximately $2,500 near the site area. The presence of the residue sands has not affected land uses or values of nearby land, although the use of the site has been restricted by the sands and the aesthetic quality of the site has been diminished by the sparsely vegetated slopes and abandoned property on the site.

1.5 RECOVERY OF RESIDUAL VALUES

Estimates of the uranium content of the 15,000 tons of gray sand residues and ore at the site by the AEC indicate an average U_3O_8 concentration of 0.19%.

The Lowman ore was processed using physical separation methods; consequently, the conventional chemical techniques would not be economically feasible. In addition, the limited amount of material available precludes economic recovery.

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.

Option II includes consolidation and stabilization of the residue piles with 2 ft of earth cover. This cover would greatly reduce the water erosion presently occurring. Gamma radiation would be reduced to background levels but radon exhalation would be reduced only 30% by the 2-ft thickness of cover material.

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 Lowman, Idaho area prior to 1973. A subsequent field survey identified seven off-site areas where use of the radioactive sands was suspected or confirmed. The cost of remedial action for these locations has been estimated to be $50,000. No significant contamination from windblown sands has been detected; thus, no separate cost for cleanup of windblown sands has been included. Therefore, the total remedial action estimated cost for off-site structures is $50,000, exclusive of engineering costs and contingency.

An extended series of measurements, such as required in the full application of the Grand Junction remedial action criteria, might modify the actual number of locations included in the remedial action. The location 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

No alternative disposal site has been considered for the Lowman radioactive residue sands. With implementation of Option II, the sands would be isolated hydrologically in a pit with a compacted clay liner and stabilized at the present site to meet the criteria for long-term storage.

1.9 REMEDIAL ACTIONS AND COST BENEFIT ANALYSES

1.9.1 Remedial Action Options

The two remedial actions are summarized in Table 1-2.

Option I consists of construction of an earthen dike between Clear Creek and the grey sand residue, installation of security fencing surrounding the site, and annual monitoring and maintenance. Also included is corrective action at two off-site locations where the radioactive sands were used in construction activities. The estimated cost of Option I is $330,000.

Under Option II, all of the radioactive materials and debris would be gathered onto one pile on the site, then stabilized with 2 ft of earth cover and isolated hydrologically from the environment. The resulting 4-acre pile would be fenced. Monitoring, maintenance, and off-site remedial action would be as in Option I. The estimated cost of Option II is $520,000.

1.9.2 Cost-Benefit Analyses

The principal reasons for adoption of the two remedial options are (a) to reduce further deterioration of site conditions through control of erosion, and (b) to limit access so that the sands cannot be removed from the site. Population and off-pile radiation levels are so small that the health benefits associated with the remedial actions are negligible.

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 Contamination	Tailings Removed for Private Use	Other Hazards On-site
ARIZONA										
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
COLORADO										
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
IDAHO										
Lowman	U	R	N	No	Yes	Yes	No	No	Yes	No
NEW MEXICO										
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
OREGON										
Lakeview	U	M-UO	N	Yes	No	Yes	Yes	No	No	No
TEXAS										
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 Contamination	Tailings Removed for Private 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.

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[a] This table does not necessarily represent conditions at the present time.

TABLE 1-2

SUMMARY OF REMEDIAL ACTION OPTIONS AND EFFECTS

Option Number	Cost[1] ($000)	Description	Benefits	Adverse Effects
I	330	Dike construction, fencing, monitoring, maintenance, and off-site remedial action	A,B	V,W,X,Y
II	520	Consolidation of sands, 2-ft stabilization, fencing, monitoring, maintenance, and off-site remedial action	A,B,C,D, E,F,G	Z

Definition of Benefits

A. Better security
B. Sands kept from entering river
C. Sands protected from erosion by wind or water
D. Gamma radiation reduced to near-background levels
E. Radon exhalation reduced by 30%
F. Minimum maintenance required
G. Large portion of site available for other purposes

Definition of Adverse Effects

V. Little decrease in erosion
W. No decrease in gamma radiation
X. No decrease in radon exhalation
Y. Entire site completely unusable for any purpose
Z. Part of site completely unusable for any purpose

Note

[1] Costs 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 Lowman, Idaho"; 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; EPA-520/4-76-013; 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.

CHAPTER 2

SITE DESCRIPTION

CHAPTER 2

SITE DESCRIPTION

The purpose of this chapter is to describe the site at Lowman, Idaho and the characteristics of the radioactive materials and residues present on the site.

2.1 LOCATION

The millsite and residue area is located approximately 0.5 mi northeast of Lowman, Idaho in Boise County. Lowman is approximately 75 mi northeast of Boise, Idaho. More specifically, the site is in Section 27, Township 9 North, Range 7 East, Boise Principal Meridian, at 44 deg 35 min 10 sec north latitude and 115 deg 36 min 30 sec west longitude. A photograph of the site and surrounding areas is shown in Figure 2-1.

2.2 TOPOGRAPHY

The topography of the site is characterized by steep, pine-covered mountains of the Boise National Forest. The location is in the western slope drainage basin of the Sawtooth Mountain Range, whose peaks 60 road miles to the east rise to over 10,000 ft. Mountain peaks in the immediate vicinity of the site rise to elevations of over 6,000 ft. The topography of the approximately 37-acre site is shown in Figure 2-2.

2.3 OWNERSHIP

The site now is owned by Velsicol Chemical Corporation, successor to the Michigan Chemical Corporation of Chicago, Illinois. Michigan Chemical acquired it from the original owners and developers, the Porter Brothers Corporation of Boise, Idaho.

2.4 HISTORY OF MILLING OPERATIONS AND PROCESSING(1)

The mill operated from 1955 to 1960 for the recovery of a columbite-euxenite concentrate and a monazite concentrate, plus other potentially valuable by-products, such as magnetite, ilmenite, zircon, and garnet. The mill feed was a jig concentrate of sands obtained from the dredging of placer gravels obtained from Bear Valley, 20 mi north of Lowman. The jig concentrate was trucked to the mill for further beneficiation.

The final concentrates were treated on a toll basis for the Porter Brothers Corporation by the Mallinckrodt Chemical Works at Hematite, Missouri. Recovered at the Mallinckrodt plant were columbium and tantalum pentoxides, uranium oxide, rare earths,

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(1)See end of chapter for references.

titanium, and thorium-iron residues. Porter Brothers Corporation held a contract with the AEC for the sale of the uranium oxide. It also held a contract with the General Services Administration covering the sale of the columbium-tantalum pentoxides.(2) Some by-product magnetite and ilmenite were shipped to the AEC in Las Vegas, Nevada, for stemming material at the Nevada Test Site, and some of the garnet sands were used for sand blasting.

The milling process consisted of wet and dry circuits. In the wet portion, the black sand was sized and magnetite removed by an electromagnetic separator. Two classifiers deslimed the feed, removing 2.7 specific gravity solids at minus-65 mesh from the sands.

Ilmenite, garnet and a small amount of magnetite were removed by induced-roll separators in the dry circuit. A columbite-euxenite bulk product was removed from monazite in a high-tension separator. The columbite-euxenite and monazite concentrates then were separately and alternately treated in a single gravity concentration circuit consisting of an air-tabling and a wet-tabling operation.

2.5 PRESENT CONDITION OF THE SITE

Figure 2-3 is a descriptive map of a portion of the site as it now exists. The original mill buildings were removed from the site, but the concrete foundations of the old mill building remain. The concrete walls of the ore storage bunkers, the scale house, wooden water tank, some sheds, and a scrap pile remain on the site. Gravel and dirt roads interlace the site.

There are about 10 separate locations on the site where radioactive sands or residues from the milling operations were deposited. One pile of original ore (dredge concentrate) remains just northeast of the old mill location. Most of these piles are on the natural bench of the site, but some grey and white sands are on the steep edge which slopes down (west) into Clear Creek. These sands (especially the grey) have been eroded by water from the site to some extent. A settling pond in the low part of the site has been the main collector of sands which have eroded off the steep-banked site. A metal-lined drainage ditch that was installed to divert upslope drainage away from the sands remains in a semi-operative condition. The sand areas, millsite, and ore storage areas occupy about 18 acres of the 37-acre site. The combined area of all the sands and ore is approximately 5 acres.

The site is about 80% covered with native grasses and trees, but there is no vegetation on the sand piles. No stabilization cover of any type has been placed on the residues or sands. At the entrance to the site (from the south) off Idaho State Highway 21, there was a cable barricade that was ineffective in keeping smaller vehicles off the site. There is some barbed-wire fencing in poor condition around the north and east perimeters of the site. Since the field survey work, a locked and posted gate has been installed at the site entrance to control vehicle access.

2.6 RESIDUES AND SOIL CHARACTERISTICS

There are just over 90,000 tons of radioactive sands, residues, and ore on the site as shown in Table 2-1.

No fine grinding nor chemical processing of the ores were performed at the site. The sand residues are angular, dense, coarse-grained, and as a result are fairly resistant to wind erosion. The heavy black sands also are resistant to water erosion.

The soil beneath the sands is sandy loam, brown to black in color and not very thick, as typical of most side-mountain soil. Glacial deposits of aggregates are also found in the site area.

2.7 GEOLOGY, HYDROLOGY, AND METEOROLOGY

2.7.1 Geology

The Lowman millsite is located on a terrace of glacial outwash material which has been incised by the swiftly flowing Clear Creek, to the west of the site, and bordered by a relatively steep-sloped ridge to the east.(3) A smaller river-laid terrace is adjacent to the west side of the millsite at a lower elevation. This terrace was used as the site of a settling pond during mill operations. Granite (granodiorite) bedrock of the Idaho batholith is exposed in the stream bed and along ridge escarpments. The upper terrace material which underlies the site and separates it from bedrock is composed of deep sandy and loamy soils, gravels, sands, boulders, and cobbles. The lower alluvial terrace is made up of riverwash material, primarily of granitic origin.

The bedrock at Lowman is of igneous origin rather than of sedimentary origin. The interface between bedrock and overlying unconsolidated materials is highly variable and influences the ground water flow systems of the area. The rocks are variably fractured and weathered. A simplified stratigraphic section of the bedrock and overlying materials is shown in Figure 2-4.

2.7.2 Surface Water Hydrology

The flowing surface waters near the site consist of Clear Creek, the South Fork Payette River, and ditches on the site. The Clear Creek drainage area is shown in Figure 2-5. Clear Creek merges with the South Fork Payette River at Lowman, which is approximately 0.5 mi south of the site. Clear Creek flows on an essentially bedrock surface and is actively downcutting its channel. It has sufficient channel capacity to carry minor floods, and there is no evidence of erosion of even the lowest terrace, although it is possible that a large flood might top this terrace. Areas of the pile nearest the bank could be subject to erosion by undercutting of the bank, but the only sandy residues that have washed downstream are those which have been eroded from the steep slopes by surface runoff.

Water quality and flooding data for Clear Creek are largely unavailable. There does not appear to be a history of significant flooding of Clear Creek except from the backup of flood waters of the South Fork Payette River. Sampling of surface waters does not indicate any contamination from the radioactive residues although contamination of surface waters near the piles could occur by physical transport of the residues in overland runoff and by seepage from the piles. The physical transport of sand from the piles has been aggravated by the steep banks of the sparsely vegetated piles, the slopes of which have been gullied up to 10 ft in depth by storm runoff. Rill erosion is occurring on the back-cut behind and adjacent to the mill foundations. The ridge to the east of the piles limits the catchment area near the site; however, a substantial trench was constructed during milling operations to convey process water from the eastern slope around the ridge to the mill. The ditch continues to channel runoff and intercepts shallow subsurface lateral flow. This concentration of flow could cause erosion problems on the glacial terrace. The placement of radioactive residues parallel to the slope of the piles traps water on the surface and has acted to discourage runoff and to increase filtration into the sands.

2.7.3 Ground Water Hydrology

Shallow, unconfined aquifers characterize the hydrology of the area. Clear Creek and the South Fork Payette River are gaining streams recharged by flows of unconfined ground waters. The mountain slope land with its veneer of soil overlying fractured bedrock releases waters at a moderate to rapid rate and dries out quite rapidly after snowmelt. The terrace lands, such as that which underlies the site, act as filters of sediment and tend to regulate overland and subsurface flow as waters percolate through the deposits before reaching the creeks and rivers. Subsurface flow at the millsite consists of percolation into the unconfined ground water system with shallow lateral flow along the interface between the unconsolidated materials and the underlying bedrock. Generalized ground water flow directions in the area are shown in Figure 2-6. There are three wells near Lowman, all of which are government wells, but none have been monitored by any government agency.

Only one seep is present on the site itself, but there are several seeps and springs nearby along the interface of the terrace with the underlying bedrock surface. One of these springs is situated along the southern margin of the glacial terrace near the source of domestic water of a nearby trailer home. Some of these springs are recharged by storage from underlying bedrock. Others, such as along the southern margin of the pile, are recharged by infiltration through the terrace deposits.

There is no problem associated with contamination of the confined ground waters of the site because there are no confined ground waters associated with the igneous bedrock of the Idaho batholith.

2.7.5 Meteorology

Virtually no direct information exists regarding the frequency, duration, and intensities of winds at Lowman. The strongest winds are those which blow up or down the valley. Local relief, orientation of streams, valleys, and mountains affect wind direction while irregular terrain and the forest canopy tend to act as windbreaks.

Average annual precipitation at the site ranges between 20 to 25 in. Snowpacks are moderate and snowmelt can occur on and off in late winter months. Runoff is usually spread over a 3- to 4-month period ending in late May. Heavy rainstorms occur approximately once every 10 yr. Such high-intensity rainfall at the site would result in serious erosion of the more susceptible areas of the piles.

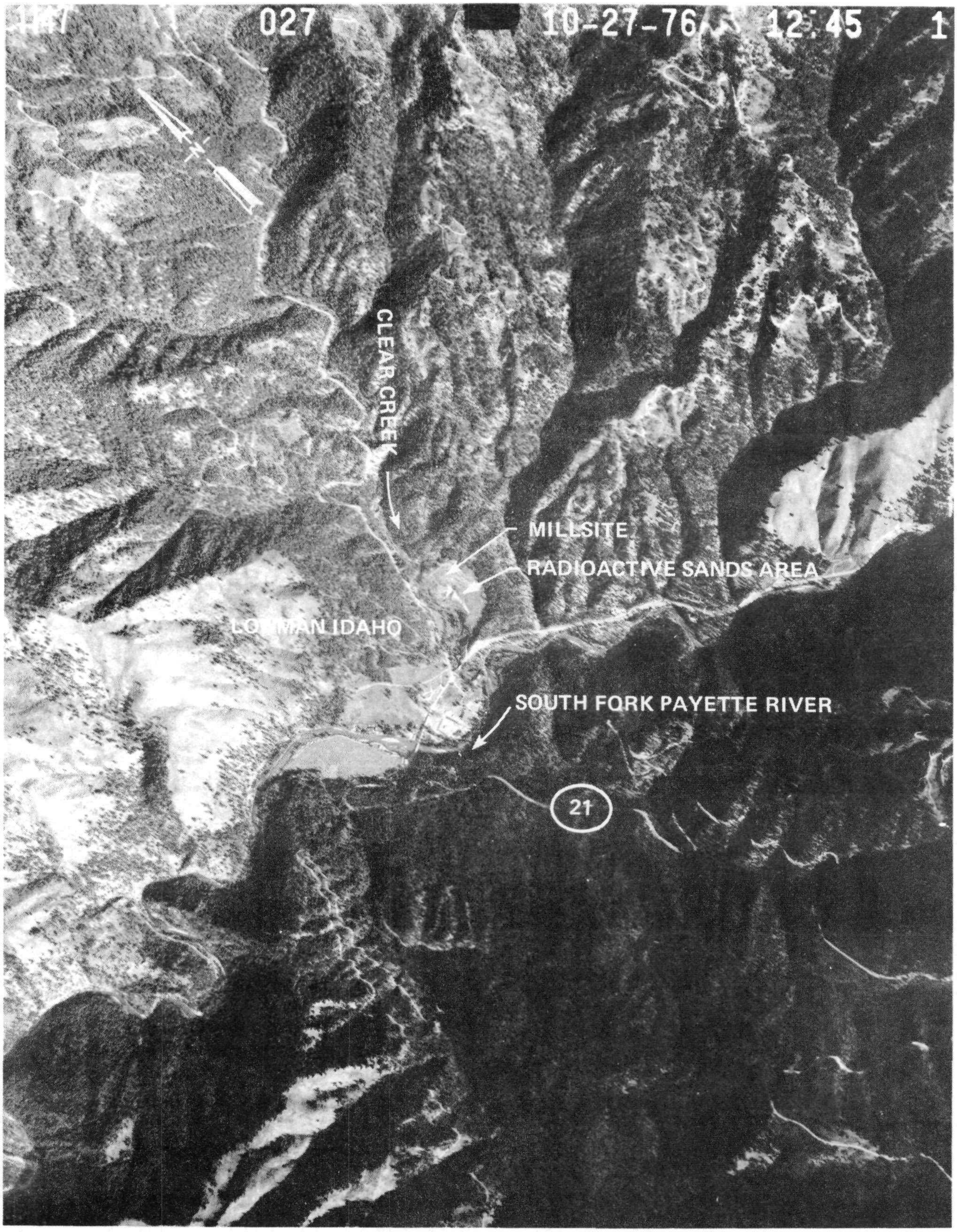

FIGURE 2-1. AERIAL PHOTOGRAPH OF SITE

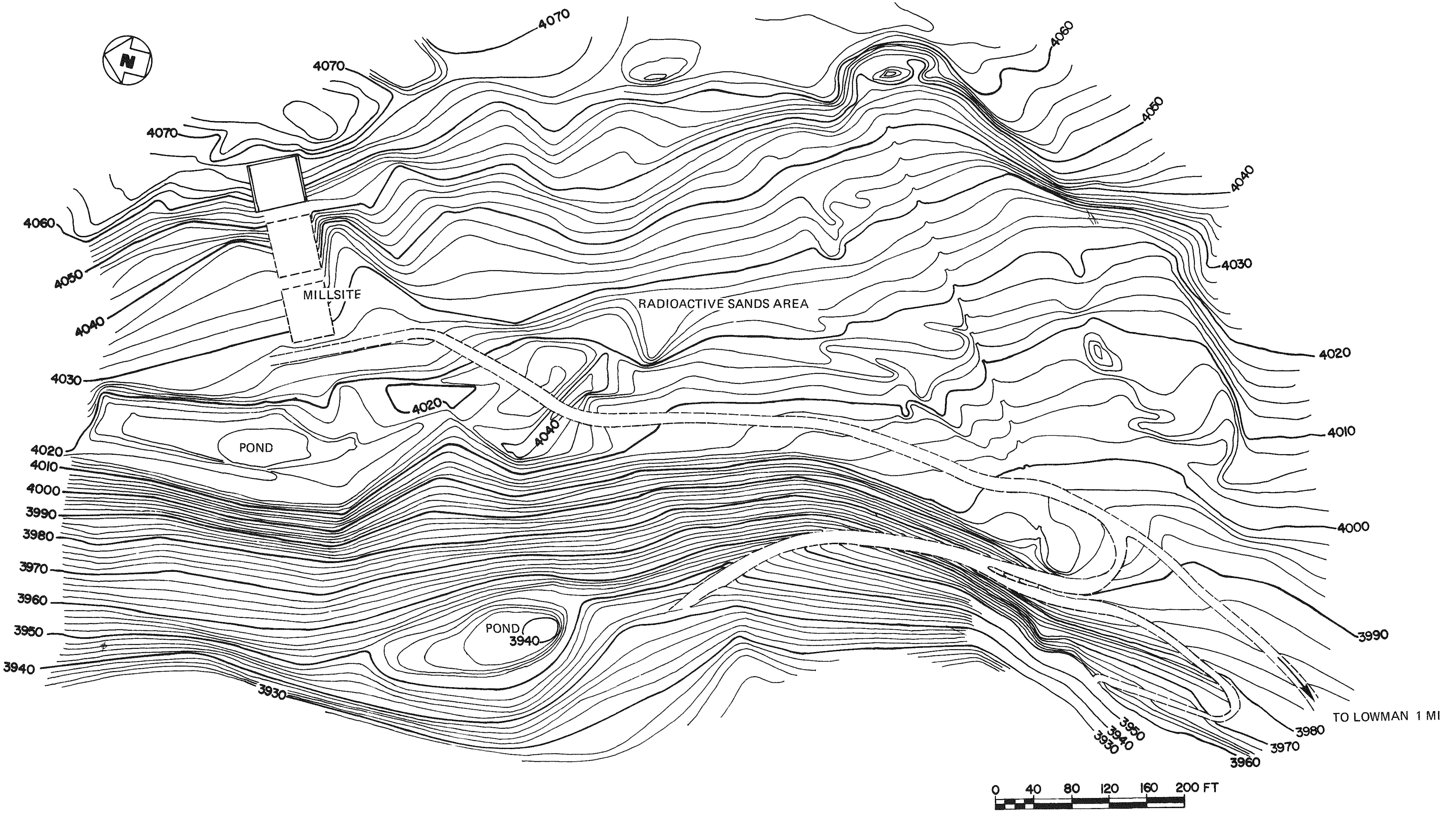

FIGURE 2-2. TOPOGRAPHICAL MAP

130-17

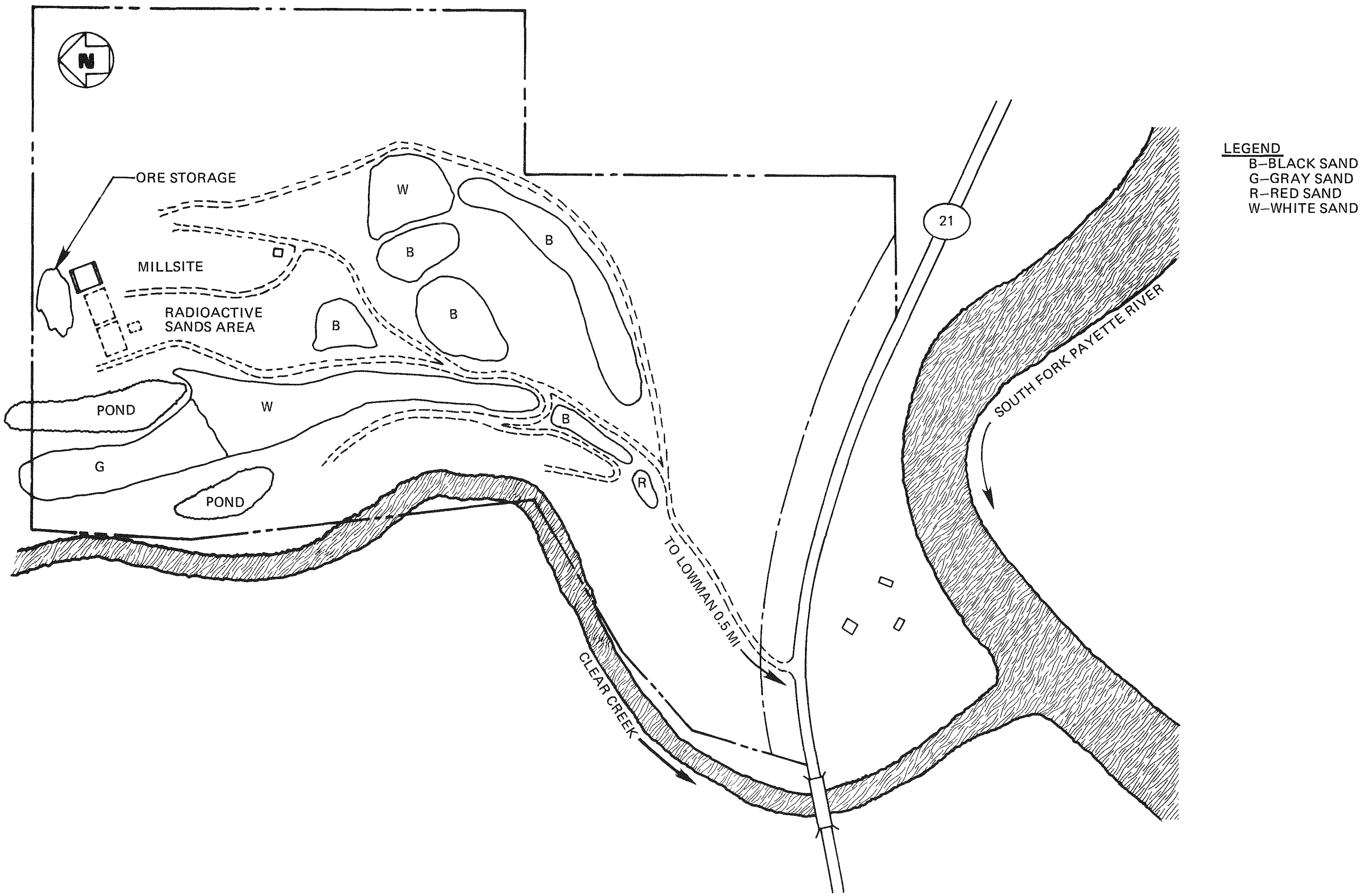

FIGURE 2-3. DESCRIPTIVE MAP

130-17

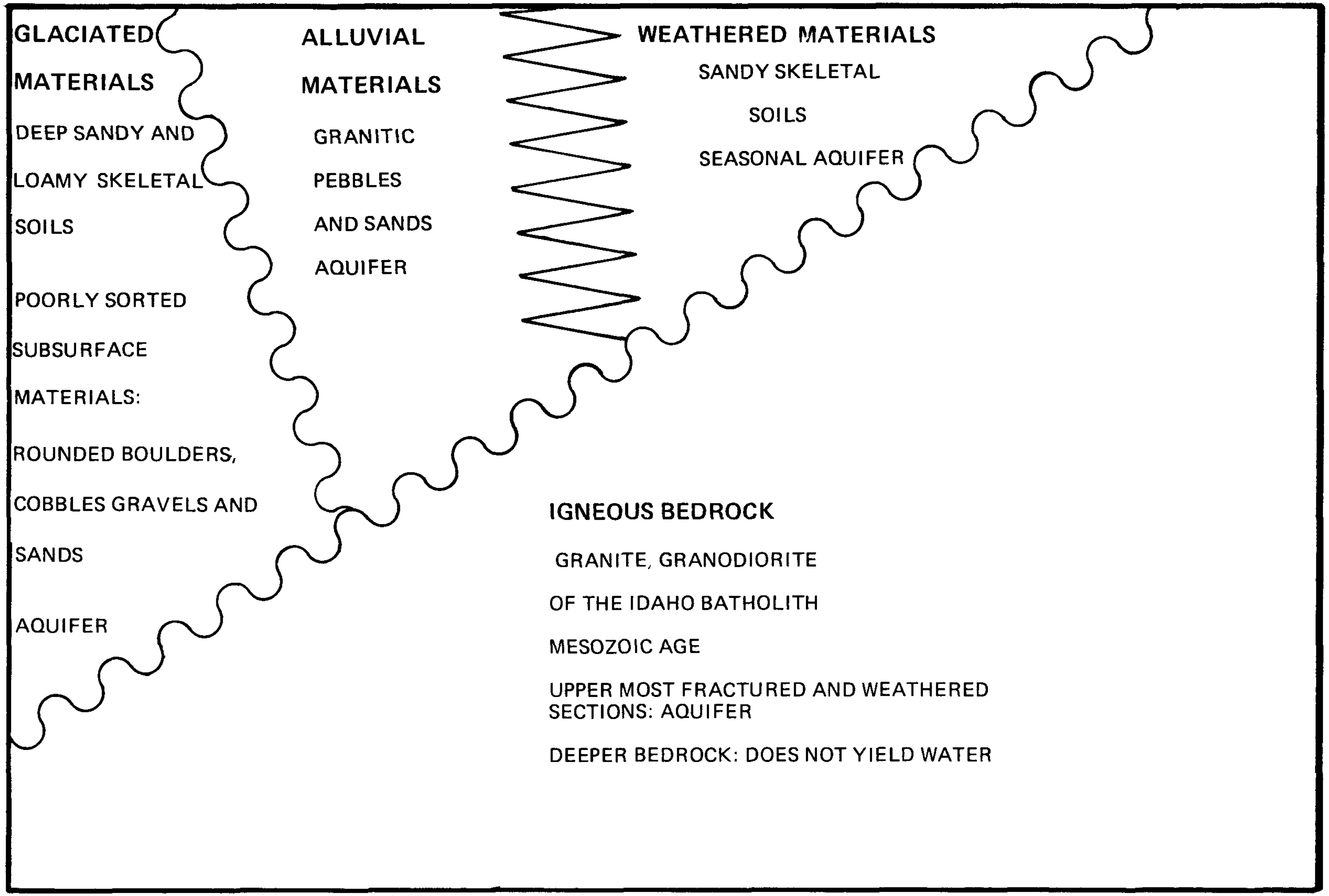

FIGURE 2-4 SIMPLIFIED STRATIGRAPHIC SECTION

130-17

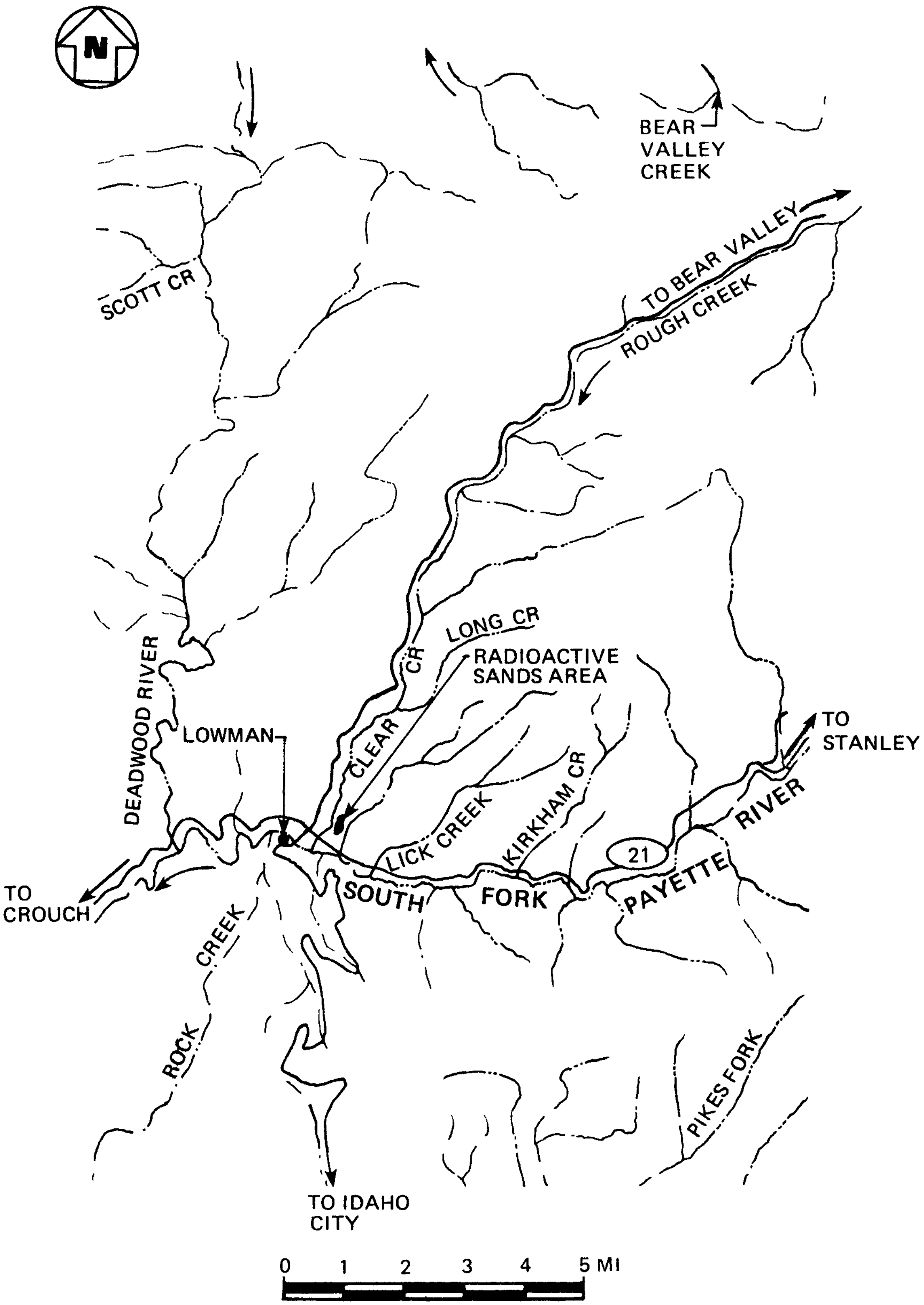

FIGURE 2-5. SURFACE DRAINAGE

130-17

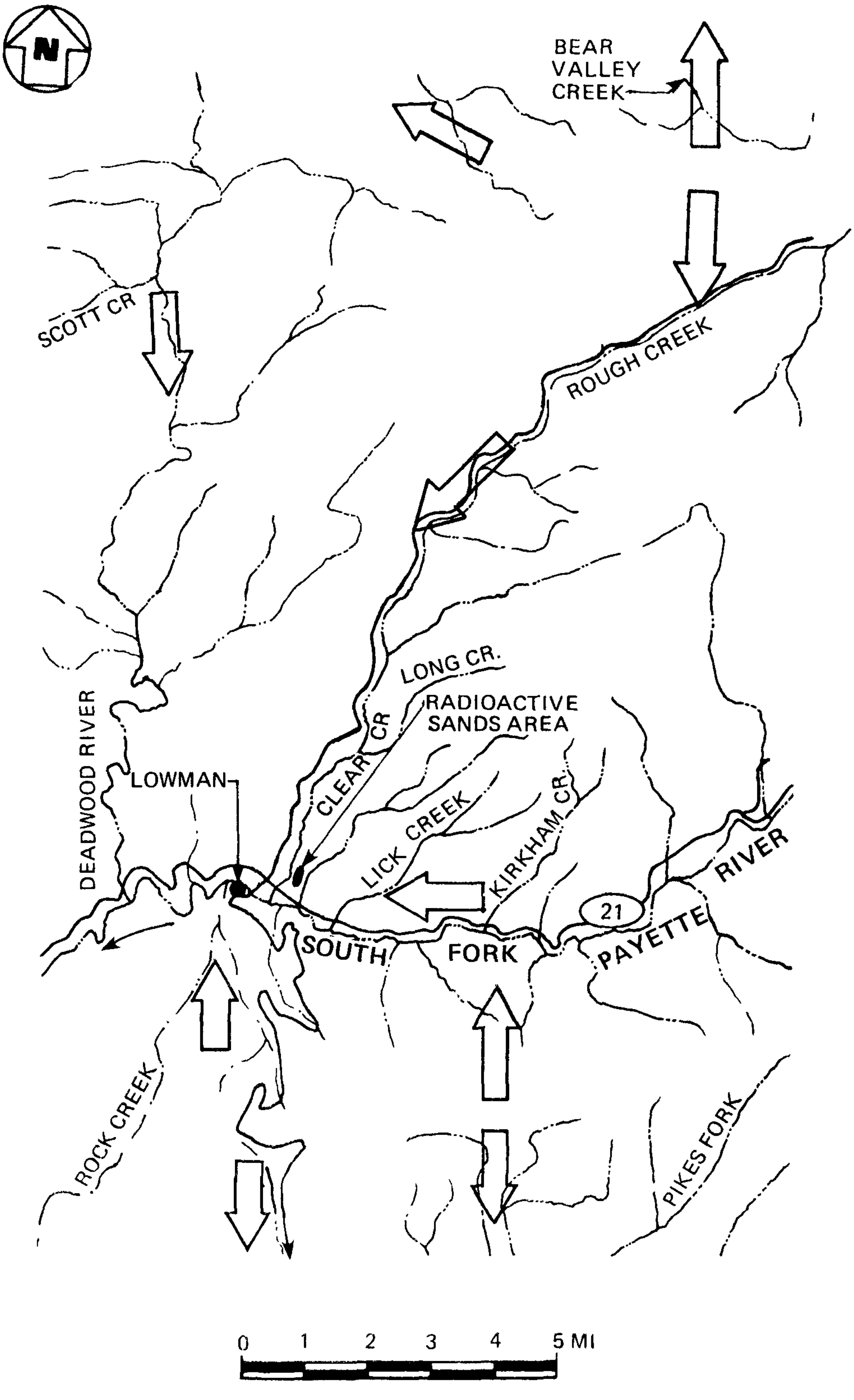

FIGURE 2-6. GENERAL DIRECTION OF GROUND WATER FLOW

130-17

TABLE 2-1

SITE RESIDUE MATERIALS

Material	Weight (Tons)	% U_3O_8
White Sand	50,000	0.01
Black Sand	23,000	0.02
Grey Sand Residue	10,000	0.18
Original Source Ore	5,000	0.22
Rounded Total	90,000	

CHAPTER 2 REFERENCES

1. "Phase I Reports on Conditions of Radioactive Sands and Residues at Lowman, Idaho"; AEC: Grand Junction, Colorado; 1974.

2. S. H. Dayton; "Radioactive Black Sand is Yielding Columbite Concentrate at Idaho Mill"; Mining World; May 1958.

3. R. E. Williams and D. D. Eier: "Hydrogeologic Study of Porter Brothers Inc. Mill Site; Lowman, Idaho"; Moscow, Idaho; 1976.

CHAPTER 3

RADIOACTIVITY AND POLLUTANT IMPACT ON THE ENVIRONMENT

CHAPTER 3

RADIOACTIVITY AND POLLUTANT IMPACT ON THE ENVIRONMENT

The principal objective of the assessment in this chapter is to determine the magnitude and characteristics of the radiation emitted from the Lowman uranium sand residue piles and the resulting potential exposure to the population residing and working in the vicinity of Lowman, Idaho. In addition, this chapter describes briefly the potential radioactive and chemical pollutants and their pathways in the environment. The notations and abbreviations used are given in Table 3-1.

3.1 RADIOACTIVE MATERIAL CHARACTERISTICS

Many elements spontaneously emit subatomic particles; therefore, these elements are radioactive. For example, when the most abundant uranium isotope, ^{238}U undergoes radioactive decay, it emits a subatomic particle called an alpha particle; the ^{238}U after undergoing decay becomes ^{234}Th, which is also radioactive; and ^{234}Th subsequently emits a beta particle and becomes ^{234}Pa. As shown in Figure 3-1, this process continues with either alpha or beta particles being emitted, and the affected nucleus thereby evolves from one element into another. It is noted in Figure 3-1 that ^{230}Th decays to ^{226}Ra, which then decays to ^{222}Rn, an isotope of radon. Radon, a noble gas, does not react chemically. The final product in the chain is ^{206}Pb, a stable isotope that gradually accumulates in ores containing uranium. Uranium ore contains ^{226}Ra and the other daughter products of the uranium decay chain. One of the daughters of ^{226}Ra is the isotope ^{214}Bi, which emits a significant amount of electromagnetic radiation known as gamma radiation. Gamma rays are very similar to X-rays, only more penetrating. The ^{214}Bi is the principal contributor to the gamma radiation exposure in the uranium-radium decay chain.

Besides knowing the radioactive elements in the decay chain, it is also important to know the rate at which they decay. This decay rate, or activity, is expressed in curies (Ci) or picocuries (pCi), where 1 pCi equals 10^{-12} Ci or 3.7×10^{-2} disintegrations per second. The picocurie often is used as a unit of measure of the quantity of a radioactive element present in soil, air, and water.

Another important parameter used in characterizing radioactive decay is known as the "half life", $T_{1/2}$. This is the time that it takes for half of any initial quantity of the radioactive atoms to decay to a different isotope. For example, it takes 4.5×10^9 yr for half the ^{238}U atoms to decay to ^{234}Th. Similarly, half of a given number of ^{222}Rn atoms will decay in 3.8 days.

The activity and the total number of radioactive atoms of a particular type depend upon their creation rates as well as their half life for decay. If left undisturbed, the radioactive components of the decay chain shown in Figure 3-1 all reach the same level of activity, matching that of the longest-lived initiating isotope. This condition is known as secular equilibrium. At Lowman, the sand residues remaining after mechanical separation of the ore contain both uranium and radium.

3.2 RADIATION EFFECTS

The radioactive exposure encountered with uranium mill tailings occurs from the absorption within the body of the emitted alpha and beta particles, and gamma radiation. The range of alpha particles is very short; they mainly affect an individual when the alpha emitter is taken internally. Beta particles have a much lighter mass than alphas, and have a longer range; but they still cause damage mainly to the skin or internal tissues when taken internally. Gamma rays, however, are more penetrating than X-rays and can interact with all of the tissue of an individual near a gamma-emitting material.

The biological effects of radiation are related to the energy of the radiation; therefore, exposure to radiation is measured in terms of the energy deposited per unit mass of a given material. In the case of radon and its daughter products, the principal effect is from alpha particles emitted after the radon and its daughter products are inhaled.

The basic units of measurement for the alpha particles from short-lived radon daughters are the working level (WL) and the working level month (WLM). The working level is defined as any combination of the short-lived radon daughters in a liter of air that will result in the ultimate emission of 1.3×10^5 MeV of alpha energy. The working level is so defined because it is a single unit of measure, taking into account the relative concentrations of radon daughter products which vary according to factors such as ventilation. One WLM results from exposure to air containing a radon daughter concentration (RDC) of 1 WL for a duration of 170 hr.

The basic units of measurement for gamma radiation exposure and absorption are the roentgen (R) and the rad. One R is equal to an energy deposition of 88 ergs/g of dry air, and 1 rad is the dose that corresponds to the absorption of 100 ergs/g of material. The numerical difference between the magnitude of the two units is often less than the uncertainty of the measurements, so that exposure of 1 R is often assumed equivalent to an absorbed dose of 1 rad or a gamma dose of 1 rem. (Refer to Glossary.)

3.3 NATURAL BACKGROUND RADIATION

There are several sources of radiation that occur naturally in the environment. Natural soils contain trace amounts of uranium, thorium, and radium that give rise to radon gas and to alpha, beta, and gamma radiation. The average background value in 9 off-site soil samples for each member of the uranium decay chain, assuming equilibrium, was 1.7 pCi/g.(1) The sample locations taken within a 90-mi radius of Lowman, and the corresponding ^{226}Ra concentrations are shown in Figure 3-2. No previous measurements are available for the area. Another natural source of radiation in the environment arises from the decay of ^{232}Th, the predominant thorium isotope. The half-life of ^{232}Th is 1.4 x 10^{10} yr. It is also the parent of a decay chain containing isotopes of radium and radon. The average background value in the same off-site samples for each member of the thorium decay chain, assuming equilibrium, is about 1.2 pCi/g of soil. Table 3-2 lists the major background radioactive sources. It is noted that background values of the radium and thorium chains vary with locations by factors of 2 and 5, respectively.

Background values of radon concentrations were measured at four locations using continuous radon monitors supplied by ERDA.(2) An average outdoor value of 1.2 pCi/l was obtained from the 24-hr samples for the vicinity of Lowman. However, the range of the measurements extends from 1.1 to 1.3 pCi/l.

Background gamma ray rates, as measured at 3 ft above the ground, also were determined at several locations greater than 0.2 mi from the site by using a calibrated and energy-compensated Geiger Mueller detector. A value of 11 μR/hr was established as the average background level, but the values ranged from 10 to 12 μR/hr.(1) Cosmic rays are part of the measured background radiation levels. The contribution from cosmic rays is generally dependent upon the altitude and is approximately 5 μR/hr in the Lowman area,(3) or approximately 45% of the measured average background value.

3.4 RADIATION EXPOSURE PATHWAYS AND CONTAMINATION MECHANISMS

As noted previously, the principal environmental radiological implications and associated health effects of uranium mill tailings are related to radionuclides of the ^{238}U decay chain: primarily ^{230}Th, ^{226}Ra, ^{222}Rn, and ^{222}Rn daughters. Although these radionuclides occur in nature, their concentrations in tailings material are several orders of magnitude greater than in average natural soils and rocks. The major potential routes of exposure to man are:

(a) Inhalation of the ^{222}Rn daughters, from decay of ^{222}Rn escaping from the pile; the principal exposure hazard is to the lungs.

(b) External whole-body gamma exposure directly from the radionuclides in the tailings pile (primarily

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(1)See end of chapter for references

from ^{214}Bi) and in surface contamination from tailings spread in the general vicinity of the pile.

(c) Inhalation of windblown tailings; the primary hazard relates to the alpha emitters ^{230}Th and ^{226}Ra, each of which causes exposure to the bones and the lungs.

(d) Ingestion by man of ground or surface water contaminated from either radioactivity (primarily from ^{226}Ra) leached from the tailings pile or from solids physically transported into surface water.

(e) Erosion and removal of tailings material from the pile by flood waters or heavy rainfall; this can create additional contaminated locations with the same problems as the original tailings pile.

(f) Physical removal from the tailings pile also provides a mechanism for contamination of other locations.

(g) 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 assessment.

The extent of radiation and pollution transport from the pile into the environment is discussed in the following paragraphs.

3.4.1 Radon Gas Diffusion and Transport

Field measurements of the radon exhalation flux from the sand residue piles using the charcoal canister technique(4) are listed in Table 3-3. The current values range from 50 to 150 pCi/m^2-s on the residue piles. The weather was dry during the measurement period but the soil was moist from rain a few days previously. Radon flux depends principally on radium content of the piles. In general, reported values of radon flux vary considerably from time to time at a single sampling location due in part to differing moisture, soil, and climatological factors, to major changes in pile configuration between different locations, and to the difficulty of performing such measurements.

Radon gas above background from the piles is predicted from the model calculation to a distance of 0.4 mi from the site. Measurement locations and corresponding 24-hr average radon concentrations including background are illustrated in Figure 3-3.

Variation of radon concentration at two locations during the measurement period and the concomitant weather conditions are shown in Figures 3-4 and 3-5. The sample location for Figure 3-4 is at the site of the old mill building. Figure 3-5 illustrates the measurements at the motel 0.5 mi southwest of the site. A diurnal variation of ^{222}Rn concentration may be seen in both figures, indicating the presence of a source of ^{222}Rn greater than background near the measurement locations. Thus, the higher-than-normal background values are not merely the result of a high instrument background count. These 24-hr measurements were obtained during atmospheric conditions normal for that time of year (September). Data were not recorded during wind or rainstorms.

Radon concentration measurements taken during this program showed a slight diurnal variation, with nighttime levels being higher than daytime. The increase in concentration is probably the result of an inversion condition and reduced wind velocities. High winds tend to disperse the radon and generally do not result in significantly higher measurements of radon concentration downwind from the pile.

The radon concentration measurements are plotted in Figure 3-6 as a function of distance from the edge of the site. Also shown in the figure are the FB&DU model results. Model calculations were performed with annual meteorology data and conservatively predicted meteorology to provide an additional estimate of the radon concentration in the vicinity of the piles. The FB&DU model first determines radon flux and the total radon releases from the piles with diffusion theory using radium soil concentrations, and pile configurations deduced from the drilling and survey data. Then, the radon transport off-pile is calculated by Gaussian diffusion(5) plus wind drift conditions. The meteorology used for the model predictions was taken at the Lowman Ranger Station during the period 1964 through 1974.

Due to the low radon concentration measured on the site, the model results were used to estimate conservatively the potential health effects resulting from radon diffusing from the Lowman site.

3.4.2 Direct Gamma Radiation

The external gamma radiation (EGR) levels, including background, measured on the site are shown in Figure 3-7. These measurements were taken 3 ft above ground with calibrated energy-compensated Geiger Mueller detectors.(1) The highest gamma radiation rate (2,450 μR/hr) was measured on the ore pile north of the mill area. The next highest radiation rate (1,220 μR/hr) was found on the grey sand residue pile along the top edge of the slope above Clear Creek. Gamma radiation rates were generally well above background rates throughout the area where residue piles are located.

Gamma rate measurements away from the piles, taken at 100-yd intervals, reached background levels within 0.2 mi north of -he site and within 0.1 mi in the other directions. These gamma radiation rate measurements are shown also in Figure 3-7. The reduction of gamma radiation as a function of distance from the piles area is shown in Figure 3-8.

3.4.3 Windblown Contaminants

Another pathway is the result of windblown radioactive sands. Prevailing winds are from the north and south through Clear Creek Valley.

Figure 3-9 shows iso-exposure lines due to the residual windblown sands as determined by EPA.(6) If scattered sands and ore are removed from inside the 10-μR/hr line (toward the piles) or if the pile is covered to provide essentially complete gamma shielding, then the remaining sands outside the line (away from the pile) would produce a new gamma exposure rate, 3 ft above ground, approximately equal to 10 μR/hr.

The 10-μR/hr iso-exposure line extends slightly to the north of the millsite to include the ore stockpile. There is little windblown radioactive material, since the background line closely follows the boundary of the area where the piles are located.

Surface soil samples were taken in the area surrounding the piles.(1) The sample locations and ^{226}Ra concentrations are shown in Figure 3-10.

Surface soil samples taken on-site contain ^{226}Ra in concentrations ranging from background levels to 15 times background. An exception was one sample taken between the lower settling pond and Clear Creek that contained 200 pCi/g of ^{226}Ra. This sample evidently included sand that had washed down the slope from the grey sand pile.

3.4.4 Ground and Surface Water Contamination

Three surface water samples were taken from the vicinity of the Lowman site and analyzed for ^{226}Ra as shown in Figure 3-10.(1) Two samples were taken from Clear Creek, one sample upstream and one downstream from the site. The upstream sample contained 0.16 pCi/l. The sample downstream contained only a trace of ^{226}Ra. The third sample taken from a spring southwest of the site contained 0.12 pCi/l of ^{226}Ra. From the water sample analyses, there is no indication of ^{226}Ra leaching from the Lowman sands into the surrounding ground and surface waters. This finding is consistent with the refractory nature of the Lowman ore and residue sands.

3.4.5 Soil Contamination

The extent of leaching of radium from the residue sands into the soil was determined by drilling hand auger holes in and around the piles and into the soil beneath them. The radioactivity profile was measured in these holes with a Geiger tube probe in a lead shield that collimates the radiation.

The gamma measurements indicated that twice background concentrations of radium were generally reached at depths of 2 to 3 ft below the interface. In a few cases, contamination was 2 to 3 times background radium concentration 3 ft below the pile-subsoil interface, but holes could not be drilled deeper with the hand auger.

3.4.6 Off-Site Sands Use

A mobile gamma survey located sites in Lowman where the gamma radiation rate was above the background level. A follow-up survey was performed at these locations to determine the source of the radiation. The results of these surveys are discussed in Chapter 7.

The Idaho Radiation Control Section, in cooperation with the EPA, measured radon working levels in a commercial establishment in Lowman, where radioactive sands had been used, from December 1973 to June 1974. Working levels ranged from 0.011 to 0.030 with an average of 0.02 for the measurement period. The occupancy factor will be considered in determining the need for remedial action.

The locations at which tailings are on vacant lands or are greater than 10 ft from structures were not subject to the criteria used in Phase II, but could constitute a problem in the future.

3.5 REMEDIAL ACTION CRITERIA

Radiological criteria established for this engineering assessment for possible remedial action applicable to uranium mill tailings are divided into two general categories: criteria applicable to structures with tailings underneath them or within 10 ft,(7) and criteria pertaining to the mill tailings site and open land.(8) Copies of the complete documents establishing these criteria are presented in Appendix A. Also given in Appendix A are the Grand Junction remedial action criteria for structures (10CFR712).

The criteria which apply to the structures are the guidelines published by the Surgeon General of the United States.(7) These guidelines recommend the following graded levels for remedial action in terms of the EGR levels and indoor RDC levels above background found within the dwellings constructed on or near uranium mill tailings:

EGR, mR/hr	RDC*, WL	Recommendation
Greater than 0.1	Greater than 0.05	Remedial action indicated
From 0.05 to 0.1	From 0.01 to 0.01	Remedial action may be suggested

EGR, mR/hr	RDC*, WL	Recommendation
Less than 0.05	Less than 0.01	No remedial action indicated

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*Based 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.

The radiological criteria for decontamination of inactive uranium millsites and for open areas are based upon EGR readings above background, measured 3 ft above ground. Decontamination should result in residual exposures that are as low as practicable. For this assessment the following criteria were used:

(a) For the sand residue piles:

   (1) Sand residue piles should be covered so that residual gamma ray levels do not exceed 0.040 mR/hr above background. The area also should be designated a control area with restricted access.

   (2) Where the site is not considered suitable for long-term stabilization, remove so that residual radium concentration in the soil does not exceed twice background values.

(b) Windblown sand residues in open land areas near to or adjacent to the site:

   (1) If gamma levels are less than 0.010 mR/hr above background, the land may be released for unrestricted use.

   (2) If gamma levels exceed 0.010 mR/hr above background, cleanup should reduce the radium soil concentration to no more than twice background.

   (3) If sand residues removal is not practicable, residual gamma levels should in any part of the area not exceed 0.040 mR/hr above background.

3.6 POTENTIAL HEALTH IMPACT

An assessment has been made of the potential health impact of the sand residues. The six environmental pathways described in paragraph 3.4 were evaluated. A summary of the evaluation of each pathway is presented below:

(a) Radon Diffusion - inhalation of radon daughters from radon diffusion constitutes the most significant pathway and results in the largest estimated population dose.(1,9) In order to estimate the health effects from the pile radon, the model values were used, which indicated elevated radon levels to 0.4 mi from the site.

(b) External Gamma Radiation - gamma radiation above background is measurable to distances up to 0.2 mi from the pile, to the north and 0.1 mi in the other directions. There are no residents in the area. People on-site will receive some gamma exposure until the piles are covered with sufficient material to reduce the gamma radiation. Exposure to the local population within 1.0 mi from the pile has been evaluated and yields a negligible health impact compared with exposure from radon daughters.

(c) Airborne Activity - the lack of significant quantities of windblown sands, toward inhabited areas indicates that direct inhalation or ingestion of tailings particles is a minor component of the total population dose. This is a general result also reported at other uranium tailings piles.(10,11) Stabilization of the Lowman sands against wind erosion will eliminate any gradual accumulation of sands off the site.

(d) Water Contamination - the ^{226}Ra activity in nearby surface water does not indicate contamination from the sands pile but a potential exists for erosion of sands into Clear Creek by surface runoff from rainstorms.

(e) Subsoil Contamination - leaching of radioactive materials into the ground beneath the pile at the millsite is on the order of 2 to 3 ft with isolated areas of deeper contamination.

(f) Physical Removal - radioactive sands which have been placed near a structure or used in its construction are sources for elevated gamma levels and radon daughter concentrations in the structure. Radiation exposure to individuals living or working in these structures can be significant. (For details refer to Chapter 7)

Only the potential health effects from the inhalation of radon daughters (pathway a) are estimated quantitatively in this assessment because it constitutes the most significant pathway.(9,11) Furthermore, it is assumed that the uncertainty in the estimates of the potential health effects from these pathways far exceeds the magnitude of the health effects from other pathways.

It is extremely difficult to predict with any assurance that a specific health effect will be observed within a given time after chronic exposure to low doses of toxic material. 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 basis that the effects are linear, using the conservative assumption of no threshold for the effects. The resulting risk estimators also have associated uncertainties due to biological variability among individuals and to unknown contributions from other biological insults which may be present simultaneously with the insult of interest. No synergistic effects are considered explicitly in this analysis. For the purpose of this engineering study, lung cancer is the potential health effect considered for RDC. The health effects were estimated using both an absolute and a relative risk model.

3.6.1 Assumptions and Uncertainties in Estimating Health Effects

Since radiation exposure from ^{222}Rn daughters is expressed in terms of working levels (WL) and working level months (WLM), total population exposures as well as health risk estimates are based upon these units, i.e. person-WLM. Exposures and resulting health effects often are expressed in terms of rems; however, estimates of the WLM-to-rem conversion factor for internal lung exposure to alpha particles from ^{222}Rn daughters vary by over an order of magnitude. Presently, there are significant differences of opinion related to the choice of an appropriate conversion factor. Consequently, disagreements of calculated health effects from RDC occur when these effects are based on the rem.

The absolute risk estimator used in this assessment is that given in the report of the National Academy of Sciences Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR report).(12) This report presents risk estimators for lung cancer derived from epidemiological studies conducted on two groups of miners, namely:

3 cancers per year per 10^6 person-WLM exposure
for uranium miners

8 cancers per year per 10^6 person-WLM exposure
for fluorspar miners

Therefore, the average of these two values was chosen as the risk estimator for use in this study. This estimator then is:

6 cancers per year per 10^6 person-WLM exposure

A dose from a given ingestion or inhalation of radionuclides varies widely due to differences in age (infants-adults), physical size, etc. This and other components of natural biological variability which exist among members of any given population, as well as the differences between exposure conditions in residences and mines, give rise to an uncertainty on the order of a factor of 3 in this parameter.(13)

The commitment, then, of 6 cancers per year has a statistical basis and relates to a total population exposure of 10^6 person-WLM. If a cancer does occur it likely will be evident during the 30-yr period following the initial exposure and latency period.(14) When the exposure is continual over an individual's lifetime, this commitment is cumulative and the risk per year increases to an ultimate value of 6 times 30, or:

180 effects per year for 30 x 10^6 person-WLM
total cumulative exposure

This mathematical expression also can be interpreted in terms of the average annual risk to an individual per unit of exposure. For example, an individual with a continuous exposure of 1 WLM annually has about a 2 x 10^{-4} probability each year of developing lung cancer from this exposure. Several investigations have been reported recently concerning the association between lung cancer incidence and RDC exposures in miners.(13,15,16) These investigations yielded risk estimator values consistent with the risk estimator used in the present assessment. The relative risk estimator can be several factors larger than the absolute risk estimator.(17)

For the purposes of this assessment, equivalent working levels inside structures are determined from the radon concentration assuming a 50% equilibrium condition. This yields the following conversion factor:

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

It is assumed that the component of indoor radon concentration due to radon exhaled from the piles is equal to the corresponding outdoor concentration component at that point. However, the concentration of radon daughters is higher indoors owing to reduced ventilation and to other sources of radon, such as building materials.

The exposure rate in terms of WLM/yr can be obtained from a continuous 0.005 WL concentration (equivalent to 1 pCi/l Rn concentration) as follows:

$$(0.005 \text{ WL})\left(8766 \frac{\text{hr}}{\text{yr}}\right)\left[\frac{1 \text{ WLM}}{1 \text{ WL } (170 \text{ hr})}\right] = 0.25 \frac{\text{WLM}}{\text{yr}}$$

In this assessment it is assumed that a gamma exposure of 1R in air is equivalent to a dose of 1 rem in soft tissue.

3.6.2 Health Effects

The model curve of radon concentration-versus-distance (Figure 3-6) was used to determine the health effects due to radon from the Lowman piles. First, an indoor radon daughter concentration is deduced from the outdoor radon concentration curve using the conversion factor 1 pCi/l of ^{222}Rn outside equals 0.25 WLM/yr inside, then, the resulting RDC distribution is multiplied by the risk estimators given previously to yield the health effect risk per person as a function of distance from the pile. The estimated annual radiation-induced lung cancer risk as a function of distance from the edge of the site is given in Figure 3-11 for the prolonged continuous exposure. The curves shown in the figure are the sum of the estimated annual radiation-induced risk from all sand piles plus the average lung cancer risk per year from all causes for residents of the State of Idaho.(18) The risk for developing lung cancer from pile radon is small compared with the natural occurrence risk.

Health effects from total population RDC exposures for the area within 1 mi from the site perimeter were calculated. The population within 1 mi of the site is very low, and the contribution of pile radon to the total radon concentration at distances more than a mile away is insignificant. Health effect values were calculated by converting the appropriate radon concentrations in the Lowman area to equivalent WLM/yr and multiplying by the absolute risk estimator. The nearest residents to the pile are approximately 0.5 mi away, where the health effect rate is 2.2×10^{-6} per person per year. For a static population, the cumulative 100-yr value is 0.01 health effects.

Also estimated are health effects from background radon concentrations. The pile-induced radon daughter health effects are approximately 4% of the background value. In 100 yr, the background radon would be expected to cause 0.26 health effects.

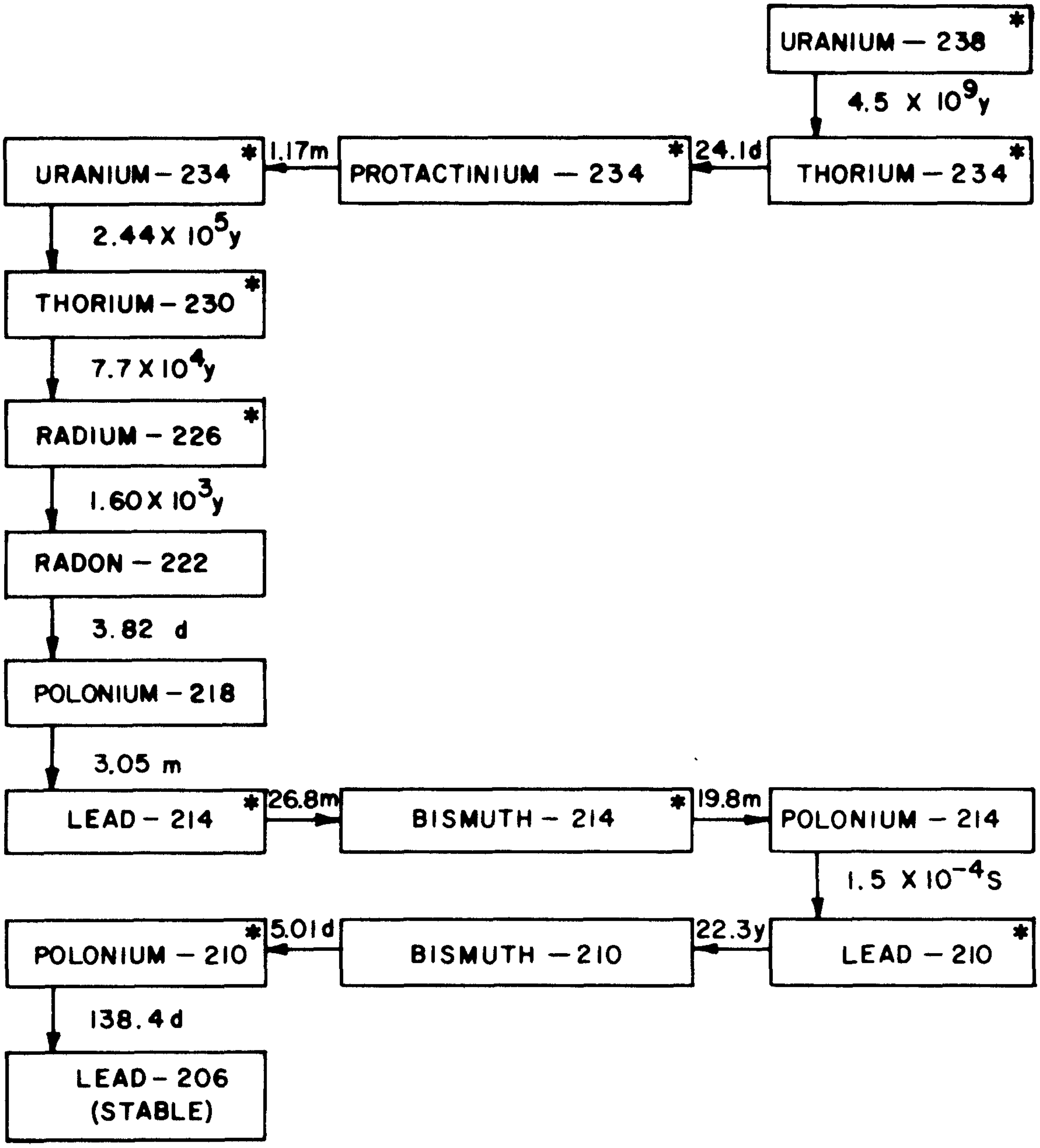
If the relative risk estimator is used, the health effects estimates are correspondingly larger, but well within the uncertainty in the health effects estimation of about a factor of 4.

No health effects were attributed to gamma radiation from the site, because gamma population is zero within 0.2 mi surrounding the site where the gamma radiation from the piles is greater than the background range.

Since the health effects from the Lowman sand residues are minimal, a detailed health effects analysis with population projections is not presented.

3.7 NONRADIOACTIVE POLLUTANTS

Four water samples were taken from the vicinity of the Lowman site and chemically analyzed. The location of these samples are shown in Figure 3-10. Two of these samples were from Clear Creek upstream and downstream from the pile. The other two samples were taken from a well and a spring downgradient from the tailings piles. The chemical analyses for these samples are listed in Table 3-4. None of these water samples indicated leaching of nonradioactive pollutants from the piles.



NOTE:

VERTICAL DIRECTION REPRESENTS ALPHA DECAY, HORIZONTAL DIRECTION INDICATES BETA DECAY. TIMES SHOWN ARE HALF LIVES. ONLY THE DOMINANT DECAY MODE IS SHOWN.

* ALSO GAMMA EMITTERS

FIGURE 3-1. RADIOACTIVE DECAY CHAIN OF URANIUM 238

130-17

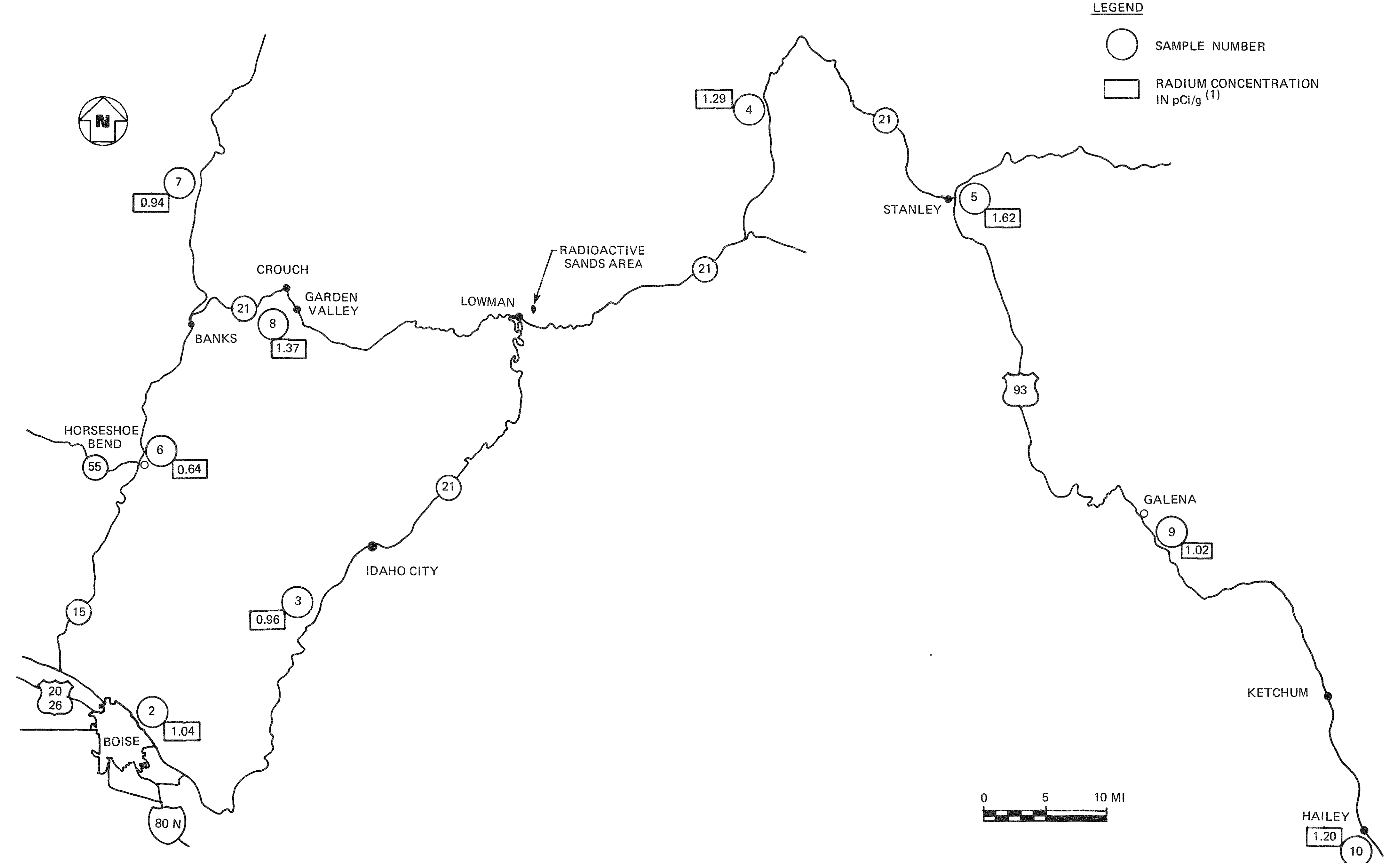
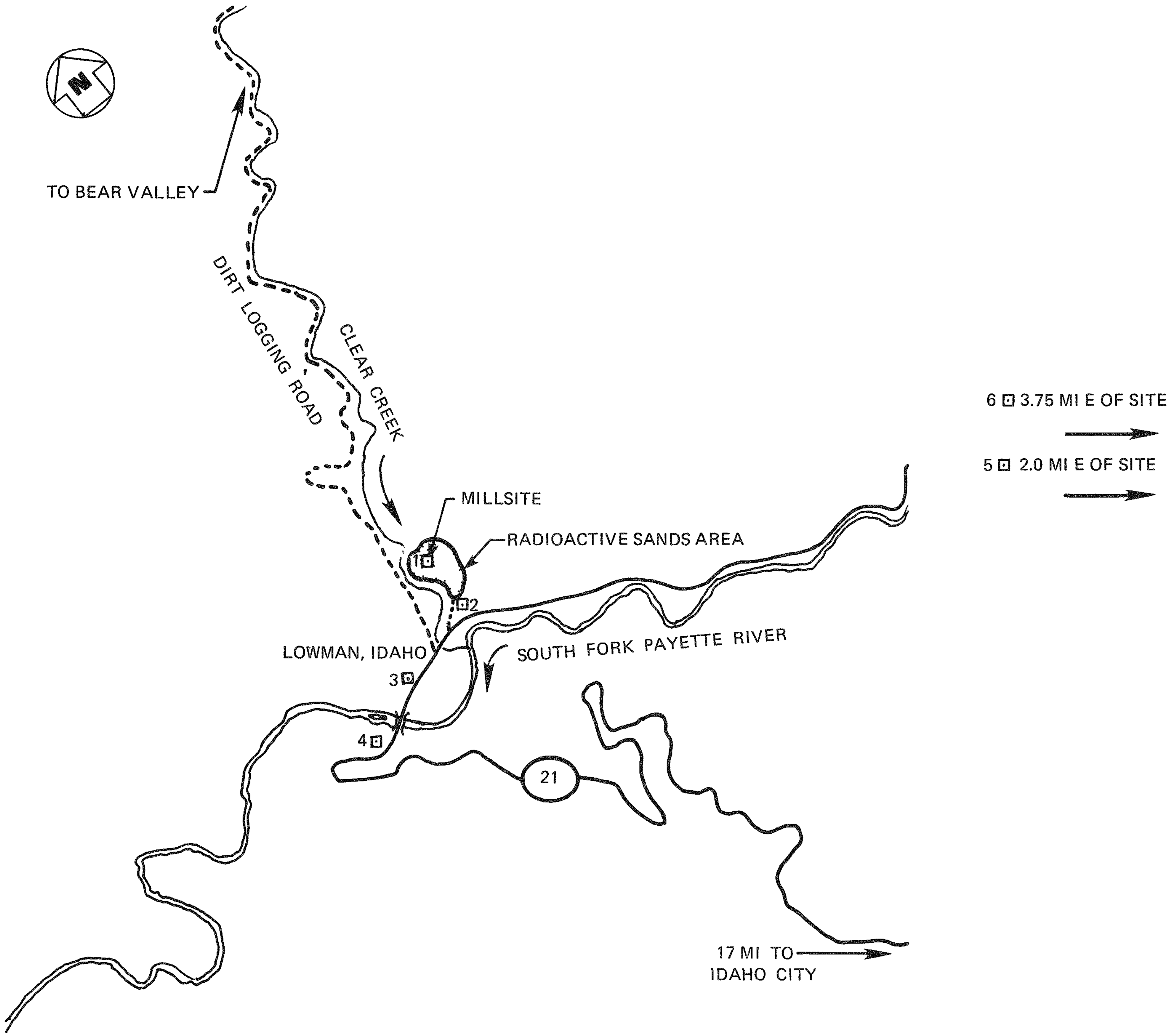


FIGURE 3-2. LOCATION FOR 226Ra BACKGROUND SAMPLES

130-17



DATE	SITE NO.	24 HR OUTDOOR (pCi/l)	24 HR INDOOR (pCi/l)	LOCATION
9/21/76	1	1.8	——	FORMER MILLSITE AREA
9/20/76	2	1.1*	——	AT GATE TO SITE, 0.1 MI S
9/21/76	3	1.1*	——	0.25 MI SW OF SITE
9/20/76	4	1.2	1.1	MOTEL, 0.5 MI SW OF SITE
9/22/76	5	1.3*	——	2.0 MI E OF SITE
9/22/76	6	1.1*	1.2	SERVICE STATION 3.75 MI E OF SITE

* LOCATIONS USED FOR BACKGROUND

FIGURE 3-3. RADON CONCENTRATION IN VICINITY OF SITE

130-17

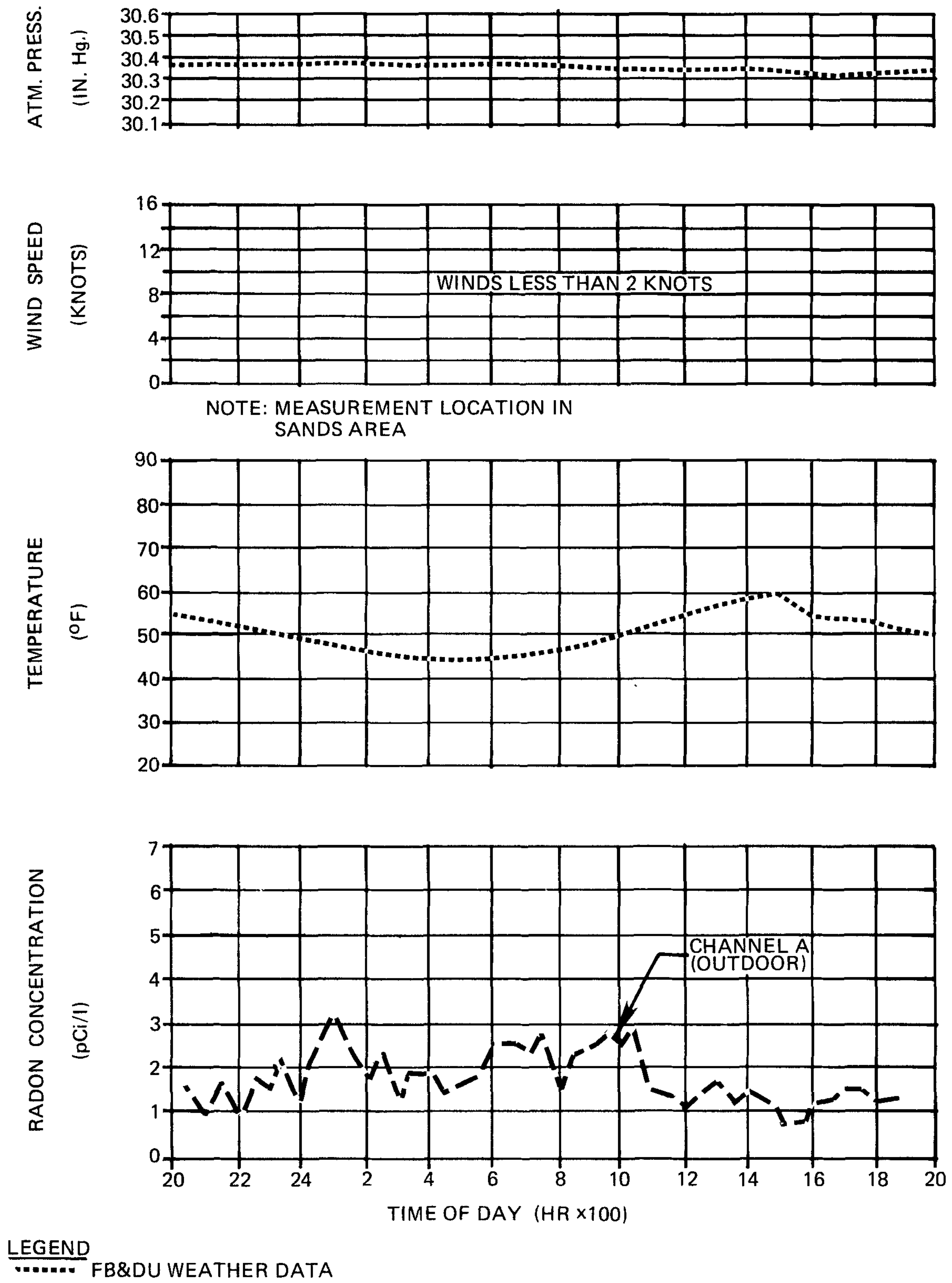


FIGURE 3-4. 222Rn AND ATMOSPHERIC TRANSIENTS IN MILL BUILDING AREA SEPTEMBER 21, 1976

130-17

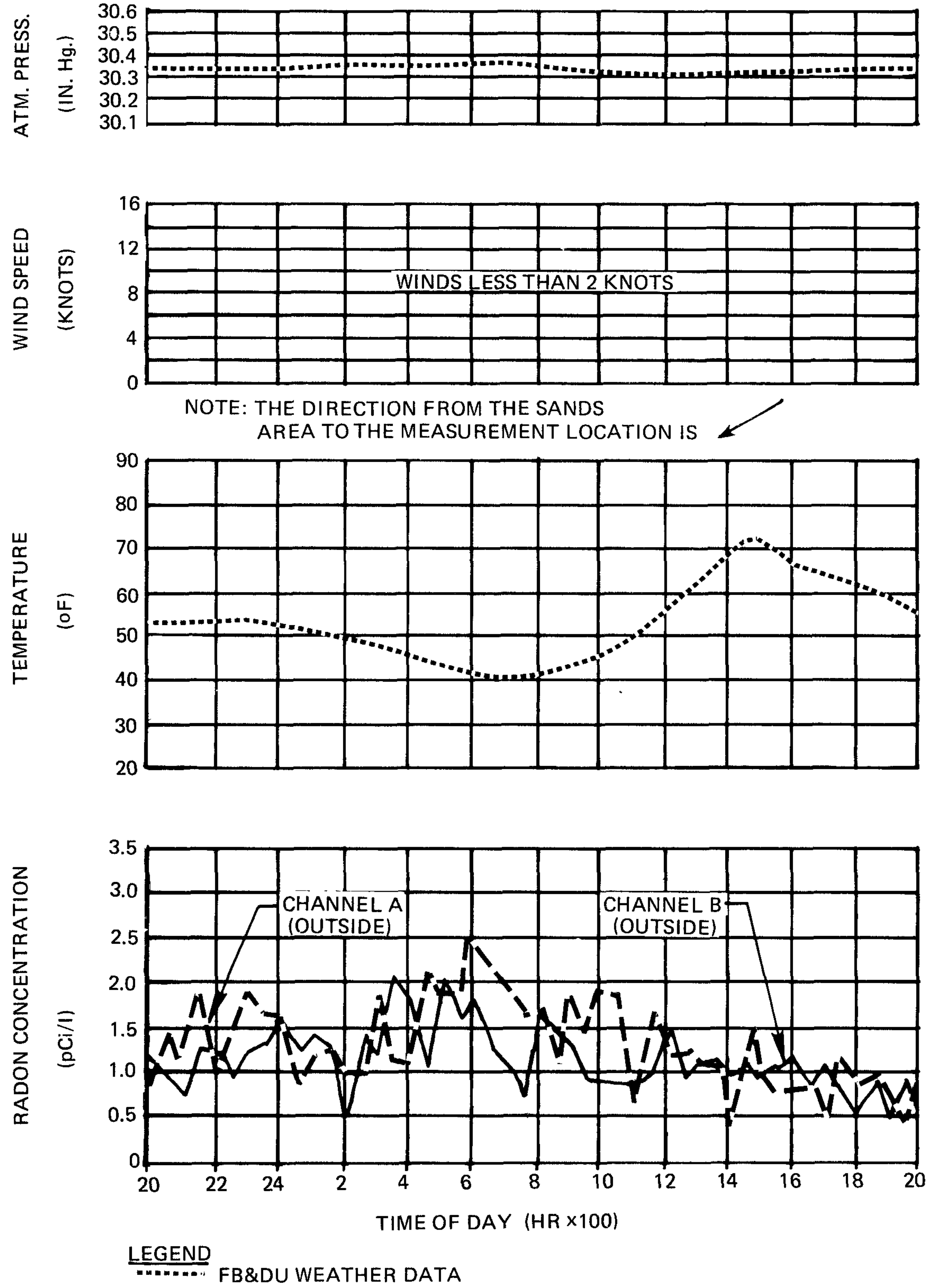


FIGURE 3-5. 222Rn AND ATMOSPHERIC TRANSIENTS AT MOTEL IN LOWMAN ON SEPTEMBER 20, 1976

130-17

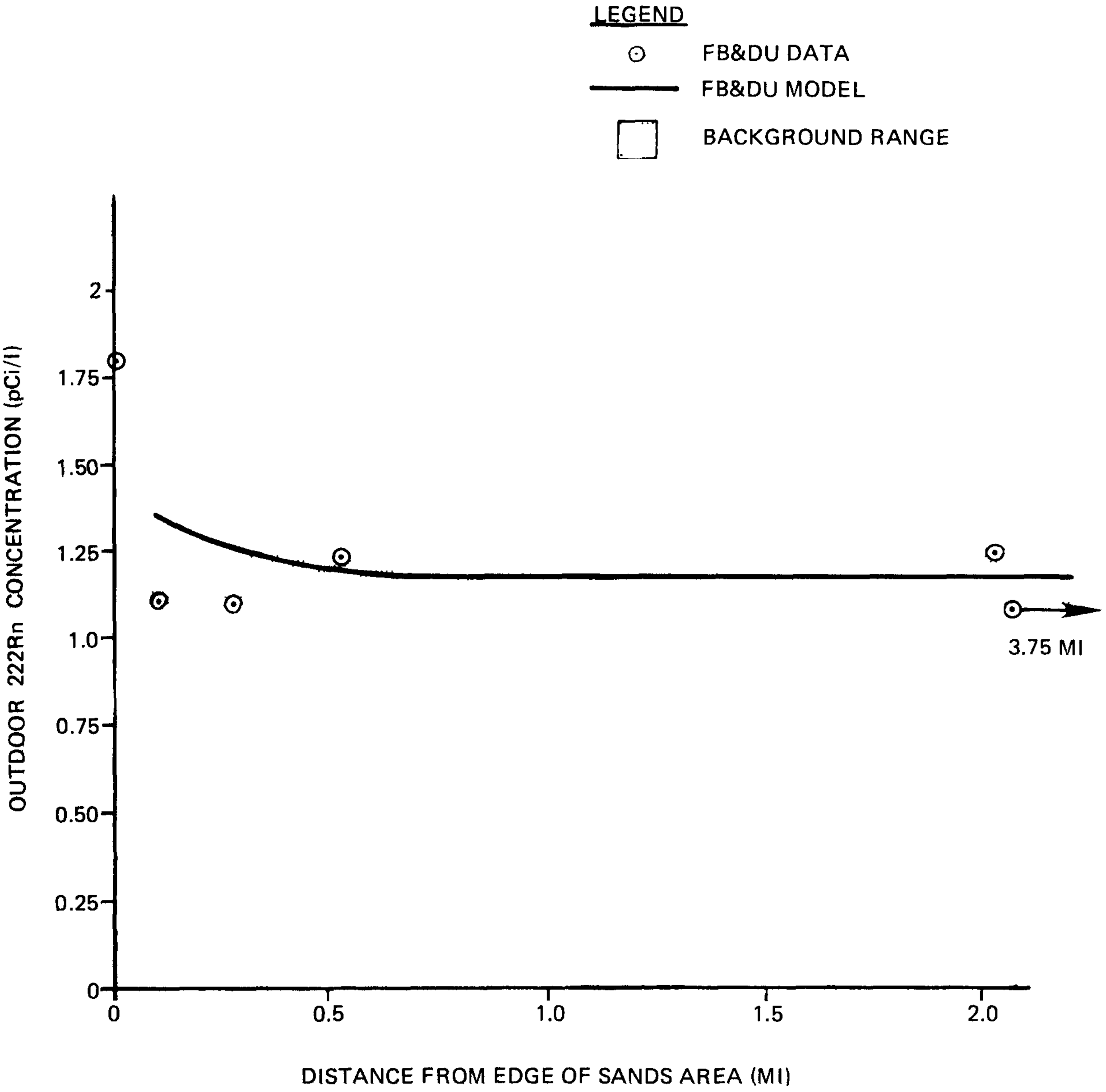


FIGURE 3-6. REDUCTION OF OUTDOOR 222Rn CONCENTRATION WITH DISTANCE FROM THE SANDS AREA

130-17

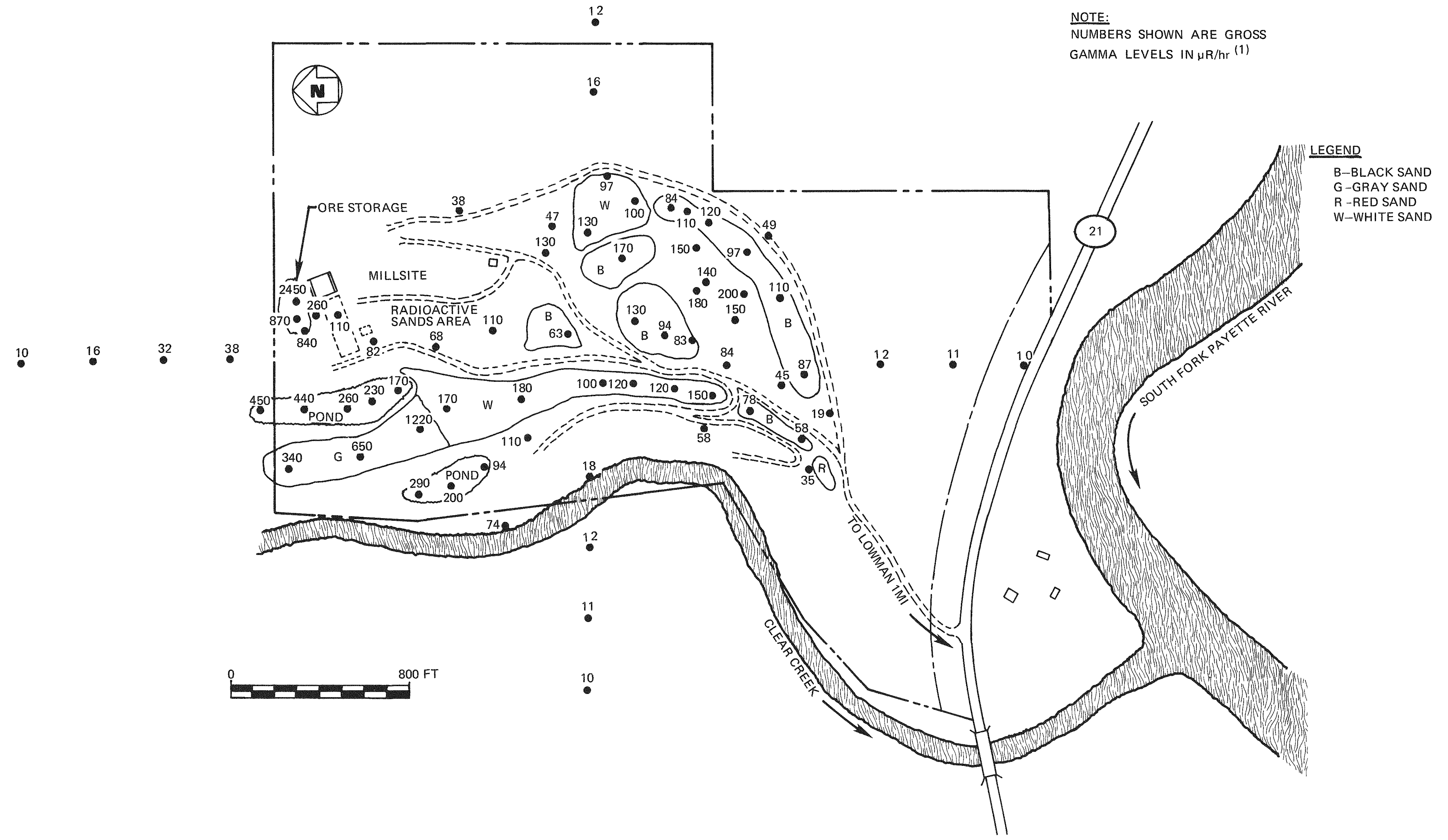


FIGURE 3-7. GAMMA LEVELS AT SITE 3 FT ABOVE GROUND

130-17

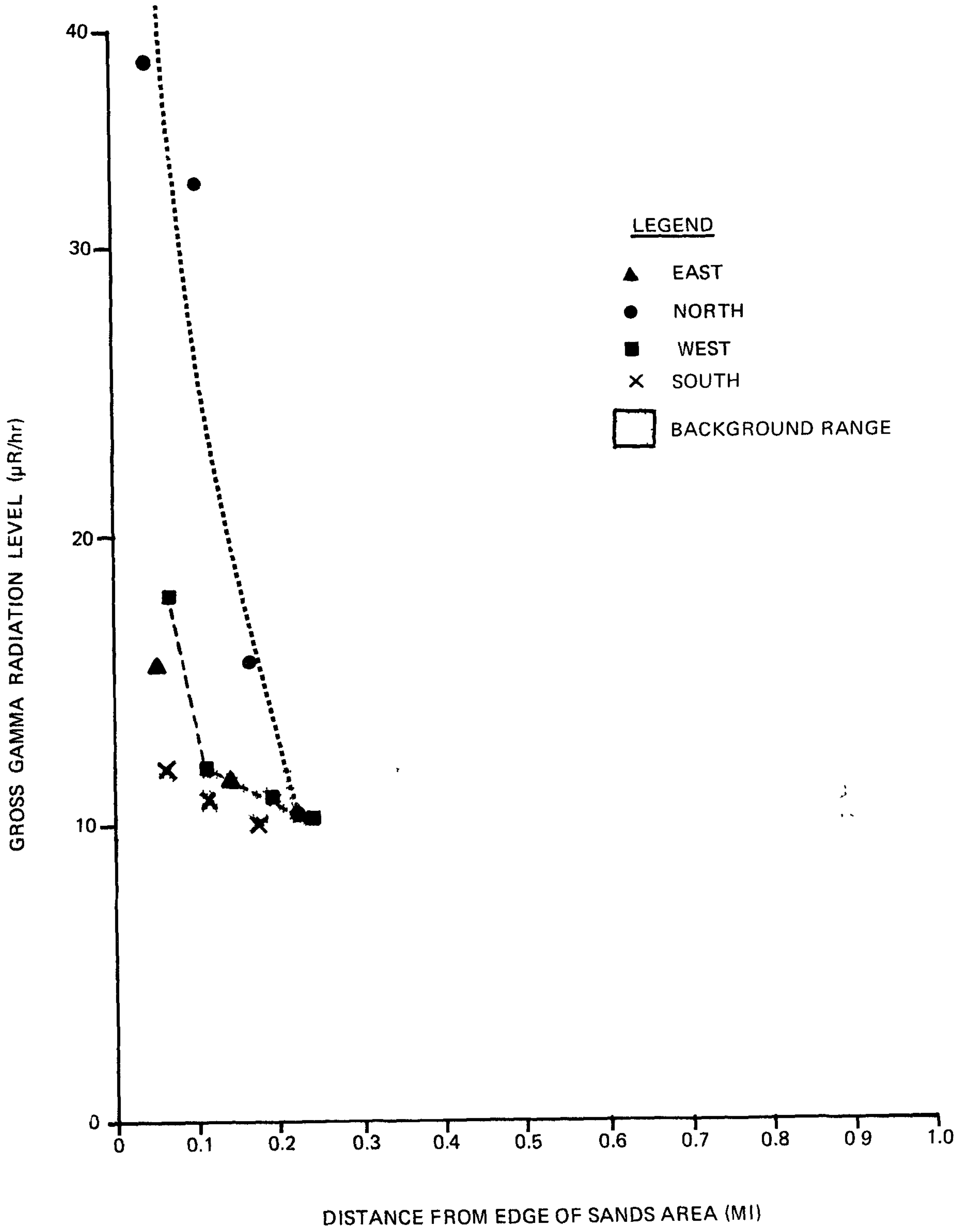
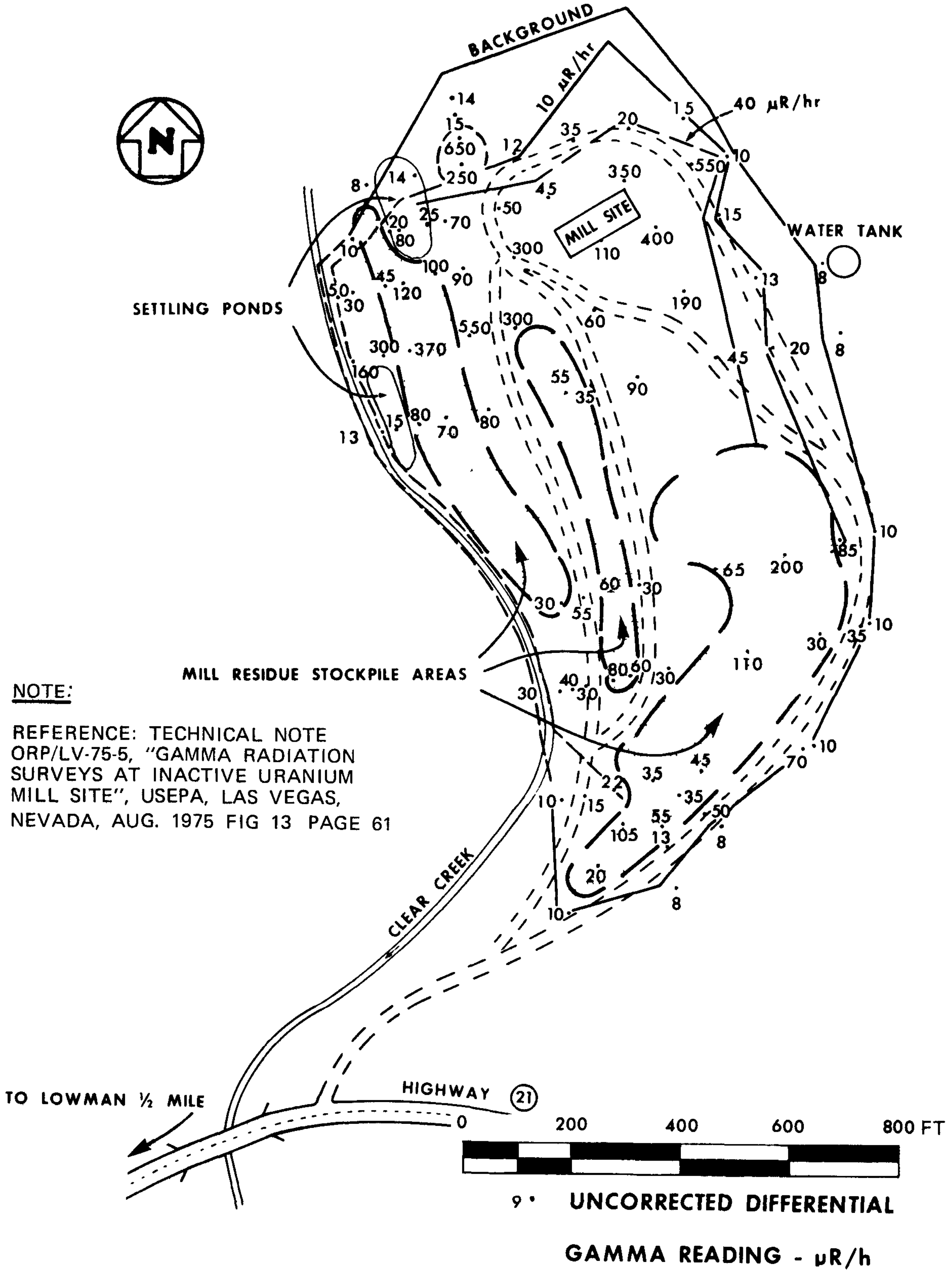


FIGURE 3-8. REDUCTION OF EXTERNAL GAMMA RADIATION LEVELS WITH DISTANCE FROM THE SANDS AREA 130-17

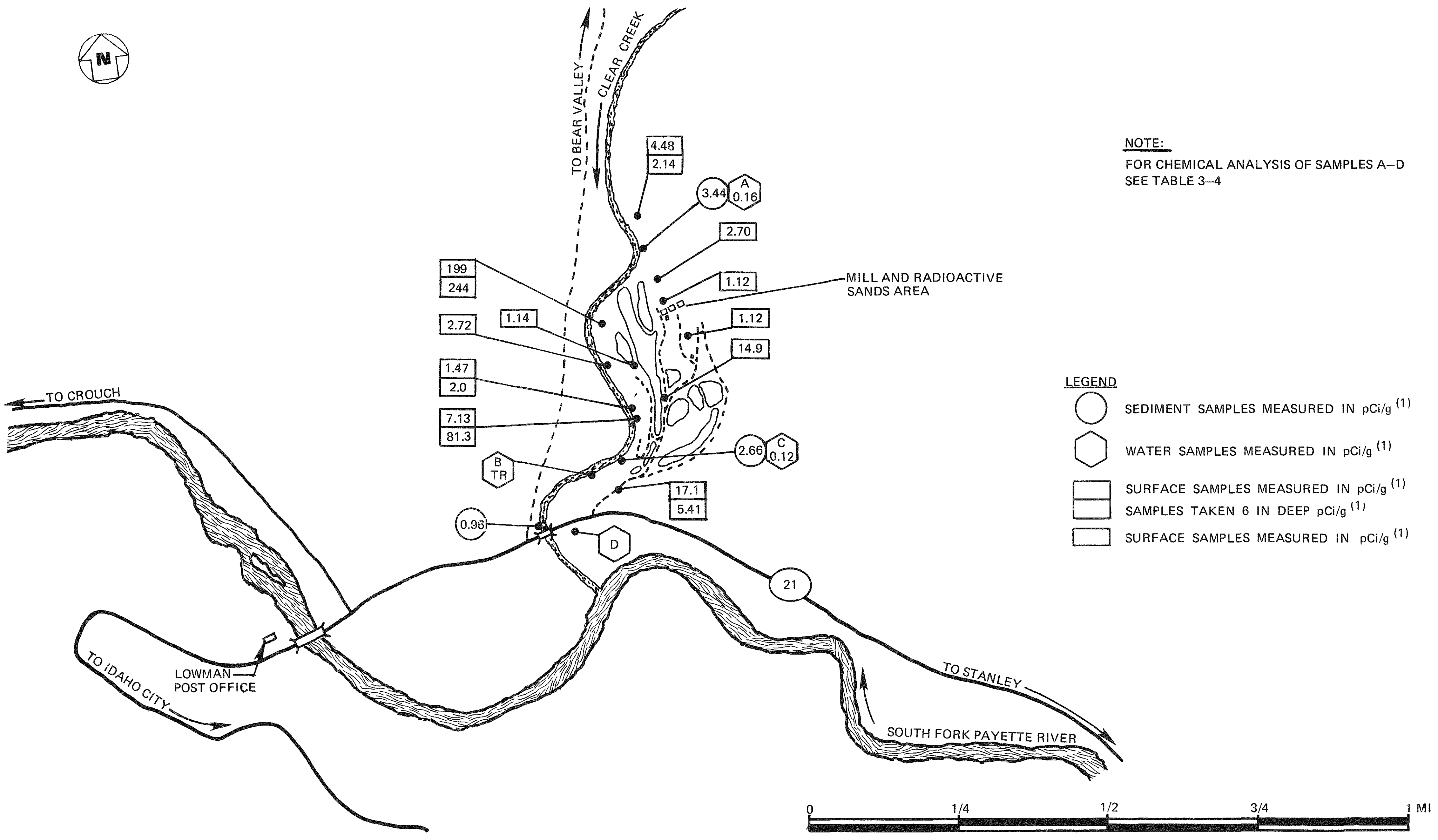


NOTE:

REFERENCE: TECHNICAL NOTE ORP/LV-75-5, "GAMMA RADIATION SURVEYS AT INACTIVE URANIUM MILL SITE", USEPA, LAS VEGAS, NEVADA, AUG. 1975 FIG 13 PAGE 61

FIGURE 3-9. EPA GAMMA SURVEY SURROUNDING MILLSITE

130-17



NOTE:
FOR CHEMICAL ANALYSIS OF SAMPLES A–D SEE TABLE 3–4

FIGURE 3-10. SURFACE AND SUBSURFACE RADIUM CONCENTRATIONS

130-17

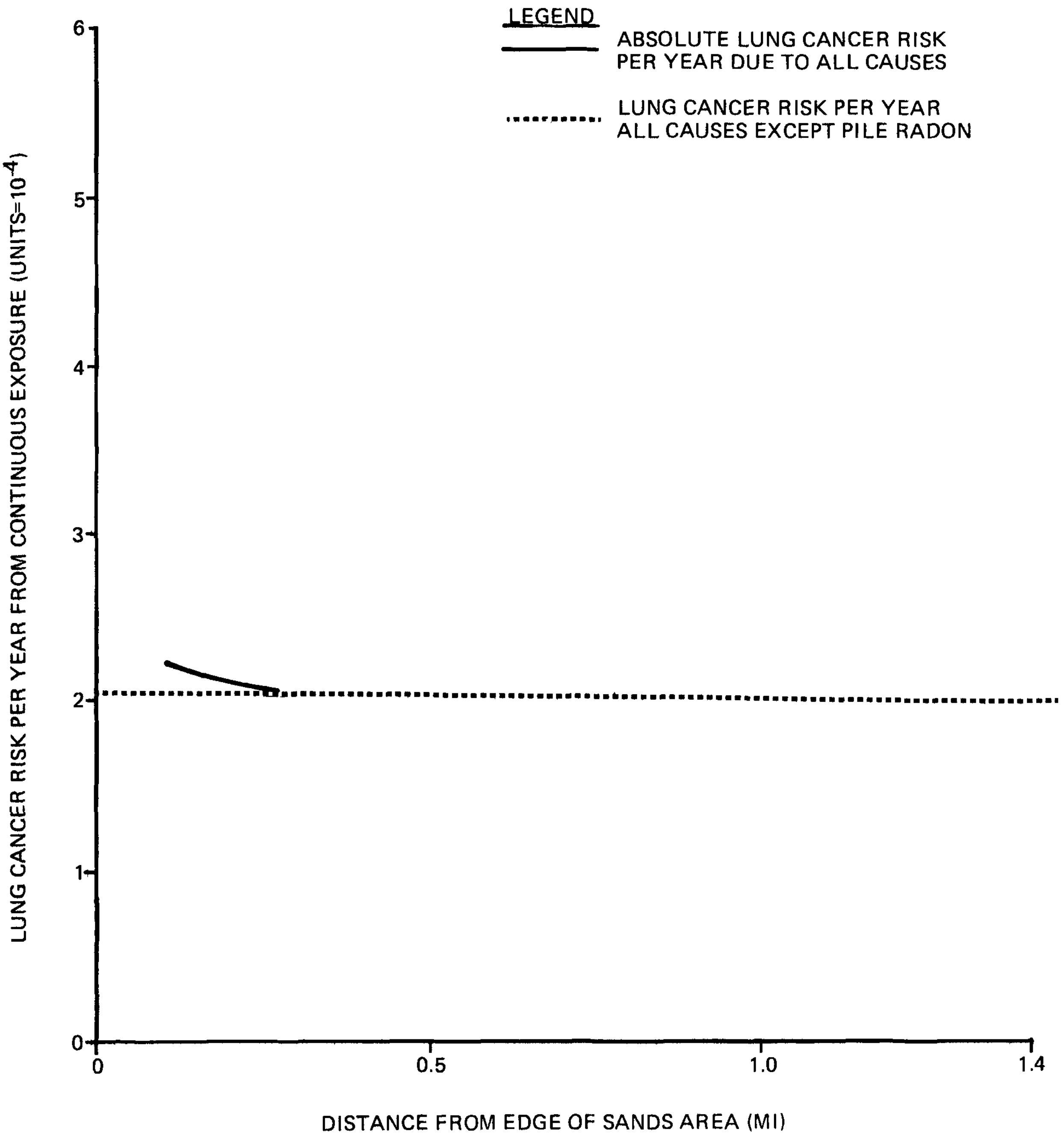


FIGURE 3-11. LUNG CANCER RISK FROM CONTINUOUS EXPOSURE TO RADON DIFFUSION

130-17

TABLE 3-1

NOTATIONS AND ABBREVIATIONS USED IN CHAPTER 3

Isotope - A particular type of element, differing by nuclear characteristics, identified by the atomic mass number given after the element name, e.g. radium-226.

Isotope Abbreviations:

^{238}U = Uranium-238

^{234}Th = Thorium-234

^{232}Th = Thorium-232

^{234}Pa = Protactinium-234

^{226}Ra = Radium-226

^{222}Rn = Radon-222

^{218}Po = Polonium-218

^{214}Pb = Lead-214

^{214}Bi = Bismuth-214

^{40}K = Potassium-40

Radiations:

alpha particle - helium nucleus; easily stopped with thin layers of material, all energy deposited locally.

beta particle - electron; penetrates about 0.2 g/cm^2 of material.

gamma rays - electromagnetic radiation; similar to X-rays, and highly penetrating.

Half-Life ($T_{1/2}$) - time required for half the radioactive atoms to decay.

TABLE 3-1 (Cont)

Working Level (WL)	- measure of potential alpha energy per liter of air from any combination of short-lived radon daughters (1 WL = 1.3 x 10^5 MeV of alpha energy).
One Working Level Month (WLM)	- WLM-Exposure to air containing a RDC of 1 WL for a duration of 170 hr.
Roentgen (R)	- that quantity of gamma radiation which yields a charge deposition of 2.58 x 10^{-4} coul/kg air. This is equal to the energy deposition of 88 ergs/g of dry air or 93 ergs/g of tissue.
μR/hr	- 10^{-6} Roentgen/hr.
Rad	- energy deposition of 100 ergs/g of material
Picocurie (pCi)	- unit of activity (1 pCi = 0.037 radioactive decays/sec or 2.2/min).
MeV	- unit of energy - 1 MeV = 1.6 x 10^{-6} erg.
Rem	- unit of energy deposition in man. 1 rem = 1 rad x quality factor. The quality factor = 20 for alpha particles.

TABLE 3-2

BACKGROUND RADIATION SOURCES IN SOIL FROM SOUTHWEST IDAHO(1)

Isotope (Decay Chain)	Average Value (pCi/g)	Range (pCi/g)
^{226}Ra (^{238}U)	1.12 ± 0.29	0.64 - 1.37
^{232}Th (^{232}Th)	1.18 ± 0.46	0.42 - 1.91
^{40}K	18.6 ± 2.5	15.4 - 22.1

TABLE 3-3

RADON EXHALATION FLUX FROM THE LOWMAN PILES

Sample	Location[a]	Radon Flux (pCi/m^2-sec)
L1	Old settling pond west of millsite	50
L2	Grey sand pile	150
L3	Grey sand-bottom of slope	100
L4	Black sand pile east of millsite	70

[a] See Figure 2-3, Chapter 2.

TABLE 3-4

CHEMICAL ANALYSES OF LOWMAN WATER SAMPLES (mg/l)

Sample[a]	As	Ba	Cd	Cr	V	Fe	Pb	Se
A - Clear Creek upstream from pile	0.008	0.07	<0.001	0.013	0.060	0.142	0.010	<0.001
B - Clear Creek downstream from pile	0.004	0.15	<0.001	<0.001	0.060	0.078	<0.001	<0.001
C - Spring south of pile	0.007	0.11	<0.001	0.007	0.020	0.326	<0.001	<0.001
D - Well south of pile	0.024	0.03	<0.001	0.011	0.120	0.417	<0.001	<0.001
EPA Interim Drinking Water Standards[b]	0.05	1.0	0.01	0.05	--	0.3[c]	0.05	0.01

[a] See Figure 3-10 for locations.

[b] Federal Register, Dec 24, 1975.

[c] Recommended limit from Manual for Evaluating Public Drinking Water Supplies, U.S. Public Health Service, 1969.

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CHAPTER 4

SOCIOECONOMIC AND LAND USE IMPACTS

CHAPTER 4

SOCIOECONOMIC AND LAND USE IMPACTS

The Lowman millsite is located in Boise County, Idaho. Idaho City, the county seat, is 34 mi southwest of Lowman by way of Idaho Highway 21. Lowman is located 71 highway miles northeast of Boise, the capitol city of Idaho. The sands and residues are located 0.5 mi east of the town of Lowman, and Idaho Highway 21 is immediately south of the site. The Boise County Boundaries are shown in Figure 4.1.

4.1 SOCIOECONOMIC BACKGROUND

It is difficult to extrapolate future demographic and economic conditions at Lowman from existing countrywide statistical data obtained for the four census records of 1940 to 1970. Census information was not reported for Lowman per se. The area's small population base fluctuates with business and mining, and tourist travel fluctuates seasonally. Only selected transportation routes are kept open year-round.

During the decades ending in 1950 and 1960, Boise County experienced considerable loss in population (from 2,333 to 1,763 persons) while that of Idaho increased at a moderate rate. During the 1960's the county reported a 7.1% increase, or an increase of approximately 117 individuals. The median age of county inhabitants has vacillated with employment patterns but has remained considerably higher than the Idaho average. The male population of the county also is high, but has dropped from 59.1% in 1940 to 50.5% in 1970, which is approximately the Idaho average. Ethnically, the population of Boise County is dominantly Caucasian. Average educational attainment in 1970 was approximately the same for Idaho and for Boise County, although the county's level had previously lagged behind the state's. Farmers and farm laborers have declined in both real numbers and percent of the total, but still remain the largest occupational sector of the county. Professionals, operators, craftsmen, and managers make up the majority of the remaining workforce. The mining sector of the economy has declined most dramatically from employing over 45% of the workforce in 1940 to employing no workers in 1970.

Traditionally Boise County has relied upon agriculture and forestry for most of its industrial output. Employment related to recreational activities will play an increasingly important role in the area as seasonal homes become an integral part of the economy. Timber will continue to be harvested, but a major expansion of the industry is unlikely because of the lack of adequate transportation in the area.

4.2 POPULATION ESTIMATES

The 1970 census figures indicate that in 1970 there were 1,763 inhabitants in Boise County, but there was no census taken for the community of Lowman. It has been estimated that Lowman itself has approximately 50 inhabitants.(1)

Several factors must be considered in determining population projections and future growth patterns for the Lowman area. The population is small and very dependent upon the futures of tourism, recreation, and the lumber industry. An adverse economy could substantially reduce even the small population of the area. There are no prospects for long-term, large-scale population growth in the immediate vicinity of the millsite. The low probability of sustained year-round population growth is low, but there is a real potential for subdivisions for summer homes; consequently, a population of 60 was used in the health effects evaluation in Chapter 3.

4.3 LAND USE

Most of the land near the site is used as forest land or for recreational homesites as depicted in Figure 4-2. Commercial activities (including a general store, a service station, a lodge, and a motel) are located along Idaho Highway 21 in Lowman. Nearby public land is used by road working crews. Throughout the region there are a number of 1-acre lots. One such subdivision tract is located across Clear Creek from the millsite.

Projected land uses for the area near Lowman are similar to present land uses, with increased development of 1-acre lots for year-round use and as second homes for vacation purposes.(2)

4.4 IMPACT OF THE RESIDUES ON LAND VALUES

Single, 1-acre lots are for sale for approximately $2,500/acre near the tailings area. The Federal Government administers much of the forest land in the area.

The presence of the tailings restricts the use of the site itself and has diminished its aesthetic quality. However, the pile has had no direct impact on land uses and values in the surrounding area.

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(1) See end of chapter for references.

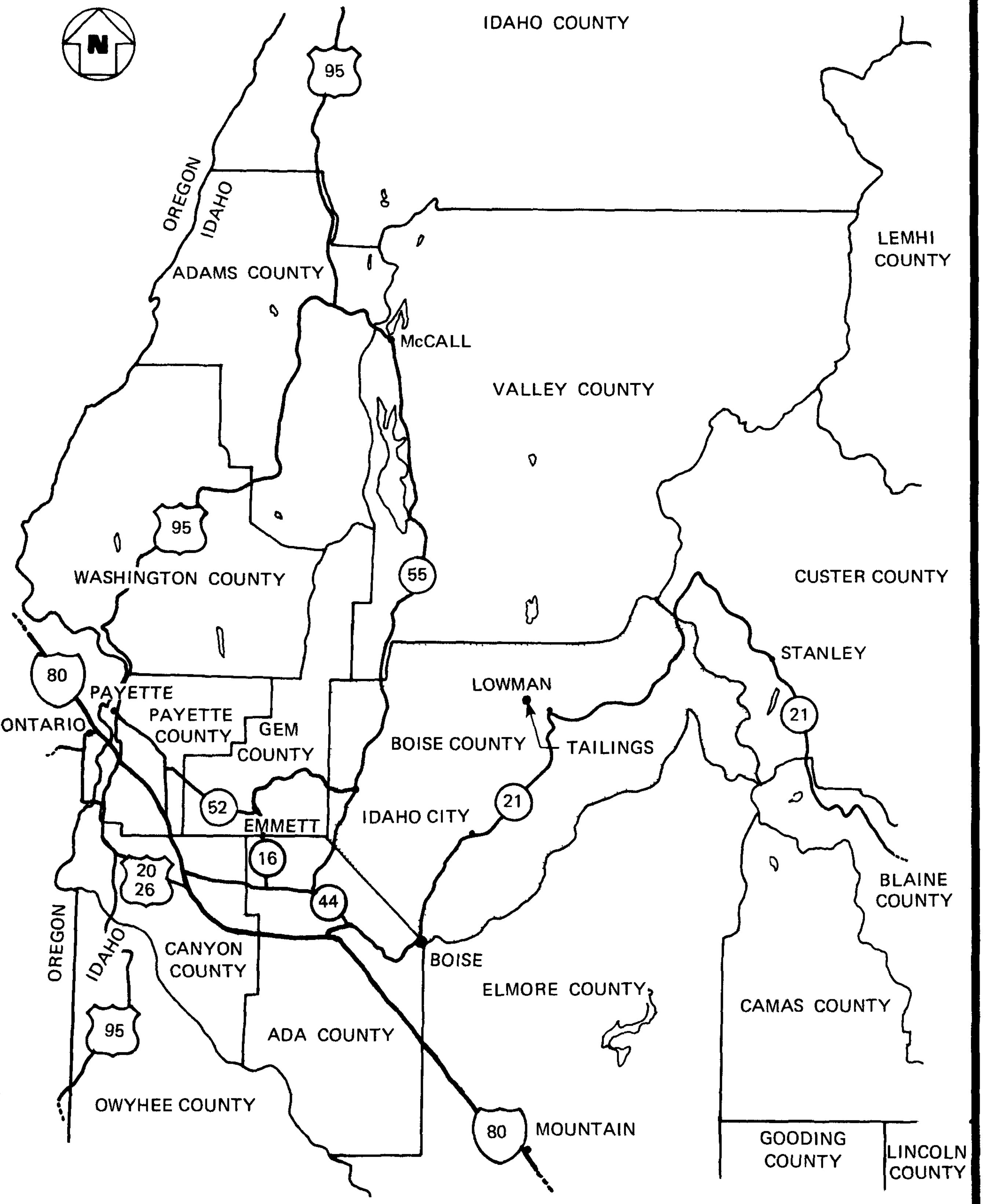

FIGURE 4-1. MAP OF BOISE COUNTY BOUNDARIES

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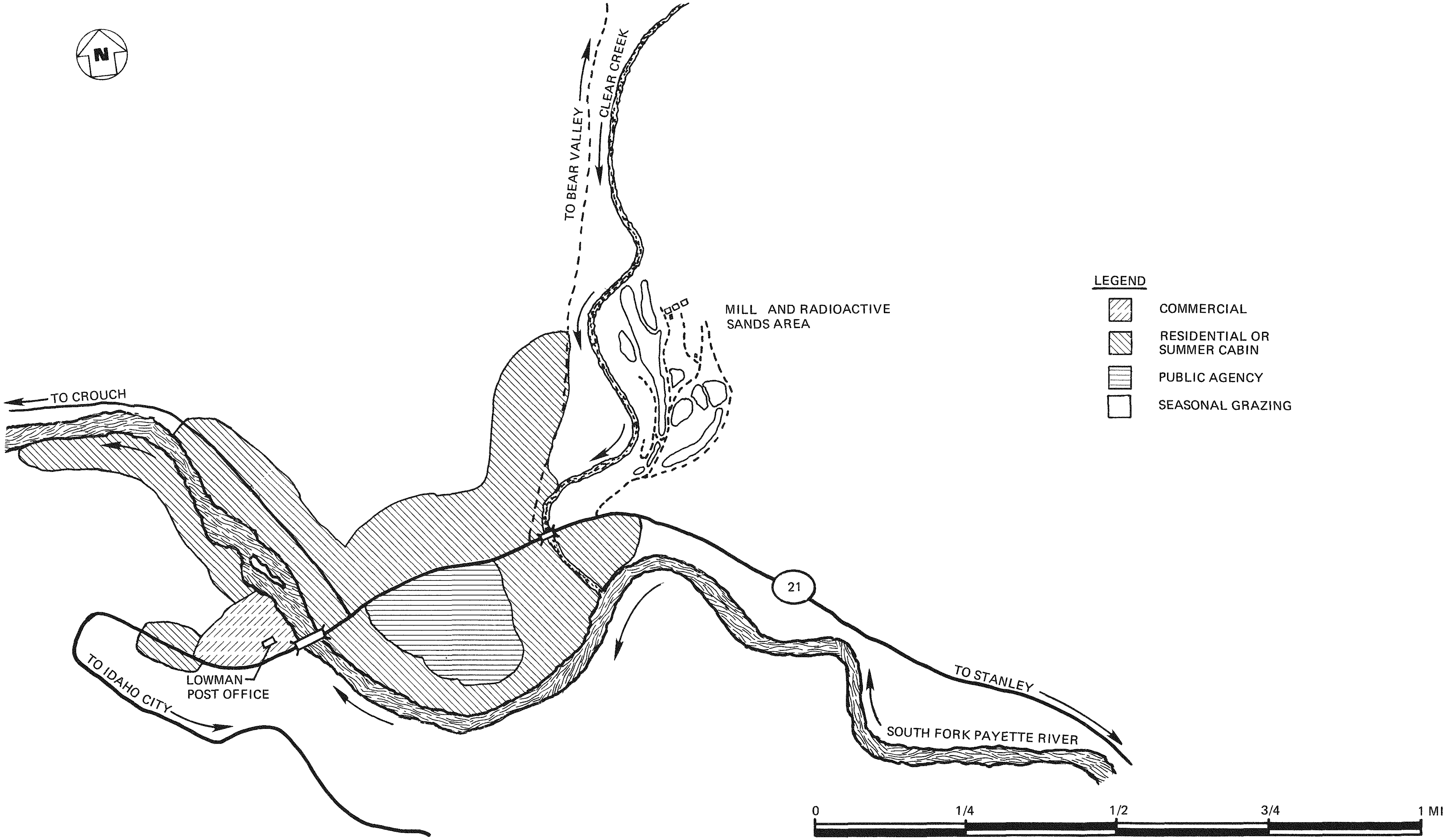

FIGURE 4-2. VICINITY LAND USE

130-17

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CHAPTER 5

RECOVERY OF RESIDUAL VALUES

CHAPTER 5

RECOVERY OF RESIDUAL VALUES

The principal purpose of this chapter is to address questions such as the following:

(a) Do the Lowman sands represent a future resource?

(b) Can the sands be utilized before stabilization?

(c) Is there any likelihood that once stabilized the pile would be disturbed again?

The feasibility of economic recovery of minerals from the radioactive ponds and residues in a function of:

(a) Total mineral recovery

(b) Processing costs

(c) Market price

Distribution of black-sand minerals in pounds per cubic yard in Upper Bear Valley is as follows: ilmenite 13.8, monazite 0.83, and radioactive blacks 0.127. The ilmenite fraction contained 26.6% TiO_2, 46.1% Fe, and 0.18% Cb_2O_5. In the former operation, euxenite (a uranium- and thorium-bearing radioactive black mineral) was upgraded for out-of-state shipment. The ore was processed using physical separation methods (eg. density, size, and magnetic separations). There are no conventional techniques available that would allow the Lowman sands to be processed economically. In fact, the Michigan Chemical Corporation was unable to find a buyer or processor for the sands.

As listed in Table 2-1, Chapter 2, only 15,000 tons (the original source ore and the grey sand residue) warrant consideration for processing; however, the radioactive ore minerals are refractory substances and, therefore, are highly resistant to chemical attack. They are also classed as resistates which reflect their resistance to chemical weathering by such processes as hydrolysis or oxidation.

The small amount of material and the fact that Michigan Chemical Corporation was unable to interest an operating mill in the material, support the conclusion that it is not economical to process this material at the present time. Other uses, such as for stemming material, may be possible; however, the further spread of this radioactive material is not advisable.

CHAPTER 6

MILL TAILINGS STABILIZATION

CHAPTER 6

MILL TAILINGS STABILIZATION

In most of the alternative remedial actions which have been considered, the stabilization of mill tailings is a required process. Government agencies and private industry have carried out limited research to develop economical and environmentally suitable methods of uranium tailings site stabilization. All present methods, technology, and research data on stabilization that are available were reviewed to determine the best approach. In addition, experiments are being conducted to determine the relative effectiveness of various stabilization techniques.

The objective of stabilizing the uranium mill tailings is to eliminate the pathways to the environment of the radioactive and other toxic particles as described previously in Chapter 3. Ideally, complete stabilization of radioactive tailings should permanently eliminate the possibilities of:

(a) Wind and water erosion

(b) Leaching of radioactive materials and other chemicals

(c) Radon exhalation from the tailings

(d) Gamma radiation emitted from the tailings

6.1 PREVENTION OF WIND AND WATER EROSION

Wind and water erosion can be prevented by chemical stabilization of the surface, complete chemical stabilization, physical stabilization, and vegetative stabilization. The radioactive sands and residues at the Lowman site differ markedly from conventional uranium mill tailings. The sand grains are larger and denser, resulting in residue piles less susceptible to wind and water erosion (except where the grey sand pile drops down the slope on the west side of the site).

6.1.1 Chemical Stabilization of the Surface

This process involves applying chemicals to the surface of the tailings to form a water- and wind-resistant crust. Chemical stabilizers have been used successfully as a temporary protection on portions of dikes and tailings ponds which have dried and become dusty, and in areas where water shortage or chemical imbalance in the tailings prevents the use of cover vegetation. Chemical surface stabilizers, however, are susceptible to physical breakup and gradual degradation and will not meet the long-term requirements for the Lowman pile.

Other complications also can arise in achieving satisfactory chemical stabilization in that the surfaces of tailings piles seldom are homogeneous, and variables such as particle size and moisture content affect the bonding characteristics of the chemical stabilizers.(1)

Tests were conducted by the Bureau of Mines(1) using certain chemicals (e.g. Compound SP-400 Soil Gard, and DCA-70 elastomeric polymers) on both acidic and alkaline uranium tailings. Subsequently, the chemicals DCA-70 and calcium lignolsulfonate were applied to the surfaces of the inactive uranium tailings ponds and dikes at Tuba City, Arizona, in May 1968, because low moisture conditions and high costs prohibited vegetative or physical stabilization. After 4 yr, approximately 40% of the dike surface showed disruption while the crust in pond areas was affected to a lesser extent. The major disruptions were attributed to initial penetration of the stabilizer by physical means such as vehicles, people, or animals crossing the tailings surface.

In 1969, a portion of the Vitro tailings at Salt Lake City, Utah, was sprayed with tarlike material as a Bureau of Mines experiment to achieve surface stabilization and to reduce wind erosion. The attempt was unsuccessful because the material decomposed and the tailings were exposed within 2 to 3 yr.

Since no chemical sealant has been used successfully to stabilize uranium tailings for more than a few years, this method has not been considered in the various stabilization alternatives presented in Chapter 9.

6.1.2 Complete Chemical Stabilization

This process, which has been used in other mineral industry operations, involves the addition of chemicals in sufficient quantities to a slurry to produce a chemical reaction which solidifies the slurry. Chemicals may be added in two ways: to a slurry pipeline, and in situ. The in situ method of stabilization is relatively new and extensive research is required in each individual situation to define the optimum chemical addition to produce the desired results.

One of the features claimed for this stabilization method is that all pollutant chemicals are locked in the solidified slurry and chemicals cannot be leached from the solid.

The cost of this stabilization method is expensive for the chemicals alone. A cover material, such as gravel, would be required to protect the solidified slurry from wind and water erosion. It is not known whether vegetation can be established after topsoil and other soil cover have been spread over the solidified

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(1) See end of chapter for references.

slurry. This probably would be a function of the specific chemical makeup of the solidified slurry and would require research to identify the conditions under which vegetation could thrive.

6.1.3 Physical Stabilization

Physical stabilization consists of isolating the contained material from wind and water erosion by covering the tailings with some type of resistant material (e.g. rock, soil, smelter slag, broken concrete, asphalt, etc.) Thin covers of concrete or asphaltic materials have been shown to break down over relatively short periods of time; and starting within a few years after application, continuing maintenance is required. A concrete covering sufficiently thick and properly reinforced would be relatively permanent and maintenance-free, but the cost would be prohibitive for large areas.

In some arid regions, where the potential for successful vegetative stabilization is slight, physical stabilization may be the preferred alternative. In such areas, combinations of pit-run sand and gravel, soil, and riprap have been placed over the tailings and have been successful in preventing wind and water erosion. An important component of physical stabilization is the proper treatment of the finished surface by such means as contour-grading and terracing. Such treatments can reduce greatly long-term maintenance costs.

6.1.4 Vegetative Stabilization

This method involves the establishment of vegetative cover on the tailings or on a growing medium placed over the tailings.

Many species of plants are self-regenerating and require little or no maintenance after growth becomes established. Vegetation can survive providing that:

(a) Evapotranspiration is not excessive

(b) Landscapes are properly shaped

(c) Nontoxic soil mediums capable of holding moisture are provided

(d) Irrigation and fertilization appropriate to the area are applied

(e) Proper selection of plants conducive to self-regeneration under conditions anticipated over a long time

Growth of vegetation at sites receiving less than 10 in. of annual precipitation and with high evapotranspiration rates requires irrigation and fertilization. At Lowman, rainfall ranges between 20 and 25 in. annually, and vegetation on the site is abundant.

One potential problem in the use of vegetative stabilization is the possibility of pickup of radioactive elements by the plants. The effect of this mechanism has not been considered in the present assessment.

6.2 PREVENTION OF LEACHING

Leaching into underground aquifers is one of the several pathways that chemicals and radioactive materials might take into the environment. There is little direct evidence that migration of radioelements from the Lowman sands is likely to constitute a problem. The techniques which could be employed to control leaching from tailings piles include the following:

(a) Employ chemical stabilization to prevent leaching into underground aquifers (this is the same stabilization system discussed in paragraph 6.1.2).

(b) Physically compact the tailings to reduce the percolation of water through the materials.

(c) Contour the tailings surface, then employ appropriate chemicals (discussed in paragraph 6.1.1) to seal the surface, thus preventing water from penetrating and destabilizing the pile.

(d) For a new site, line the storage area with an impermeable membrane (bentonitic clays and various plastic materials commonly are used for this purpose).

Sands and residues at Lowman are markedly different from usual uranium tailings and present a minimal adverse impact to ground and surface waters. They were dredged from placer deposits and are highly resistant to leaching or chemical attack.

6.3 REDUCTION OF RADON EXHALATION

Little research has been directed toward reduction of radon exhalation from tailings piles. While there are materials that can seal or contain the gas in small quantities, none of these are suitable for permanent coverage of large areas.

From simplified diffusion theory estimates, about 13 ft of dry soil(2,3) are needed to reduce radon flux by 95%, but only a few feet of soil are needed if a high moisture content in the cover material is maintained. Figure 6-1 illustrates curves of the reduction of radon exhalation flux for three soil types versus depth of cover based upon the theory and diffusion coefficients presented in the above references. Research is under way to explore more precisely the problems associated with reducing and eliminating the exhalation of radon from radioactive tailings material. The effects of applying various chemical stabilizers and varying thicknesses of stabilizing earth covers and combinations of materials are still being investigated. The results may have an important impact in planning radon exhalation control.

6.4 REDUCTION OF GAMMA RADIATION

A few feet of cover material are sufficient to reduce gamma radiation to acceptable levels.

The reduction of gamma exposure rates resulting from a packed earth covering is given in Figure 6-2.(4,5) Two feet of cover reduces the gamma levels by about two orders of magnitude. Therefore, an average cover of 2 ft should reduce gamma levels to less than 10 μR/hr above background.

6.5 ASSESSMENT OF APPLICABILITY

Available data indicate that none of the methods used thus far to stabilize uranium tailings sites has been a totally satisfactory solution to uranium tailings site radiation problems. Some of the methods examined have exhibited short-term advantages, but no economical long-term solutions have become apparent. Consequently, new methods of stabilization may have to be developed and additional engineering research may be required. However, one of the present remedial action options includes physical stabilization of the tailings with at least 2 ft of cover. This action will further reduce gamma radiation and wind and water erosion.

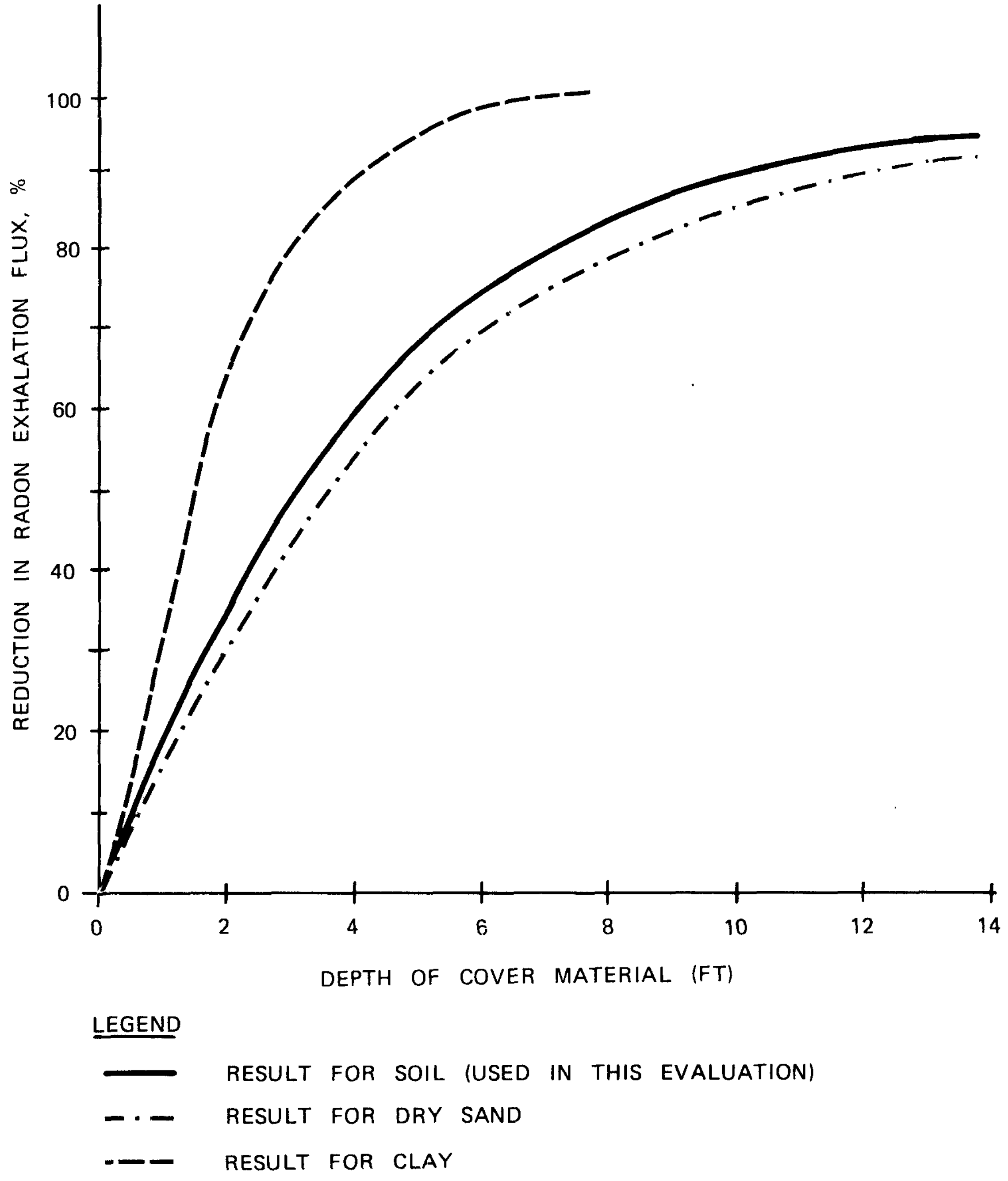

FIGURE 6-1. REDUCTION OF RADON EXHALATION FLUX WITH DEPTH OF COVER

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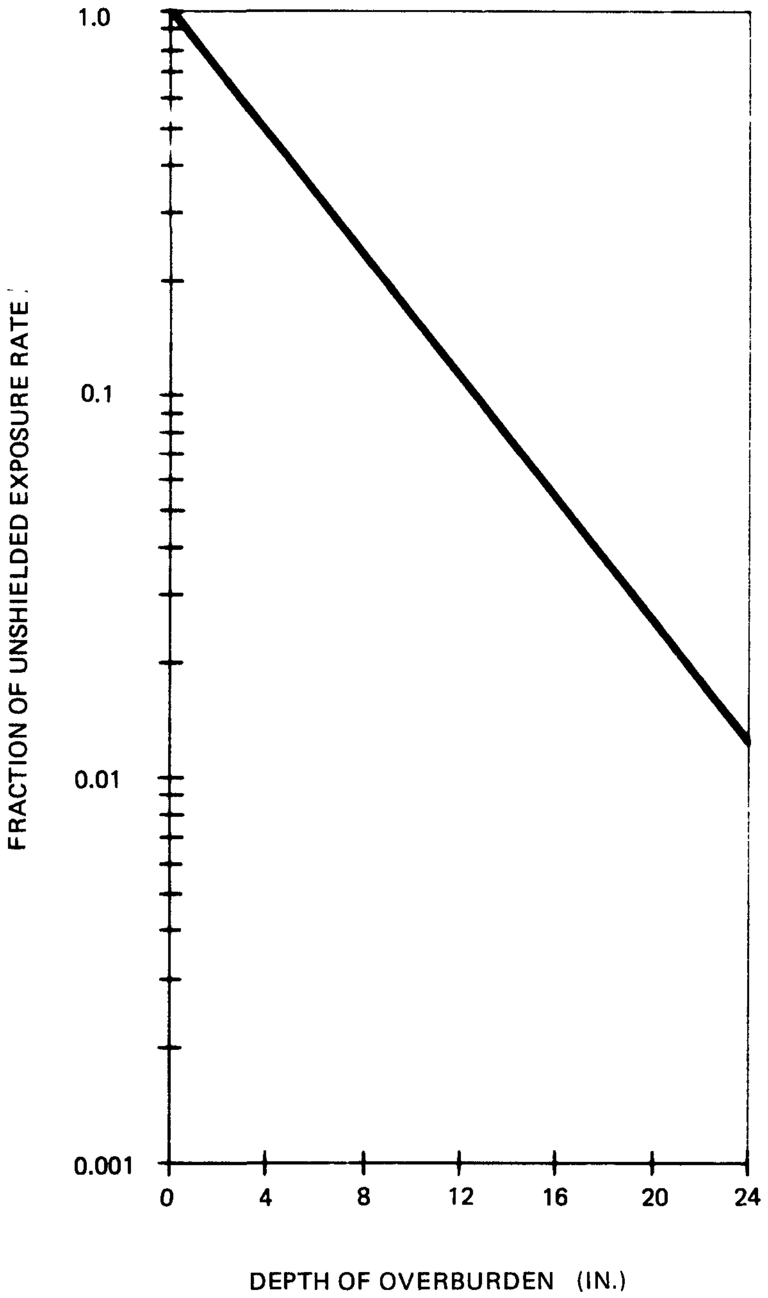

FIGURE 6-2. REDUCTION OF GAMMA EXPOSURE RATE RESULTING FROM PACKED EARTH SHIELDING

130-17

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CHAPTER 7

OFF-SITE REMEDIAL ACTION

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OFF-SITE REMEDIAL ACTION

Two closely related objectives of this engineering assessment are to identify those structures and land areas off-site where tailings are located and, based upon the Surgeon General's guidelines and on criteria established for this assessment, to estimate the costs of appropriate remedial action. Some radioactive sands (considered equivalent to tailings) have been transported off the Lowman site by individuals.

7.1 DATA SOURCES

A mobile scanning unit, operated by the AEC under an interagency agreement with EPA, performed a gamma radiation survey of the Lowman, Idaho area prior to 1973. Of the 25 structures scanned, 10 anomalies were reported. A joint team from the EPA Office of Radiation Programs, Las Vegas, Nevada (EPA-ORP-LV) and the Idaho Department of Health performed individual gamma surveys of 13 locations to determine the source of the anomalies and, if the anomalies were due to tailings, how they had been used.(1) The sand residues at the Lowman site are not strictly tailings, but the EPA survey used the standard terminology. High and low inside and outside gamma readings were recorded. A gamma map was drawn if gamma readings inside the structures exceeded 20 μR/hr.

An EPA gamma survey(2) for windblown tailings was the data source used for consideration of the remedial action for open land areas.

7.2 REMEDIAL ACTION FOR STRUCTURES

A follow-up survey of the anomalies(1) indicated that there were eight off-site locations with possible tailings use. One of these locations was a sandpile; the remaining seven locations were associated with a commercial establishment. Five of the seven locations were classified as "tailings surrounding and up against," while two locations tailings were "under and surrounding" the structures.

The cost for remedial action at off-site structures has been estimated at $50,000 based upon available information, primarily the follow-up gamma survey results.(1) The cost covers remedial action for off-site contaminated locations with tailings under and against the structures.

An extended series of measurements, such as required in the full application of the Grand Junction remedial action criteria,

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(1)See end of chapter for references.

might modify the actual number of locations included in the remedial action. The location 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.

7.3 REMEDIAL ACTION FOR OPEN LANDS

The extent of windblown tailings is indicated by the EPA data(2) in Figure 3-9, Chapter 3. Because of the coarseness of the residues, there is virtually no contamination from windblown materials offsite. Therefore, costing of the cleanup of windblown contamination has been included in the millsite decontamination.

CHAPTER 7 REFERENCES

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CHAPTER 8

LONG-TERM STORAGE SITE SELECTION

CHAPTER 8

LONG-TERM STORAGE SITE SELECTION

The existing Lowman site can meet the criteria specified for long-term control of stabilized tailings. On-site options for remedial stabilization and other corrective actions for the site are described in Chapter 9. One of these options can provide for the long-term site stabilization and effective control of radiation required for the area in which the residues and radioactive sands are located presently, without removing the contaminated material to an alternate disposal site. Therefore, no specific alternative long-term storage sites have been selected for the Lowman radioactive sands.

CHAPTER 9

REMEDIAL ACTIONS AND COST-BENEFIT ANALYSES

CHAPTER 9

REMEDIAL ACTIONS AND COST-BENEFIT ANALYSES

Various remedial actions for the radioactive sands and residues were investigated. The alternatives presented are those considered to be the most realistic and practical when evaluated in regard to present technology, equipment, existing site conditions, and proximity of the material to existing and potential human occupancy. Remedial measures for the site can be separated into two basic categories.

(a) No action on the residues, but provision for a dike to prevent residues from entering Clear Creek, and for maintenance and better fencing for security.

(b) Consolidation of the residue materials and the application of a stabilization cover to the resultant pile, plus maintenance and security fencing.

Several of the remedial measures are common to both the alternative approaches costed; these measures were considered in estimating the total cost of each option. For example, fencing would be required in both options. The standard fencing is 6-ft-high chainlink fence with three strands of barbed wire along the top. Also, radiation warning signs would be displayed prominently on the fence and gates and in other appropriate areas. Off-site remedial action, as indicated in Chapter 7, is included in both option costs.

Long-term maintenance also would be required for both options. Maintenance generally would include periodic monitoring and repair of fences, signs, and stabilizing cover where applicable. Provision for the annual maintenance costs for an extended period of time is included in the form of a perpetual care fund which, at 7% annual interest, would provide the money necessary for projected monitoring and maintenance functions. The perpetual care fund is a mechanism to indicate the long-range control and financing needed to maintain the integrity of the inactive materials.

Since the site was in its present condition prior to the formulation of the Idaho Radiation Safety Requirements for Radioactive Mineral Mill Tailings (Appendix B), Option I provides for only minimal remedial action. The remedial actions suggested for Option II, however, are intended to meet the requirements specified by the State of Idaho. Applicable portions of the regulations are included in Appendix B.

A discussion of the concepts involved in stabilization of mill tailings (sands) and the applicability of these concepts to the Lowman site have been detailed in Chapter 6.

9.1 MINIMAL REMEDIAL ACTION (OPTION I)

The principal objectives of this option are to provide improved security, continued monitoring, maintenance of fencing and drainage around the radioactive sands and residues, and to protect the adjacent creek from contamination by these materials.

At the north edge of the site, west of the old mill foundations, some of the grey-colored sands are resting on the downslope side of the ledge which drops rapidly off into the lower (most westerly) portion of the site adjacent to Clear Creek. At the toe of this slope is an old settling pond. Water has eroded the sands down the slope and into this shallow pond. South of the grey sands along the top of the slope are white-colored sands. These sands show minor erosion. Under this option a dike would be constructed between the toe of the slope and the creek. This dike would serve as a barrier to keep the radioactive sands on the site, and as a dam to contain water run-off and to prevent sands from entering the creek. The dike would be constructed of imported rock and boulders with clay on the side which faces the slope (east). The dike would be approximately 650 ft long, 6 ft high including 1.5 ft buried into the natural soil of the area, about 8 ft wide at the base, and 2 ft wide on top.

9.1.1 Security and Maintenance

Based on the radiometric levels present at the site and on Phase II criteria, the entire site would be designated as a "control area". A 6-ft-high chainlink fence topped by three strands of barbed wire would be installed completely around the 37-acre site. Radiation warning signs would be posted on the security fencing. No irrigation would be required; but physical maintenance would be required periodically, primarily to repair the fencing or to do minor grading aimed at preventing erosion from upslope drainage.

9.1.2 Resulting Impacts

Under Option I the release of radioactive materials from the pile would continue, but public access would be made more difficult by more improved fencing. The site would have no commercial, industrial, or residential use.

9.1.3 Costs

As shown in Table 9-1, $393,000 is the lowest cost option for the site. The major cost components are as follows:

(a)	Engineering (12% of item b)	$ 20,000
(b)	Remedial action	160,000
(c)	Environmental assessment and EIS preparation	40,000

(d)	Contingency (15% of items a, b, and c)	$ 33,000
(e)	Perpetual care fund	140,000
	Total Cost	$393,000

The perpetual care fund at 7% interest would provide approximately $9,800/yr for monitoring and maintenance of the fencing and the sands and residues.

9.2 CONSOLIDATION AND STABILIZATION OF MATERIALS (OPTION II)

The principal objective of this option is to gather all of the radioactive sands, residues, contaminated soil, and debris into one location on the site where they will be stabilized and isolated hydrologically, so far as geologic conditions will allow.

The location on the site which appears to be the best place to gather, bury, and stabilize the sands (considering stability, upslope drainage, and aquifer problems) is the southeast corner. Approximately 4 acres would be required in the area east of the road which leads into the site. The southern edge of the pile would be at the heel of the natural embankment, which is on the east and south edge of the site near the edge of the tree line. The natural soil would be excavated to a depth of 2 ft or to bedrock and stockpiled for later use as stabilization cover. The pit would be lined with a minimum of 12 in. of compacted clay. The ore pile then would be deposited in the pit, followed by the grey sand residue, the white sands, the debris, and the black and red sands. The 4 acres would be filled to an average depth of just over 10 ft. The surface of the pile would be gently sloped from the top of the bank on the east and south (near the tree line) toward the west. The pile would then be covered with a minimum of 6 in. of the same type of clay that was used as a bottom liner. On top of this layer, the removed top soil would be placed; river-run gravel then would be mixed with the soil to achieve a blend that will withstand erosion yet permit natural growth to become established. The total cover, including clay, would be 2 ft deep. The finished surface of the pile would be contour-graded with ridges at right angles to the slope to discourage erosion and retain moisture. No revegetation is proposed since natural vegetation soon would establish itself on the stabilized pile. Water from upslope which might drain naturally on the surface of the stabilized pile would be diverted by means of drainage ditches.

Off-site remedial action at the locations as described in Chapter 7 would be included.

9.2.1 Security and Maintenance

The stabilized pile would be completely surrounded with the same type of fencing and signs as those for Option I. The necessary monitoring and physical maintenance would assure the integrity of the stabilization, fencing, and drainage system. No irrigation program would be required.

9.2.2 Resulting Impacts

Option II stabilization would be effective in preventing the spread of sands by wind and water. The 2-ft cover of material would reduce gamma radiation to near background levels, but would not reduce significantly the exhalation of radon from the pile (about 30%).

The remainder of the site would have limited use because of the radioactivity associated with the physical presence of the pile.

9.2.3 Costs

The cost of this option is estimated at $590,000. The major cost component are as follows:

(a)	Engineering (10% of item b)	$ 35,000
(b)	Remedial action	350,000
(c)	Environmental assessment and EIS preparation	60,000
(d)	Contingency (15% of items a, b, and c)	65,000
(e)	Perpetual care fund	80,000
	Total Cost	$590,000

The perpetual care fund at 7% interest would provide approximately $5,600/yr for monitoring and maintenance. The projected maintenance would be less than that of Option I by about $4,200/yr, primarily because of less fencing, the ease of maintenance on a stabilized pile, and of the ability of natural vegetation to establish itself on the pile.

Further reduction in radon emission can be accomplished by increasing the stabilization cover as shown in Figure 6-1. The cost per foot of additional cover on the pile is estimated at $20,000.

9.3 ANALYSES OF COSTS AND BENEFITS

The purpose of this section is to compare the cost of the two alternatives with the corresponding projected benefits. As summarized in Table 9-1, the total estimated costs for the remedial options are $393,000 for Option I and $590,000 for Option II.

9.3.1 Health Benefits

As discussed in Chapter 3, the dominant effect on health from uranium mill tailings (sands) occurs by inhalation of radon daughters, and the benefits resulting from the remedial action alternatives are directly related to the resulting reduction in exposure of the public to radon daughters. The radon exhalation is reduced by the application of cover material, or the physical removal of the sands. Option I offers no further reduction in radon exhalation because the pile cover will not be increased. However, it does contain provisions necessary to restrict access to the site.

Option II reduces radon exhalation by about 30%, and there is a health benefit associated with that reduction. The reduction in radon exhalation is, however, insignificant compared to the background radon levels in the Lowman vicinity. Therefore, the major benefits associated with this option result from restricting access to the site and by providing erosion control. No cost-benefit analysis was performed because of the very small health benefit of the options.

9.3.2 Land Value Benefits

Most of the land surrounding the site is under U.S. Forest Service control.

The presence of the radioactive sands and residues affects land usage and values only slightly. Under Option I there would be no change in values. Under Option II the site could have limited other uses, and thus increase in value.

TABLE 9-1

COST ESTIMATE SUMMARY

Option No.	Description	Estimated Cost ($)*
I	Fencing, dike construction and maintenance	393
II	Consolidation of sands and rubble, 2-ft stabilization cover, drainage modifications, maintenance, and fencing	590

*Costs are in thousands of dollars, based on 1977 value. Both options include off-site remedial action at two locations.

APPENDIX A

REMEDIAL ACTION CRITERIA

A.1 Surgeon General's Guidelines

A.2 Radiological Criteria for Decontamination of Inactive Uranium Mill Sites

A.3 Grand Junction Remedial Action Criteria (10CFR712)

APPENDIX A

REMEDIAL ACTION CRITERIA

The remedial action criteria used for the Phase II assessment of the cleanup of mill tailings are presented in the following documents:

A.1 SURGEON GENERAL'S GUIDELINES

DEPARTMENT OF HEALTH, EDUCATION AND WELFARE,
PUBLIC HEALTH SERVICE,
Washington, D. C., July 1970.

DR. R. L. CLEERE,
Executive Director, Colorado State Department of Health, 4210
E. 11th Avenue, Denver, Colorado

DEAR DR. CLEERE: I am pleased to respond to your letter of January 29 in which you asked Dr. M. W. Carter, Director of our Southwestern Radiological Health Laboratory, for Public Health Service and/or U. S. Atomic Energy Commission assistance in providing exposure guidelines applicable to homes with high concentrations of radon progeny.

The enclosed graded recommendations for action have been developed within the framework of existing Federal Radiation Council guidance for occupational exposure to airborne concentrations of radon and its daughters (progeny). Also, graded action levels applicable to external gamma radiation are included.

You will note in the accompanying Explanatory Notes that these recommendations apply specifically to dwellings constructed with or on uranium mill tailings. Further qualifications in the Explanatory Notes should be consulted before these recommendations are applied.

The specific information which your Department is developing on the variability of radon daughter concentrations in dwellings and on optimum control measures will be essential towards making those decisions necessary in applying the recommendations.

These recommendations have been directed to the Atomic Energy Commission for comment. Because of the urgency attached to your receiving the recommendations as soon as possible, they have been forwarded to you in advance of receiving AEC views and comments. We will advise you of the AEC response when received.

Sincerely yours,

PAUL J. PETERSON,
Acting Surgeon General

Enclosure:

RECOMMENDATIONS OF ACTION FOR RADIATION EXPOSURE LEVELS IN DWELLINGS CONSTRUCTED ON OR WITH URANIUM MILL TAILINGS

External gamma radiation:

Level:	Recommendations
Greater than 0.1 mR/hr . . .	Remedial action indicated.
From 0.05 to 0.1 mR/hr . . .	Remedial action may be suggested.
Less than 0.05 mR/hr . .	No action indicated.

Level:	Recommendations
Greater than 0.05 WL	Remedial action indicated.
From 0.01 to 0.05 WL	Remedial action may be suggested.
Less than 0.01 WL	No action indicated.

EXPLANATORY NOTES

1. These recommendations are written specifically for dwellings constructed on or with uranium mill tailings. This situation may involve continuous exposure of members of the public to radon daughter product activities and whole-body gamma irradiation levels in excess of the background radiation levels found within dwellings in the area not constructed with or on uranium mill tailings.

2. Although the initial concern was the presence of radon daughter product activities within these dwellings, preliminary surveys have indicated that in some instances, the gamma radiation levels were of prime importance. Thus, recommendations are made concerning both types of radiation. The recommendations applicable to a particular dwelling will be determined by whichever type of radiation has the high level.

3. Three levels for action are recommended for both external gamma and radon daughter product exposures. This graded system of actions is proposed to allow latitude in the middle ranges for the judgment of the on-site investigators.

4. The external gamma and radon daughter product levels proposed constitute exposures which are in addition to the natural background levels found within dwellings in the area not constructed on or with uranium mill tailings. In the Grand Junction, Colorado, area these levels are approximately 0.01 mR/hr (approximately 90 mrem/yr) and 0.004 Working Levels (WL) (approximately 0.2 CWLM/yr) respectively (1).

5. The expected health effects of concern will be different for the two types of radiation; i.e., leukemia for whole-body gamma radiation exposure and lung cancer for exposure to inhaled radon daughter products. This expectation is based, in part, on findings derived from population studies such as the Japanese atomic bomb

survivors and uranium miners. These specific health effects are considered to be mutually exclusive. The basis for this assumption is that the expected radiation contribution to whole-body exposure from inhaled radon and daughter products would be considerably less than the direct exposure from external gamma radiation at the levels encountered in the dwellings. Conversely, the external gamma radiation contribution to the lung dose is considered to comprise a negligible additional risk of lung cancer.

6. (a) A Working Level (WL) is the term used to describe radon daughter product activities in air. This term is defined as any combination of short-lived radon daughter products in 1 liter of air that will result in the ultimate emission of 1.3×10^5 MeV of potential alpha energy (2). The numerical value of the WL is derived from the alpha energy released by the total decay through Ra C' of the short-lived radon daughter products, Ra A, Ra B and Ra C, at radioactive equilibrium with 100 pCi of ^{222}Rn per liter of air (3).

6. (b) A Working Level Month (WLM) is the term used to express the occupational exposure incurred in one working month of 170 hours by a uranium miner laboring in an atmosphere containing radon daughter products; i.e., one working month in a mine atmosphere containing 1 WL of radon daughter products equals 1 WLM.

6. (c) Cumulative Working Level Months (CWLM) is the term used to express the total accumulated occupational exposure to radon daughter products in air; i.e., an air concentration of radon daughter products of 1 WL would, in one working month, equal 1 WLM, and in 1 year or 12 months would equal 12 CWLM.

6. (d) Since occupational exposures are based upon 170 hours per month and continuous exposure involves approximately 170 hours per week, then an occupational exposure to an air concentration of 1 WL is equivalent to continuous exposure to 0.025 WL.

7. These recommendations are based on the assumption of a linear, non-threshold dose-effect relationship. The lack of definitive information precludes allowances for possible differences in radio-sensitivity due to age, sex, or other biological characteristics.

8. No action is indicated when the external gamma exposure rate is less than 0.05 mR/hr and the radon daughter product activity is less than 0.01 WL since under conditions of continuous exposure these levels would result in maximum annual exposures of approximately 400 mrem and 0.5 CWLM, respectively. The maximum annual value of 400 mrem is less than the dose limits recommended for an individual body exposure to external gamma irradiation.

The ICRP (5) recommends that the annual dose limit for members of the public shall be 1/10 of the corresponding annual occupational maximum permissible dose. The maximum annual value of 0.5 CWLM of radon daughter product exposure is approximately 1/10 of the 4 CWLM annual occupational exposure limit recommended by the FRC (6) for implementation on 1 January 1971, and less than 1/20 of the annual occupational exposure limit of 12 CWLM recommended for uranium miners in the present FRC regulations (4).

9. Remedial action may be suggested in the case of external gamma exposure rates of 0.05-0.10 mR/hr or radon daughter product activities of 0.01-0.05 WL since under conditions of continuous exposure these levels would result in maximum annual exposures of approximately 400-900 mrem and 0.5-2.5 CWLM. The upper limit of these ranges exceeds the strictly applied recommendations of the FRC and ICRP for exposures of an individual member of the public. However, this extension seems justified in situations in which unforeseen exposures have occured, since as stated by ICRP (5) "in general it will be appropriate to institute countermeasures only when their social cost and risk will be less than those resulting from the exposure." It is further stated by the ICRP (5) that very low levels of risk are implied in the dose limits for members of the public and that it is likely to be of minor consequence to their health if the dose limits are marginally or even substantially exceeded.

10. Remedial action is indicated at gamma exposures greater than 0.1 mR/hr or at radon daughter product activities greater than 0.05 WL. Under conditions of continuous exposure, these levels would result in minimum annual exposures of 900 mrem and 2.5 CWLM. All values above these would indicate the necessity for remedial action, since at these levels the maximum annual exposures recommended by the FPC and ICRP for an individual member of the public is exceeded.

11. With respect to the external gamma irradiation, from the estimates published by ICRP (7), it can be interpolated that the annual risk of leukemia under conditions of continuous exposure to 500 mrem per year is an increased incidence of about 10 cases per year per million persons exposed. The natural annual incidence of leukemia for all ages is given by ICRP (8) as 10-100 cases per million persons. With respect to radon daughter product exposures, it has been estimated by Archer and Lundin (9) that an exposure of 120 CWLM to a group of white adult males in the United States appears to approximately double the normal lung cancer incidence which for this population is about 2-3 cases per year per 10,000 persons. At an annual exposure of 2.5 CWLM, 48 years would be required to reach 120 CWLM.

12. It is considered that implementation of these recommendations for the various exposure ranges would make it highly unlikely that any serious health effects would result from exposure to radon daughter products or external gamma irradiation in this particular situation.

13. It is suggested that remedial action be taken only after an adequate number of measurements taken under a diversity of temporal and climatic conditions have clearly established that the average exposure is in excess of 0.1 mR/hr or 0.05 WL exist and in instituting corrective measures. However, it is considered that the additional health risks from continued exposure over this time period are of lesser consequence than the economic and social discomfitures of precipitous action.

Approved.

/s/ PAUL J. PETERSON,
for Jesse L. Steinfeld, M.D.,
Surgeon General, Public Health Service

July 27, 1970

REFERENCES

1. Personal communication, Mr. Robert D. Siek, Colorado State Department of Health.

2. U.S. Public Health Service Publication No. 494, Control of Radon and Daughters in Uranium Mines and Calculations on Biologic Effects, 1957.

3. Federal Radiation Council Report No. 8 Revised, Guidance for the Control of Radiation Hazards in Uranium Mining, 1967.

4. Federal Radiation Council Report No. 1. Background Material for the Development of Radiation Protection Standards, 1960.

5. Recommendations of the International Commission on Radiological Protection, ICRP Publication 9, 1966.

6. Federal Register, Vol. 34, No. 10, pp 576-577, 1969.

7. The Evaluation of Risks from Radiation, ICRP Publication 8, 1966.

8. Radiosensitivity and Spatial Distribution of Dose, ICRP Publication 14, 1969.

9. V.E. Archer and F. E. Lundin, Jr., Radiogenic Lung Cancer in Man: Exposure-Effect Relationship, Environmental Research 1, pp 370-383, 1967.

A.2 RADIOLOGICAL CRITERIA FOR DECONTAMINATION OF INACTIVE URANIUM MILL SITES*

1. General

Radiological criteria for an engineering assessment of possible remedial actions applicable to uranium mill tailings piles and for the decontamination of inactive uranium mill sites are provided herein. These criteria are applicable to the sites, to their surrounding areas which have been contaminated by radioactive materials from the sites, and to buildings in which the materials have been used.

Critical radiation exposure pathways from inactive uranium mill sites to members of the general population are:

(a) Radon escaping from the tailings pile carried by the wind into habitable structures where the holdup time is long enough, resulting in buildup of radon daughters to levels greater than the ambient air.

(b) Tailings material used for construction of habitable structures can result in a buildup of radon daughters and increased gamma levels.

(c) Gamma rays from tailings material cause whole body radiation exposure. This includes not only the "gamma shine" from the tailings pile that exposes people living nearby, but also the radiation exposure from tailings material that has been eroded off the pile onto surrounding land. The mill sites always show elevated gamma exposure levels because of contamination by ore, tailings solids, and process solutions.

(d) ^{226}Ra, Th, and other radionuclides from tailings piles can be leached into ground water and thereafter into public and irrigation water supplies.

(e) Windblown particulate material (Ra and Th) from the tailings pile can be inhaled causing a radiation dose to the lung.

Remedial actions may be required on inactive uranium mill tailings piles to reduce or prevent excess radiation exposure from radon progeny, gamma radiation, ^{226}Ra, and radioactive particulate material. If tailing material has been used as a building material, remedial actions may be required to reduce radon concentrations and/or gamma activity levels. Remedial actions performed on tailings piles

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*Provided by U S Environmental Protection Agency, as attachment to letter dated Dec 1974.

and decontamination of mill sites and surrounding contaminated areas should result in residual exposures that are as low as practicable. There is no single permissible exposure level applicable to all such cases. An evaluation should be made on a case-by-case basis of the risk involved, balanced against (1) the cost of reducing the residual contamination, and (2) the economic effect on alternatives such as restricting the use of the land. The result of such an analysis can be used by all concerned to define the "as low as practicable" residual level of contamination that will be acceptable and determine whether restrictions will be required on the use of any contaminated land.

2. Tailings Pile or Pond

The operation of uranium mills results in the generation of waste material which is disposed of in tailings piles and ponds. Environmental contamination has occurred at those sites where measures were not taken to control the movement of the radioactive material. In order to restore the environmental quality and provide for protection of the public, such sites should be decontaminated and result in residual gamma radiation levels which are as low as practicable. For most situations this would require decontamination of the area by (1) removal of radioactive material to a location where the material would be isolated from the biosphere, or (2) providing sufficient cover such that the resultant gamma radiation levels are as low as practicable, preferably at background. However, under certain topographical conditions and economic considerations wherein complete removal is not practicable, the residual levels should not exceed 40 μR/hr above background. This value is arbitrarily chosen for the purpose of providing an engineering estimate on cleanup of contaminated areas. It is considered to be sufficiently low that the expected exposures occurring after any remedial action at this level would not constitute a public concern. However, this should not be considered as the final criterion.* The gamma radiation level is the net, corrected measurement at 3 ft above the ground.

For each site a determination should be made of the radium concentration in the soil. Cleanup should reduce the soil concentration to less than two times the radium background specific for the area.

If the radioactive material remains in place and stabilized, the area should be designated as a controlled area. Due to the difficulty of controlling radon diffusion and the existing state-of-the-art of stabilization, the land should be restricted as to human occupancy and be properly fenced to limit access.

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*When all phase II information is complete and the health impact of remedial actions identified an overall determination of as low as practicable protection levels can be assessed appropriately. Therefore, the above numbers are subject to change.

The ^{226}Ra activity contribution from the site in ground or surface water should meet applicable state or federal standards.

3. Open Land Areas

This area refers to all land beyond the fence of the sites where tailings are located. As with the tailings areas, decontamination of the uranium mill site and other areas contaminated by wind- or water-eroded tailings should result in residual gamma levels which are as low as practicable. Cleanup of the area would require returning of the windblown tailings material to the site and establishing a controlled area, or moving all the material to a location that will isolate the material from the biosphere.

If the residual gamma levels are less than 10μR/hr above background, the land may be released for unrestricted use. If residual levels are equal to or greater than 10μR/hr above background at a given site a determination should be made of the radium concentration in the soil. Cleanup should reduce the soil concentration to no more than two times the radium background specific for the area. Under certain topographical conditions wherein complete removal of tailings is not possible or practicable, the residual levels should be as low as practicable but should not exceed 40μR/hr above background and access should be controlled. This value is arbitrarily chosen for the purpose of providing an engineering estimate on cleanup of contaminated areas. The gamma radiation level is the net, corrected measurement at 3 ft above the ground.

4. Structures

It is possible that there will be several industrial and residential structures where tailings have been utilized for construction purposes. When it has been determined that tailings were used in the construction, the lower limits of the guidelines established by the Surgeon General for structures in Grand Junction, Colorado, will be used.

A.3 GRAND JUNCTION REMEDIAL ACTION CRITERIA (10CFR712)

PART 712—GRAND JUNCTION REMEDIAL ACTION CRITERIA

AUTHORITY: Sec. 203, 86 Stat. 226.

§ 712.1 Purpose.

(a) The regulations in this part establish the criteria for determination by ERDA of the need for, priority of and selection of appropriate remedial action to limit the exposure of individuals in the area of Grand Junction, Colo., to radiation emanating from uranium mill tailing which have been used as a construction-related material.

(b) The regulations in this part are issued pursuant to Pub. L. 92–314 (86 Stat. 222) of June 16, 1972.

§ 712.2 Scope.

The regulations in this part apply to all structures in the area of Grand Junction, Colo., under or adjacent to which uranium mill tailings have been used as a construction-related material between January 1, 1951, and June 16, 1972, inclusive.

§ 712.3 Definitions.

As used in this part:

(a) "Administrator" means the Administrator of Energy Research and Development or his duly authorized representative.

(b) "Area of Grand Junction, Colo.," means Mesa County, Colo.

(c) "Background" means radiation arising from cosmic rays and radioactive material other than uranium mill tailings.

(d) "ERDA" means the U.S. Energy Research and Development Administration or any duly authorized representative thereof.

(e) "Construction-related material" means any material used in the construction of a structure.

(f) "External gamma radiation level" means the average gamma radiation exposure rate for the habitable area of a structure as measured near floor level.

(g) "Indoor radon daughter concentration level" means that concentration of radon daughters determined by: (1) Averaging the results of 6 air samples each of at least 100 hours duration, and taken at a minimum of 4-week intervals throughout the year in a habitable area of a structure, or (2) utilizing some other procedure, approved by the Commission.

(h) "Milliroentgen (mR) means a unit equal to one-thousandth (1/1000) of a roentgen which roentgen is defined as an exposure dose of X or gamma radiation such that the associated corpuscular emission per 0.001293 gram of air produces, in air, ions carrying one electrostatic unit of quantity of electricity of either sign.

(i) "Radiation" means the electromagnetic energy (gamma) and the particulate radiation (alpha and beta) which emanate from the radioactive decay of radium and its daughter products.

(j) "Radon daughters" means the consecutive decay products of radon-222. Generally, these include Radium A (polonium-218), Radium B (lead-281), Radium C (bismuth-214), and Radium C' (polonium-214).

(k) "Remedial action" means any action taken with a reasonable expectation of reducing the radiation exposure resulting from uranium mill tailings which have been used as construction-related material in and around structures in the area of Grand Junction, Colo.

(l) "Surgeon General's guidelines" means radiation guidelines related to uranium mill tailings prepared and released by the Office of the U.S. Surgeon General, Department of Health, Education and Welfare on July 27, 1970.

(m) "Uranium mill tailings" means tailings from a uranium milling operation involved in the Federal uranium procurement program.

(n) "Working Level" (WL) means any combination of short-lived radon daughter products in 1 liter of air that will result in the ultimate emission of 1.3×10^5 MeV of potential alpha energy.

§ 712.4 Interpretations.

Except as specifically authorized by the Administrator in writing, no interpretation of the meaning of the regulations in this part by an officer or employee of ERDA other than a written interpretation by the General Counsel will be recognized to be binding upon ERDA.

(b) Where ERDA approved data on indoor radon daughter concentration levels are not available:

(1) For dwellings and schoolrooms:

(i) An external gamma radiation level of 0.05 mR/hr. or greater above background.

(ii) An indoor radon daughter concentration level of 0.01 WL or greater above background (presumed).

(A) It may be presumed that if the external gamma radiation level is equal to or exceeds 0.02 mR/hr. above background, the indoor radon daughter concentration level equals or exceeds 0.01 WL above background.

(B) It should be presumed that if the external gamma radiation level is less than 0.001 mR/hr. above background, the indoor radon daughter concentration level is less than 0.01 WL above background, and no possible need for remedial action exists.

(C) If the external gamma radiation level is equal to or greater than 0.001 mR/hr. above background but is less than 0.02 mR/hr. above background, measurements will be required to ascertain the indoor radon daughter concentration level.

(2) For other structures: (i) An external gamma radiation level of 0.15 mR/hr. above background averaged on a room-by-room basis.

(ii) No presumptions shall be made on the external gamma radiation level/indoor radon daughter concentration level relationship. Decisions will be made in individual cases based upon the results of actual measurements.

§ 712.3 Determination of possible need for remedial action where criteria have not been met.

The possible need for remedial action may be determined where the criteria in § 712.7 have not been met if various other factors are present. Such factors include, but are not necessarily limited to, size of the affected area, distribution of radiation levels in the affected area, amount of tailings, age of individuals occupying affected area, occupancy time, and use of the affected area.

§ 712.5 Communications.

Except where otherwise specified in this part, all communications concerning the regulations in this part should be addressed to the Director, Division of Safety, Standards, and Compliance, U.S. Energy Research and Development Administration, Washington, D.C. 20545.

§ 712.6 General radiation exposure level criteria for remedial action.

The basis for undertaking remedial action shall be the applicable guidelines published by the Surgeon General of the United States. These guidelines recommend the following graded action levels for remedial action in terms of external gamma radiation level (EGR) and indoor radon daughter concentration level (RDC) above background found within dwellings constructed on or with uranium mill tailings:

EGR	RDC	Recommendation
Greater than 0.1 mR/hr.	Greater than 0.05 WL.	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.

§ 712.7 Criteria for determination of possible need for remedial action.

Once it is determined that a possible need for remedial action exists, the record owner of a structure shall be notified of that structure's eligibility for an engineering assessment to confirm the need for remedial action and to ascertain the most appropriate remedial measure, if any. A determination of possible need will be made if as a result of the presence of uranium mill tailings under or adjacent to the structure, one of the following criteria is met:

(a) Where ERDA approved data on indoor radon daughter concentration levels are available:

(1) For dwellings and schoolrooms: An indoor radon daughter concentration level of 0.01 WL or greater above background.

(2) For other structures: An indoor radon daughter concentration level of 0.03 WL or greater above background.

§ 712.9 Factors to be considered in determination of order of priority for remedial action.

In determining the order of priority for execution of remedial action, consideration shall be given, but not necessarily limited to, the following factors:

(a) Classification of structure. Dwellings and schools shall be considered first.

(b) Availability of data. Those structures for which data on indoor radon daughter concentration levels and/or external gamma radiation levels are available when the program starts and which meet the criteria in § 712.7 will be considered first.

(c) Order of application. Insofar as feasible remedial action will be taken in the order in which the application is received.

(d) Magnitude of radiation level. In general, those structures with the highest radiation levels will be given primary consideration.

(e) Geographical location of structures. A group of structures located in the same immediate geographical vicinity may be given priority consideration particularly where they involve similar remedial efforts.

(f) Availability of structures. An attempt will be made to schedule remedial action during those periods when remedial action can be taken with minimum interference.

(g) Climatic conditions. Climatic conditions or other seasonal considerations may affect the scheduling or certain remedial measures.

§ 712.10 Selection of appropriate remedial action.

(a) Tailings will be removed from those structures where the appropriately averaged external gamma radiation level is equal to or greater than 0.05 mR/hr. above background in the case of dwellings and schools and 0.15 mH/hr. above background in the case of other structures.

(b) Where the criterion in paragraph (a) of this section is not met, other remedial action techniques, including but not limited to sealants, ventilation, and shielding may be considered in addition to that of tailings removal. ERDA shall select the remedial action technique or combination of techniques, which it determines to be the most appropriate under the circumstances.

APPENDIX B

IDAHO RADIATION SAFETY REQUIREMENTS FOR RADIOACTIVE MINERAL MILL TAILINGS

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IDAHO RADIATION SAFETY REQUIREMENTS FOR RADIOACTIVE MINERAL MILL TAILINGS

Sec. I.1 Scope. The regulations in this part establish requirements for radioactive mineral mill tailings piles and ponds associated with active mills, inactive mills, and closed or abandoned mills. The provisions of this Part I are in addition to, and not in substitution for, other applicable provisions of: (a) these regulations, and (b) any specific license issued to a mill operator, pursuant to Section B.30 of these regulations, subsequent to the effective date of this Part I.

Sec. I.2 Maintenance of Piles and Ponds at All Mills

(a) If pile edges are adjacent to a river, creek, gulch or other watercourse that might reasonably be expected to erode the edges during periods of high water, the exposed slopes shall be stabilized and the edges shall be diked and riprapped sufficiently to prevent erosion of the pile.

(b) Drainage ditches shall be provided around the pile edges sufficient to prevent surface runoff water from neighboring land from reaching and eroding the pile.

(c) Access to the pile and pond areas shall be controlled by the operator or owner and properly posted.

(d) The pile shall be maintained in such a manner that excessive erosion of, or environmental hazard from, the radioactive materials does not occur.

(e) The owner of the tailing pile site shall give the Radiation Control Agency written notice thirty (30) days in advance of any contemplated transfer of right, title of interest in the site by deed, lease, or other conveyance. The written notice shall contain the name and address of the proposed purchaser or transferee. Prior written approval of the Radiation Control Agency shall be obtained before the surface area of the land shall be put to use.

(f) With the exception of reprocessing at the site prior written approval of the Radiation Control Agency must be obtained before any tailings material is removed from any active or inactive mill site or tailings pile.

(g) The Radiation Control Agency may waive or modify individual requirements in regard to stabilization or utilization of tailings material if it can be shown that they are unnecessary or impracticable in specific cases.

Sec. I.3 Additional Requirements for Inactive Mills

(a) Before abandonment, sale, or transfer of any kind and in any manner of a tailings site the operator shall determine that all requirements of Section I.2 of this

Part I are fulfilled at such site. If the requirements of Section I.2 of this Part I are not fulfilled at such time, the operator who abandons, sells, or transfers such site shall fulfill the requirements of Section I.2 of this Part I and shall, in addition, return to the site any tailings pile material which has been removed from the tailings pile by natural forces.

(b) Before abandonment, sale, or transfer of any kind and in any manner of a tailings site the operator shall determine that the following requirements are fulfilled:

(1) Ponds shall be drained and covered with materials that prevent blowing of dust. Water drained from the ponds shall be disposed of in a manner approved by the Radiation Control Agency.

(2) Taking into consideration the types of materials at each site, piles shall be leveled and graded so that there is, insofar as possible, a gradual slope to ensure that there shall be no low places on the pile where water might collect. Side slopes shall be stabilized by riprap, dikes, reduction of grades, vegetation, or any other method or combination of methods that will ensure stabilization.

(3) The pile shall be stabilized against wind and water erosion. The method of stabilization may consist of vegetation or a cover of soil, soil contraining rock or stone, rock or stone, cement or concrete products, petroleum products, or any other soil stabilization material presently recognized or which may be recognized in the future, or any combination of the foregoing as may be required for proper protection from wind or water erosion.

(4) Detailed plans for stabilizing tailings piles shall be submitted to the Radiation Control Agency for review and approval prior to undertaking stabilization of the pile.

(5) If the requirements of Sec. I.3(b)(1), (2), (3) and (4) of this Part I are not fulfilled before the abandonment, sale, or transfer of a tailings site, the operator who abandons, sells or transfers such site shall fulfill the requirements of Sec. I.3 (b)(1), (2), (3) and (4) of this Part I and shall, in addition, return to the site any tailings pile material which has been removed from the tailings pile by natural forces.

Section I.4 Waiver. The Radiation Control Agency will waive the requirements of Sec. I.3 of this Part I for a sale or transfer of a mill tailings site to a person who plans to continue operating the associated mill or mills for the same purpose. Such waiver shall not be granted until the new operator has obtained a license from the Radiation Control Agency issued pursuant to Sec. B.30, of Part B of these regulations.