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A SUMMARY OF THE ENGINEERING ASSESSMENT OF INACTIVE URANIUM MILL TAILINGS

MASTER

SHIPROCK SITE
SHIPROCK, NEW MEXICO

JULY 1981

PREPARED FOR

UNITED STATES DEPARTMENT OF ENERGY
ALBUQUERQUE OPERATIONS OFFICE
URANIUM MILL TAILINGS
REMEDIAL ACTIONS PROJECT OFFICE
ALBUQUERQUE, NEW MEXICO

CONTRACT NO. DE-AC04-76GJ01658

BY

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Prepared for

U.S. DEPARTMENT OF ENERGY
ALBUQUERQUE OPERATIONS OFFICE
URANIUM MILL TAILINGS REMEDIAL ACTIONS
PROJECT OFFICE
ALBUQUERQUE, NEW MEXICO

Contract No. DE-AC04-76GJ01658

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NOTICE

This engineering assessment has been performed under DOE Contract No. DE-AC04-76GJ01658 between the U.S. Department of Energy and Ford, Bacon & Davis Utah Inc.

Copies of this report may be obtained from the Uranium Mill Tailings Remedial Action Project Office, U.S. Department of Energy, Albuquerque Operations Office, Albuquerque, New Mexico 87115.

FOREWORD

This report is a summary of a parent report (issued under separate cover), entitled "Engineering Assessment of Inactive Uranium Mill Tailings for Shiprock Site, Shiprock, New Mexico." Both reports have been authorized by the U.S. Department of Energy (DOE), Albuquerque Operations Office, Uranium Mill Tailings Remedial Action Project Office, Albuquerque, New Mexico, under Contract No. DE-AC04-76GJO1658. These reports are revisions of an earlier report dated March 1977, entitled "Phase II - Title I Engineering Assessment of Inactive Uranium Mill Tailings, Shiprock Site, Shiprock, New Mexico," which was authorized by DOE, Grand Junction, Colorado, under Contract No. E(05-1)-1658.

These reports have become necessary as a result of changes that have occurred since 1977 which pertain to the Shiprock site and vicinity, as well as changes in remedial action criteria. The new data reflecting these changes are summarized in this report. Evaluation of the current conditions is essential to assessing the impacts associated with the options suggested for remedial actions for the tailings.

Ford, Bacon & Davis Utah Inc. (FB&DU) has received excellent cooperation and assistance in obtaining new data to prepare these reports. Special recognition is due Richard H. Campbell and Mark Matthews of DOE, as well as Harold Tso and Ben Benally of the Environmental Protection Commission, Navajo Nation, and Chris Eastin of the Navajo Engineering and Construction Authority. The Bureau of Indian Affairs, Shiprock Agency, contributed information, as did several local, county, and state agencies and private individuals.

ABSTRACT

Ford, Bacon & Davis Utah Inc. has reevaluated the Shiprock site in order to revise the March 1977 engineering assessment of the problems resulting from the existence of radioactive uranium mill tailings at Shiprock, New Mexico. This engineering assessment has included the preparation of topographic maps, the performance of core drillings and radiometric measurements sufficient to determine areas and volumes of tailings and radiation exposures of individuals and nearby populations, the investigations of site hydrology and meteorology, and the evaluation and costing of alternative corrective actions.

Radon gas released from the 1.5 million dry tons of tailings at the Shiprock site constitutes the most significant environmental impact, although windblown tailings and external gamma radiation also are factors. The eight alternative actions presented in this engineering assessment range from millsite decontamination with the addition of 3 m of stabilization cover material (Option I), to removal of the tailings to remote disposal sites and decontamination of the tailings site (Options II through VIII). Cost estimates for the eight options range from about $13,400,000 for stabilization in place to about $37,900,000 for disposal at a distance of about 16 mi.

Three principal alternatives for the reprocessing of the Shiprock tailings were examined:

(a) Heap leaching

(b) Treatment at an existing mill

(c) Reprocessing at a new conventional mill constructed for tailings reprocessing.

The cost of the uranium recovered would be about $230/lb by heap leach and $250/lb by conventional plant processes. The spot market price for uranium was $25/lb early in 1981. Therefore, reprocessing the tailings for uranium recovery is not economically attractive.

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CHAPTER 1

A SUMMARY OF THE ENGINEERING ASSESSMENT OF INACTIVE URANIUM MILL TAILINGS

CHAPTER 1

A SUMMARY OF THE ENGINEERING ASSESSMENT OF INACTIVE URANIUM MILL TAILINGS

1.1 INTRODUCTION

The U.S. Energy Research and Development Administration (ERDA) contracted in 1975 with Ford, Bacon & Davis Utah Inc. (FB&DU) of Salt Lake City, Utah, to provide architect-engineering services and final reports based on the assessment of the problems resulting from the existence of large quantities of radioactive uranium mill tailings at inactive mill sites in eight western states and in Pennsylvania. In 1980, the U.S. Department of Energy (DOE) contracted with FB&DU to produce revised reports of the sites designated in the Uranium Mill Tailings Remedial Action (UMTRA) program in order to reflect the current conditions, new criteria and options, and to estimate current remedial action costs.

A preliminary survey (Phase I) was carried out in 1974 by the U.S. Atomic Energy Commission (AEC) in cooperation with the U.S. Environmental Protection Agency (EPA) and the affected states. In a summary report,[1] ERDA identified 17 sites in Arizona, Colorado, Idaho, New Mexico, Utah, and Wyoming for which practical remedial measures were to be evaluated. Subsequently, ERDA added five additional sites (Riverton and Converse County, Wyoming; Lakeview, Oregon; Falls City and Ray Point, Texas). More recently, DOE has added a site in Canonsburg, Pennsylvania, one near Baggs, Wyoming, and two sites in North Dakota (Belfield and Bowman) and deleted Ray Point, for a total of 25 sites. DOE continues to investigate the status of the site near Baggs, Wyoming. Most of the mills at these sites produced by far the greatest part of their output of uranium under contracts with the 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.

Prior to 1975, the studies of radiation levels on and in the vicinities of these sites were limited in scope. The data available were insufficient to permit assessment of risk to people with any degree of confidence. In addition, information on practicable measures to reduce radiation exposures and estimates of their projected costs was limited. The purposes of these recent studies performed by FB&DU have been to update the information necessary to provide a basis for decision making for appropriate remedial actions for each of the 25 sites.

Evaluations of the following factors have been included in this engineering assessment in order to assess the significance of the radiological conditions that exist today at the Shiprock site:

(a) Exhalation of radon gas from the tailings

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

(c) Land contamination from windblown tailings

(d) Hydrology and contamination by water pathways

(e) Potential health impact

(f) Potential for extraction of additional minerals from the tailings

Investigation of these and other factors originally led to the evaluation of 11 potential practicable remedial action alternatives.[2] Since that time, some alternatives have been judged unacceptable because of new criteria that have been proposed. In the work performed in the preparation of this report, the remedial action alternatives are revised as follows:

(a) Option I - Stabilization of tailings on site with a 3-m cover

(b) Option II - Disposal at site 2, Many Devils, 4 mi south of tailings piles

(c) Option III - Disposal at site 1, Shiprock Campground, 6.8 mi south of tailings piles

(d) Option IV - Disposal at site 5, Rattlesnake, 8.3 mi west of tailings piles

(e) Option V - Disposal at site 8, Salt Creek Area, 8.5 mi northeast of tailings piles

(f) Option VI - Disposal at site 6, Oil Field, 8.5 mi southeast of tailings piles

(g) Option VII - Disposal at site 4, Hogback, 16 mi southwest of tailings piles

(h) Option VIII - Disposal at site 7, Operating Open-Pit Coal Mines, 26 mi east of tailings piles

1.1.1 Background

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

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

Dr. James L. Liverman, testifying for the AEC, proposed that a comprehensive study should be made of all such piles, rather than treating the potential problem on a piecemeal basis. He proposed that the study be a cooperative two-phase undertaking by the states concerned and the appropriate federal agencies, such as the AEC and EPA. Phase I would involve site visits to determine such aspects as their condition, ownership, proximity to populated areas, prospects for increased population near the site, and need 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, adapted from Reference 1, summarizes the conditions in 1980. Based on the findings presented in the Phase I report, the decision was made to proceed with Phase II.

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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.

On May 5, 1975, ERDA, the successor to AEC, announced that Ford, Bacon & Davis Utah Inc. of Salt Lake City, Utah, 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. Work at the Shiprock site began in February 1976, and the original Phase II - Title I Engineering Assessment was published in March 1977.[2]

On November 8, 1978, the Uranium Mill Tailings Radiation Control Act of 1978 (PL 95-604) became effective. This legislation provides for state participation with the Federal Government in the remedial action for inactive tailings piles. Pursuant to requirements of PL 95-604, the EPA has the responsibility to promulgate remedial action standards for the cleanup of areas contaminated with residual radioactive material and for disposal of tailings. The U.S. Nuclear Regulatory Commission (NRC) has the responsibility for enforcing these standards.

In 1979, DOE established the UMTRA Program Office in Albuquerque, New Mexico. Work on the program has since been directed by personnel in that office. The supplementary field work by FB&DU in support of this report was performed during the week of August 25, 1980.

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 a continuation of the assessment made for Title I requirements and has been prepared by FB&DU. In connection with the field studies made in 1976, the Oak Ridge National Laboratory (ORNL) at Oak Ridge, Tennessee, under separate agreement with DOE, made measurements of the radioactivity concentrations in the soil and water samples and gamma surveys. The EPA staff provided the results of radiation surveys they previously had made at the Shiprock site.

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

(a) Preparation of an engineering assessment report for each site, and preparation of a comprehensive report suitable for submission to the Congress on reasonable remedial action alternatives and their estimated cost.

(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 at which mill tailings containing radium could be disposed; and once such sites are identified, performance of evaluations and estimation of 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) Review existing information about 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.

1.2 SITE DESCRIPTION

1.2.1 Location

The Shiprock site is located on a 230-acre tract of land on the Navajo Indian Reservation, on the south side of the San Juan River as it passes through the town of Shiprock, New Mexico. The site is shown in the aerial photograph in Figure 2-1.* The relationship of the site to its surroundings is shown in the regional map in Figure 2-2. The country generally is arid and desert-like, with low rolling hills and occasional steep ridges and mesas. Vegetation is sparse except on some irrigated lands along the river. The elevation of the site is about 4,960 ft above sea level.

1.2.2 Ownership and History of Milling Operations and Processing

The mill was constructed and operated from 1954 to 1963 by Kerr-McGee Oil Industries, Inc., and from 1963 to 1968 by Vanadium Corporation of America and its successor, Foote Mineral Company.

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*Figures and tables referenced in this summary are extracted from Chapters 2 through 9 of the parent report and are in the addendum.

Before and during the milling operations the site was leased from the Navajo Tribe. When the Foote Mineral Company's lease expired in 1973, full control of the site reverted to the Navajo Nation.

During its operating life (1954 to 1968) the mill processed 1.5 million dry short tons of ore, including ore concentrate from the Monument Valley mine. The average grade was 0.25% U_3O_8 and 1.07% V_2O_5. The mill produced 3,711 tons of U_3O_8 in concentrate. Vanadium concentrate also was produced in 1955 and again from 1960 to 1968.

The ore processed at Shiprock was mostly sandstone containing carnotite as the principal ore mineral. Ore was trucked to the mill from many small mines. During the Kerr-McGee operation, about 80% of the ore came from company-controlled mines in northeastern Arizona; the rest came from other small mines, the majority in northeastern Arizona and northwestern New Mexico. After the change in ownership in 1963, more than half of the ore came from the Uravan Mineral Belt. The average distance hauled was approximately 100 mi.

1.2.3 Present Condition of the Site

Figure 2-6 is a descriptive map of the site as it now exists. The tailings are located in two adjacent piles and cover approximately 72 acres. The upper (north) pile covers 26 acres and varies from 14 to 40 ft in height. This pile has been stabilized with 0.5 to 2 ft of pit-run soil and gravel, and some natural plant growth has taken root. The upper pile has resisted wind erosion. The dikes built along the pile face that abuts the San Juan River have prevented the spread of the tailings to the river as a result of water erosion.

The lower (south) pile covers 46 acres and is approximately 15 ft in height. It contains the contaminated materials and rubble that were removed from the mill and the ore storage areas during recent decontamination efforts. The lower pile is covered with approximately 0.5 ft of material and/or soil as a result of decontamination activities by the Navajo Engineering and Construction Authority (NECA).

After mill operations ceased in 1968, some of the buildings and equipment were dismantled and buried in the tailings and washes. A few buildings have been left standing.

In November 1973, the Navajo Tribal Chairman asked the EPA and other federal agencies for assistance in stabilizing the tailings and in developing procedures for site decontamination. During April 1974, radiation surveys around the site were conducted by the EPA to determine the extent of contamination from wind and water erosion of mill tailings in order to provide a basis for defining a decontamination plan, a cost estimate,

and necessary procedures. The plan developed by the EPA was given to the Navajo Tribe in October 1974.

In 1973, however, the Navajo Tribe already had authorized the NECA to use the site as a training school to instruct Navajo students in the operation of earthmoving machinery. The NECA is headquartered at the site and uses the buildings for administration, classroom, shop, and storage purposes. At the time of the EPA survey, the NECA training program was utilizing portions of the tailings piles for practice in earthmoving techniques. The EPA decontamination plan therefore specified that the NECA earthmoving training program would include the removal of contaminated soil from areas surrounding the piles and placement of these materials on the piles. All buildings were to be decontaminated, as well as the entry road and parking and ore storage areas. An interim stabilization cover of 6 in. of earth was to be placed on the lower pile, and containment dikes were to be constructed. The plan was based on 10 tasks resulting from input by the Navajo Environmental Protection Commission, Indian Health Service, New Mexico Environmental Improvement Agency, as well as from the EPA and the NECA. The decontamination project is now complete.

The activities of the NECA between 1977 and 1980 have resulted in extensive changes in the condition and configuration of the Shiprock site. These changes are apparent upon comparison of the aerial photograph, Figure 2-1 in the 1977 report, with Figure 2-1 in this report. The upper tailings pile surface has been left relatively undisturbed. However, a graded road now surrounds the pile, and the dikes along the upper pile face, where it abuts the San Juan River, have been reduced to grade, rendering the whole eastern area relatively flat. The lower pile is also surrounded by a dike, the top of which has been graded to form a road, and grading on the surface of the pile is evident in Figure 2-1. These changes are also reflected in Figure 2-3. Two estimated profiles of the upper and lower piles in cross-section are shown in Figure 2-5.

The irrigation system that had been installed on the lower pile for dust control during decontamination has been dismantled and partially removed. The component parts remain scattered over the tailings pile. The depressed area at the extreme north end of the site has been filled in, and the contours of the old pond have been modified considerably. Immediately south of the old plant office building, part of the former raffinate pond area, now decontaminated, has been fenced in and is currently used by the NECA as a shipping and receiving area.

Only four of the original mill buildings at the site remain; they are the shower building, the engineering office building, and the classroom and shop buildings. The main mill building has been completely demolished and removed. The former plant office building is now leased to the U.S. Public Health Service Water and Sanitation Engineering Group. The NECA

shop and equipment storage area is in good condition, and is fenced with chainlink and secured by a guard at night.

There are two new buildings on site; one is a maintenance shop and motor pool area and the other, a two-story concrete structure, houses the NECA engineering and administrative offices. The NECA no longer uses the site for the training of Navajo operators of earthmoving equipment; this function was moved to Crown Point, New Mexico, in 1978.

1.2.4 Tailings and Soil Characteristics

Several types of materials make up the Shiprock tailings: a combination of uranium and vanadium tailings, dike material, rubble, and stabilization cover of pit-run gravel. Bulk densities range between 82 and 107 lb/ft^3. Borings and samples taken from the piles indicate that the tailings were not uniformly deposited in the tailings ponds. There are approximately 1.5 million dry tons of tailings and 1.58 million tons of other contaminated materials on site. As given in Table 2-1, the total mass, including moisture, of all materials (dikes, tailings, rubble, stabilization cover, and contaminated earth) is approximately 3.2 million tons. The soil on the site is a combination of decomposed shale and a conglomerate of river-deposited sand and cobbles with a maximum dimension of 12 in.

1.2.5 Geology, Hydrology, and Meteorology

The Shiprock tailings and millsite are situated on benchland adjacent to the southwest bank of the San Juan River; the benchland is an ancient river terrace that has been left elevated from continued downcutting of the river.

Underlying much of the tailings are up to 10 ft of terrace deposits that form a layer between the Mancos Shale and the tailings. These materials have been deposited over a long period of time on the benchland by the San Juan River when it flowed at a higher level. The materials are poorly sorted and range in size from 12-in. boulders to sand- and silt-sized particles that are cemented together in places. The Mancos Shale directly below this alluvium is at least several hundred feet thick. A simplified stratigraphic cross-section is illustrated in Figure 2-9.

The elevated topography at the millsite eliminates the possibility of flooding or erosion of the tailings by the waters of the San Juan River. Undercutting of the bank also is not a problem. South and west of the tailings, the terrain is relatively flat near the site. Drainage from the higher ground farther to the south is carried to Dead Mans Wash, which empties into the San Juan River about 0.5 mi southeast of the site.[1]

The confined ground water aquifers underlying the site are protected against contamination by both an upward pressure gradient and thick impermeable strata, and there is no possibility of contamination of these aquifers from the tailings. There is a potential for further contamination of the terrace gravel immediately underlying the tailings piles if sufficient water is allowed to collect and percolate through sections of the piles. However, reshaping of the surface of the piles can prevent the collection of rainwater in a single area.

As indicated by eolian deposits (see Figure 2-10), the prevailing winds are from the southwest. For the purposes of health effects calculations, meteorological data recorded at the Farmington airport were used. In any case, the direction of transport of materials by winds is away from population centers and over farmlands.

1.3 RADIOACTIVITY AND POLLUTANT IMPACTS ON THE ENVIRONMENT

About 85% of the total radioactivity originally in uranium ore remained in the tailings after removal of the uranium. The principal environmental radiological impact and associated health effects arise from the ^{230}Th, ^{226}Ra, ^{222}Rn, and ^{222}Rn daughters contained in the uranium tailings. Although these radionuclides occur in nature, their concentrations in tailings material are several orders of magnitude greater than their average concentrations in the earth's crust. Because of the chemical treatments they have experienced, they appear to be more soluble and, therefore, more mobile.

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 piles. The principal exposure results from inhalation of the ^{222}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 piles.

(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 that can occur; however, this pathway was not considered in this study.

1.3.1.1 Radon Gas Diffusion and Transport

Measurements of radon flux from the tailings, made in 1976[2] using the charcoal canister technique,[3] ranged from 53 to 157 pCi/m^2-s on the tailings piles. Measurements of radon flux made in August 1980 ranged from 2.1 to 340 pCi/m^2-s, with the mean flux on the upper and lower tailings piles estimated to be about 110 pCi/m^2-s. Radon flux depends principally on radium content of tailings; however, it also varies considerably because of moisture, soil characteristics, and climatological conditions.

Short-term radon measurements were performed by FB&DU in 1976 with continuous radon monitors (Wrenn chambers) supplied by ERDA at 12 locations in the vicinity of the Shiprock tailings piles. The locations and values of the radon measurements are shown in Figure 3-5. One set of measurements on the upper pile indicated an average radon concentration of 12 pCi/l for a 24-hr period. Measurements in the NECA office and training buildings averaged about 7 pCi/l for 24 hr.

No further measurements of atmospheric radon were possible in 1980 since calibrated instrumentation was not available during the field work. It is judged that radon attributable to the piles is smaller because of the greater depths of cover material on the lower pile.

No background measurements of radon in the atmosphere were available prior to the measurements performed during this assessment. Four 24-hr measurements of atmospheric radon at locations from 0.8 to 3 mi from the tailings site indicated an average background concentration of about 0.8 pCi/l.

Radon daughters measured by ORNL personnel[4] in the NECA office building concurrently with FB&DU measurements ranged from 0.006 to 0.02 WL.

1.3.1.2 Direct Gamma Radiation

The range of natural background values in the Shiprock area was between 6 and 13 μR/hr, as measured by ORNL. A value of 13 μR/hr was used by the EPA as the average background

gamma radiation level,[5] and 9 μR/hr was determined in these studies. Above the surface of the tailings piles, gamma readings ranged from 30 to over 300 μR/hr. This could be reduced to near-background levels by a cover of approximately 2 ft of sand and gravel.

1.3.1.3 Windblown Contaminants

Measurements of radioactive airborne particulates were performed at several locations around the Shiprock tailings site by the EPA, Office of Radiation Programs, Las Vegas Facility (ORP-LVF), during a 7-mo period in 1974.[5] The concentrations of all isotopes measured were below the most restrictive maximum permissible concentrations given in 10 CFR 20.

A 10 μR/hr isoexposure line determined by the EPA in 1974 and believed to be due to residual windblown tailings is illustrated in Figure 3-14. Also shown in this figure is an estimate, based on measurements made by FB&DU in 1980, of that area within which soil contamination was in excess of 5 pCi/g of ^{226}Ra.

1.3.1.4 Ground and Surface Water Contamination

Water samples were obtained from two surface locations and three locations along the San Juan River. No water was found in any of the holes drilled through the tailings piles to investigate subsoil contamination. Water from a pond near the ore storage area contained 2 pCi/l of dissolved ^{226}Ra.[4] A dissolved ^{226}Ra concentration of 3.5 pCi/l was measured in a water sample taken from a stagnant pond at the base of the shale bluff at the northeast corner of the tailings site. These figures compare with the EPA Interim Primary Drinking Water Regulations[6] of 5-pCi/l total maximum concentration of ^{226}Ra and ^{228}Ra.

1.3.1.5 Soil Contamination

The leaching of radium from the tailings into the subsoil generally extends about 3 ft before reaching the background level of 1.7 pCi/g. Two times the background level was reached at approximately 2 ft beneath the tailings-soil interface. In some regions of the ore storage area, the radium concentration is 2 times background at depths of about 3 ft. In the mill area, contamination to an 8-ft depth has been found in isolated locations.

1.3.2 Remedial Action Criteria

For the purpose of conducting the original engineering assessment,[2] provisional criteria provided by the EPA were used. The criteria were in two categories, and applied either to structures with tailings present or to land areas to be decontaminated. For structures, the indoor radiation level

below which no remedial action was indicated was considered to be an external gamma radiation level of less than 0.05 mR/hr above background and a radon daughter concentration of less than 0.01 WL above background. Land could be released for unrestricted use if the external gamma radiation levels were less than 10 μR/hr above background. When cleanup was necessary, residual radium content of the soil after remedial action should not exceed twice background in the area.

Since enactment of the Uranium Mill Tailings Radiation Control Act of 1978 (PL 95-604), which was effective November 8, 1978, the EPA has published interim (45 FR 27366) and proposed (46 FR 2556) standards for structures and open lands. These standards establish the indoor radon daughter concentration, including background, below which no remedial action is indicated at 0.015 WL. The indoor gamma radiation limit is 0.02 mR/hr above background.

For open land, remedial action must provide reasonable assurance that the average concentration of ^{226}Ra attributable to residual radioactive material from any designated processing site in any 5-cm thickness of soils or other materials within 1 ft of the surface, or in any 15-cm thickness below 1 ft, shall not exceed 5 pCi/g.

Environmental standards have been proposed by the EPA (46 FR 2556) for the disposal of residual radioactive materials from inactive uranium processing sites. These standards require that disposal of residual radioactive materials be conducted in a way which provides a reasonable assurance that for at least 1,000 yr following disposal:

(a) The average annual release of ^{222}Rn from the disposal site to the atmosphere by residual radioactive materials will not exceed 2 pCi/m^2-s.

(b) Substances released from residual radioactive materials after disposal will not cause:

(1) the concentrations of those substances in any underground source of drinking water to exceed the level specified below,* or

(2) an increase in the concentrations of those substances in any underground source of drinking water where the concentrations of

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*These requirements apply to the dissolved portion of any substance listed above at any distance greater than 1.0 km from a disposal site that is part of an inactive processing site, or greater than 0.1 km if the disposal site is a depository site.

those substances prior to remedial action exceed the levels specified below for causes other than residual radioactive materials.*

Substance	mg/l
Arsenic	0.05
Barium	1.0
Cadmium	0.01
Chromium	0.05
Lead	0.05
Mercury	0.002
Molybdenum	0.05
Nitrogen (in nitrate)	10.0
Selenium	0.01
Silver	0.05
	pCi/l
Combined ^{226}Ra and ^{228}Ra	5.0
Gross alpha particle activity (including ^{226}Ra but excluding radon and uranium)	15.0
Uranium	10.0

(c) Substances released from the disposal site after disposal will not cause the concentration of any harmful dissolved substance in any surface waters to increase above the level that would otherwise prevail.

Since the passage of PL 95-604, the NRC has published final regulations for uranium mill tailings licensing in the Federal Register (45 FR 65521). They include the requirement that the stabilization method must include an earth cover of at least a 3-m thickness and sufficient to reduce the radon emanation rate from the tailings to 2 pCi/m^2-s above background. In addition, seepage of materials into ground water should be reduced by design to the maximum extent reasonably achievable.

While these standards may undergo further limited revisions, they will not likely experience changes that would significantly alter the nature of the remedial actions or their estimated costs. Therefore, the interim and proposed standards as indicated above form the basis for determining required remedial actions and their associated costs.

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*These requirements apply to the dissolved portion of any substance listed above at any distance greater than 1.0 km from a disposal site that is part of an inactive processing site, or greater than 0.1 km if the disposal site is a depository site.

1.3.3 Potential Health Impact

Radon gas exhalation from the piles and the subsequent inhalation of radon daughters account for most of the total dose to the population within 2 mi of the Shiprock site under present conditions. The gamma radiation exposure from the piles is virtually zero past 0.4 mi. The population density within 0.5 mi of the perimeter of the piles is low.

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 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 pile. If the diffusion path can be made long enough, then, theoretically, virtually all of the radon and its daughter products will have decayed before escaping to the atmosphere. Calculations using the theoretical techniques of Kraner, Schroeder, and Evans[7] earlier indicated that 13 ft of earth cover would be required to reduce the radon diffusion from the Shiprock tailings by 95%. Later experimental work[8] has demonstrated that 2 to 3 ft of compacted clay may be sufficient to reduce radon flux to less than 2 pCi/m^2-s, assuming the continued integrity of the clay cover.

The health significance to man of long-term exposure to low-level radiation is a subject that has been studied extensively. Since the end results of long-term exposure to low-level radiation may be diseases such as lung cancer or leukemia, which are also attributable to many other causes, 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 and others 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, a health effect is a case of lung cancer.) This is the basis of the health effects calculated 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-III report).[9] This report presents risk estimators for lung cancer derived from epidemiological studies of both uranium miners and fluorspar miners. The average of the age-dependent absolute risk estimator for these two groups as applied to the population at large is 150 cancers per year per 10^6 person-WLM of continuous exposure, assuming a lifetime plateau to age 75. The term WLM means working level months, 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 or with the parent radon. Because of the many factors that contribute to natural biological variability and of the many differences between exposure conditions in mines and residences, this estimator (150 cancer cases per year per 10^6 person-WLM of continuous exposure) is considered to have an uncertainty factor of about 3. Another means of expressing risk is the relative risk estimator, which yields risk as a percentage increase in health effects per 10^6 person-WLM of continuous exposure. However, this method has been shown to be invalid[10] and is not considered in this assessment.

For the purpose of this engineering 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 the background value under present conditions, it was calculated that the average lung cancer risk attributable to radon released from the piles in the area within 6 mi of the Shiprock site is 6.3×10^{-6} per person per year, or about 14% of the average lung cancer risk due to all causes for the Navajo Nation (4.5×10^{-5}).[11] For those within 0.75 mi of the site, the average lung cancer risk due to the piles is 2.0×10^{-5} per person per year, or about 44% of the cancer risk due to all causes.

The 25-yr health effects were calculated for three population projections using a present estimated population of 6,052 in the 0- to 6-mi area, and 960 in the 0- to 0.75-mi area. The results for pile-induced radon and background radon for the two areas (0 to 6 mi and 0 to 0.75 mi) were as follows:

25-Year Cumulative Health Effects within 6 Miles of Edge of Site

Projected Population Growth	Pile-Induced RDC	Background RDC
0.8% constant growth rate	1.1	4.8
2.5% declining growth rate*	1.2	5.4
4.0% declining growth rate*	1.3	6.2

25-Year Cumulative Health Effects within 0.75 Mile of Edge of Site

Projected Population Growth	Pile-Induced RDC	Background RDC
0.8% constant growth rate	0.52	0.74
2.5% declining growth rate*	0.59	0.83
4.0% declining growth rate*	0.68	1.0

Pile-induced radon daughter health effects are approximately 23% and 70% of the background radon daughter health effects for the 0- to 6-mi and 0- to 0.75-mi areas, respectively. The exposure and consequent risk will continue as long as the radiation source remains in its present location and condition.

1.3.4 Nonradioactive Pollutants

There are other potentially toxic materials in the tailings. Chemical analyses of solid tailings samples from drill holes on the Shiprock tailings piles showed arsenic, barium, vanadium, and lead in concentrations between 100 and 600 ppm. The highest selenium, cadmium, and chromium concentrations were 52 ppm, 2 ppm, and 15 ppm, respectively. Iron concentration was as high as 14,700 ppm.

Samples from stagnant water in the Shiprock ore storage area contained concentrations of arsenic 10 times the maximum allowable concentration for drinking water and selenium 60 times the maximum allowable. However, there was no measurable increase in selenium found in the San Juan River below the millsite. Samples taken upstream and downstream from the millsite indicated increased concentrations of arsenic, iron, cadmium, and lead in the river below the site. The arsenic and lead additions are small and the resulting contents in the river are below the limits of the EPA Interim Primary Drinking Water Regulations.[6] The cadmium and iron concentrations are relatively large. However, impurity levels of these two

*Declines linearly from its initial value to zero in 25 yr and remains constant at zero thereafter.

minerals upstream from the tailings are substantially above the recommended limits of the EPA drinking water regulations. Consequently, removal of the tailings apparently would not substantially upgrade the environmental quality of the San Juan River, nor increase its potential use.

1.4 SOCIOECONOMIC AND LAND USE IMPACTS

Because all reservation land is owned commonly by the Navajo Nation, there is no conventional valuation for these properties. However, there are several criteria that might be used to assess the value of the site land. Land values might be estimated on the basis of recent exchanges of tribal land for off-reservation land, lease payments for Navajo lands, or comparisons with similar-use off-reservation land. Even more important is that Shiprock has been designated by tribal authorities to be one of five Navajo communities with the greatest potential for primary growth. It is expected to absorb some of the growth impact of the Navajo Irrigation Project, proposed coal gasification plants, and oil exploration and development activities. If the tribe's efforts to attract industry succeed, the expansion of agriculture and increased mineral activity will produce pressures to develop the tailings site area for industrial and commercial use. Since the location of the tailings site is adjacent to an industrial park along the San Juan River, and near U.S. Highway 666 and the new Shiprock airport, the value of the site is estimated to range from $50 to $3,500/acre, depending on its use.

1.5 RECOVERY OF RESIDUAL VALUES

Available historical records that provide reliable data on specific mineral contents of the Shiprock tailings site are limited. Only a few samples of tailings were obtained during this study. Consequently, calculations based on these samples would not be statistically representative.

There are, however, five factors that can be considered to evaluate whether reprocessing Shiprock tailings to extract uranium and other mineral values would be practicable:

(a) The amount of tailings present

(b) Concentrations of residual values

(c) Projected recovery

(d) Current market price of recovered values

(e) Proximity to processing mills

Three principal alternatives for the reprocessing of the Shiprock tailings were examined:

(a) Heap leaching

(b) Treatment at an existing mill

(c) Reprocessing at a new conventional mill constructed for tailings reprocessing.

The cost of the uranium recovered would be about $230/lb and $250/lb of U_3O_8 by heap leach and conventional plant processes, respectively. The spot market price for uranium was $25/lb early in 1981. Therefore, reprocessing the Shiprock tailings for uranium recovery does not appear to be economical under present market conditions.

1.6 MILL TAILINGS STABILIZATION

Investigations of methods of stabilizing uranium mill tailings piles from wind and water erosion have indicated a variety of deficiencies among the methods. Chemical stabilization (treatment of the tailings surface) has been successful only for temporary applications and is thus viewed as inadequate for currently proposed disposal criteria. Volumetric chemical stabilization (solidifying the bulk of the tailings) techniques appear to be costly and of questionable permanence. Physical stabilization (emplacement of covers over the tailings) methods using soil, clay, or gravel have been demonstrated on a laboratory scale to be effective in stabilizing tailings. Artificial cover materials are attractive but have the disadvantage of being subject to degradation by natural and artificial forces. Vegetative stabilization (establishment of plant growth) methods are effective in limiting erosion. However, where annual precipitation is less than about 10 in., soil moisture content may be inadequate to ensure viability of the plant life.

Migration of contaminants into ground water systems must be limited under the NRC and EPA criteria. Control of water percolating through the tailings can be accomplished by stabilizing chemically, by physically compacting the cover material, and by contouring the drainage area and tailings cover surface. Isolation of the tailings from underlying ground water systems can be accomplished by lining a proposed disposal site with natural or artificial impermeable membranes.

Several materials have been identified which sufficiently retard radon migration so that the radon flux is substantially reduced, on a laboratory scale. Unfortunately, no large-scale application has been undertaken which would demonstrate that these materials satisfy all of the technical criteria in the EPA-proposed standards and NRC regulations for licensing of uranium mills. However, extensive investigations of these questions continue in the Technology Development program of the Uranium Mill Tailings Remedial Actions Project Office in Albuquerque, New Mexico.

In view of findings from stabilization research, it appears that physical stabilization of tailings with 3 m of well-engineered cover material may be sufficient to appropriately stabilize tailings at their disposal site to meet NRC regulations.

1.7 OFF-SITE REMEDIAL ACTION

A mobile scanning unit performed a gamma radiation survey of the Shiprock area in 1971. Nine anomalies above the background criteria were discovered. Ore was found and removed from one location. Three locations had tailings more than 10 ft from structures and were not considered further. Tailings were found within 10 ft of four houses, and the last location was a former ore-buying station. Since the mobile survey, an additional location was found with elevated gamma and working level measurements. The latter six locations will be considered for remedial action based upon more complete measurements.

1.8 DISPOSAL SITE SELECTION

In this report, seven of the alternative remedial action options include moving the Shiprock tailings to a disposal site. The corresponding seven disposal sites were selected after consultation with officials of the Navajo Environmental Protection Agency, the State of New Mexico, the Indian Health Service, and the Bureau of Indian Affairs. Each site was evaluated to a limited extent on the bases of hydrology, meteorology, geology, ecology, economics, and proximity to population centers. Seven other potential disposal sites in three general areas have been identified for disposal of the Shiprock tailings and evaluated to a limited extent.[12] Since the responsibility for disposal site selection lies with the Federal Government, with input from the Navajo Indian Tribe, the disposal sites evaluated in this report must be considered only as tentative. Subsequent studies associated with preparation of the Environmental Impact Statement will result in a recommended disposal site that is fully characterized and satisfies appropriate disposal site characteristics.

The relative locations of the disposal sites listed in Table 1-2 as Options II through VIII are shown in Figure 8-1. In each of these options, surface material would be removed, as appropriate, from the disposal area and stockpiled. A retaining dike and diversion ditches would be constructed if necessary. The tailings would be emplaced, contoured, and covered with 3 m of soil. The surface would be covered with 0.3 m of riprap or vegetation established for erosion control, and the entire site would be fenced.

1.9 REMEDIAL ACTIONS AND COST-BENEFIT ANALYSES

1.9.1 Remedial Action Options

The remedial action options examined include stabilization of the tailings piles in their present location and removal of all radioactive materials to an area where these materials could be isolated from the public. The options for which cost estimates were made include stabilization on the present site with 3 m of cover material and the removal of tailings to seven possible locations. The options are summarized in Table 1-2.

The basis for comparison, from which the cost effectiveness of other remedial alternatives can be judged, is the present condition of the site with no remedial action.

Option I represents remedial action activities to stabilize the piles more completely in their present location with the addition of a 3-m depth of cover and the construction of additional dike protection. Erosion of the tailings would be controlled more completely, and radon exhalation would be reduced to not more than 2 pCi/m^2-s above background. The site would have limited future use.

Seven sites were evaluated for possible disposal of the Shiprock tailings and contaminated materials, and cost estimates for disposal at each site were made. Their locations are given in Figure 8-1 and Table 8-1.

The Many Devils site (Option II) rarely is used for grazing and appears to be an unauthorized dump site. This site has the advantage of being closest to the Shiprock site, but the disadvantage of being closest to human habitation.

The Shiprock Campground site (Option III) is attractive because it is near the tailings site and easily accessible from existing roads. However, the site's accessibility is also a potential liability because of the possibility of encroachment.

The Rattlesnake site (Option IV) would offer the advantages of a limited amount of land disturbed during disposal (being relatively near the tailings site) and a convenient haul route. The primary disadvantages are the location of the site on sandstone bedrock, which may act as a ground water recharge area, and the limited amount of material available for stabilization cover.

The Salt Creek site (Option V), presently used as grazing land, has all the advantages of the Many Devils site except that it is located farther from the tailings site.

The Oil Field site (Option VI) includes several possible disposal locations with the advantages of excellent drainage and proximity to cover materials and highways. The major

disadvantage is the insufficient amount of cover materials on the site itself.

The Hogback site (Option VII) in the area southeast of Shiprock is very isolated. Its principal disadvantage is cost distance from the tailings site.

Option VIII, providing for the disposal of tailings in a mined-out area of an open-pit coal mine, would provide a disposal area that would isolate the tailings from the public. The 26-mi haul distance, however, represents a disadvantage of this potential disposal site. In addition, site availability and the timing of placement raise questions about the viability of this site for disposal.

1.9.2 Cost-Benefit Analyses

As summarized in Table 9-1, the total estimated costs for the eight remedial action options vary from about $13,400,000 to about $37,900,000. Each of these options would have associated health and monetary benefits. The options are identified by number in Paragraph 1.1.

The number of cancer cases avoided per million dollars expended for each option is given in Figure 9-2. The curves in Figure 9-2 indicate an increase in benefit-cost ratio with time due to the greater reduction in population exposure over longer periods of time as a result of remedial action. The potential cancer cases avoided for each option and the cost per potential cancer case avoided are given in Table 9-2.

TABLE 1-1

SUMMARY OF CONDITIONS NOTED AT TIME OF 1980 SITE VISITS

	Condition of Tailings[a]	Condition of Structures On Site[b]	Mill Housing[c]	Adequate Fencing, Posting, Security	Property Close to River or Stream	Houses or Industry within 0.5 Mi	Evidence of Wind or Water Erosion	Possible Water Contam-ination	Tailings Removed for Private Use	Other Hazards On Site
ARIZONA										
Monument Valley	U	R	N	No	No	Yes	Yes	No	Yes	No
Tuba City	U	PR-UO	E-P	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	Yes	Yes	Yes	No
Gunnison	S	B-O	N	No	Yes	Yes	No	Yes	No	No
Maybell	S	R	N	Yes	No	No	Yes	No	No	No
Naturita	RMS	PR-O	N	Yes	Yes	Yes	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	Yes	Yes	Yes	Yes	Yes	No	No
Slick Rock (UCC)	S	R	E-P	Yes	Yes	Yes	No	Yes	No	No
IDAHO										
Lowman	U	R	N	No	Yes	Yes	Yes	Yes	Yes	No
NEW MEXICO										
Ambrosia Lake	U	PR-O	N	No	No	No	Yes	No	No	No
Shiprock	S	PR-O	N	Yes	Yes	Yes	No	Yes	Yes	No
NORTH DAKOTA										
Belfield	R	PR-O	N	No	No	Yes	No	No	No	No
Bowman	R	R	N	No	No	No	No	No	No	No
OREGON										
Lakeview	S	B-O	N	Yes	No	Yes	Yes	No	No	No

TABLE 1-1 (Cont)

	Condition of Tailings[a]	Condition of Structures On Site[b]	Mill Housing[c]	Adequate Fencing, Posting, Security	Property Close to River or Stream	Houses or Industry within 0.5 Mi	Evidence of Wind or Water Erosion	Possible Water Contam-ination	Tailings Removed for Private Use	Other Hazards On Site
PENNSYLVANIA										
Canonsburg	P	B-O	N	Yes	Yes	Yes	No	Yes	Yes	Yes
TEXAS										
Falls City	P	B-O	N	Yes	No	No	Yes	No	No	No
UTAH										
Green River	S	B-Y	N	Yes	Yes	Yes	Yes	Yes	No	No
Mexican Hat	U	PR-UO	E-O	No	No	Yes	Yes	Yes	No	No
Salt Lake City	U	R	N	No	Yes	Yes	Yes	Yes	Yes	Yes
WYOMING										
Converse County	U	R	N	Yes	No	No	No	No	No	No
Riverton	S	PR-O	N	No	No	Yes	No	No	No	No

[a]S - Stabilized but requires improvement

P - Partially stabilized

U - Unstabilized

RMS - Reprocessed, moved and stabilized - contamination remaining

R - Removed - contamination remaining

[b]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

[c]N - None

E - Existing

O - Occupied

P - Partially occupied

TABLE 1-2

SUMMARY OF REMEDIAL ACTION OPTIONS AND EFFECTS

Option Number	Site Specific Cost ($000)	Description of Remedial Action	Benefits	Adverse Effects
I	13,400	The piles would be stabilized in place with 3 m of local earth cover. Natural vegetation would be established or a 0.3-m cover of riprap would be provided. On- and off-site contaminated materials would be cleaned up as necessary.	A-E,H,I	X
II	25,600	The tailings, contaminated soil and rubble would be removed by truck to site 2, Many Devils area, located about 4 mi from the tailings site. The tailings site would be decontaminated as in Option I and released for unlimited use.	A,C-G, I,J	--
III	29,000	Same as Option II, except tailings removed to site 1, Shiprock Campground, located about 6.8 mi from the tailings site.	A,C-G, I,J	--
IV	27,400	Same as Option II, except tailings removed to site 5, Rattlesnake area, located about 8.3 mi from the tailings site.	A,C-G I,J	--
V	30,100	Same as Option II, except tailings removed to site 8, Salt Creek area, located about 8.5 mi from the tailings site.	A,C-G I,J	--

TABLE 1-2 (Cont)

Option Number	Site Specific Cost ($000)	Description of Remedial Action	Benefits	Adverse Effects
VI	29,500	Same as Option II, except tailings removed to site 6, Oil Field area, located about 8.5 mi from the tailings site.	A,C-G, H,I	--
VII	37,900	Same as Option II, except tailings removed to site 4, Hogback area, located about 16 mi from the tailings site.	A,C-G, H,I	--
VIII	34,100	Same as Option II, except tailings removed to site 7, Operating Open-Pit Coal Mines, located about 26 mi from the tailings site.	A,C-G, H,I	--

Notes

1. All options include on- and off-site remedial action.

2. For Options II through VIII, costs include removal of 3 ft of contaminated earth below the tailings.

TABLE 1-2 (Cont)

Definition of Benefits

A. Off-site structures decontaminated
B. Access to the tailings site controlled by fencing and posting
C. Off-site windblown tailings cleaned up
D. Wind and water erosion controlled
E. Gamma radiation reduced
F. The source of gamma radiation and radon gas removed from the area
G. No building restrictions on or near site
H. The prime use of the final disposal location unchanged
I. Radon flux reduced to not more than 2 pCi/m^2-s
J. Maintenance and fencing eliminated

Definition of Adverse Effects

X. Limited use of the tailings site

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CHAPTER 1 REFERENCES

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ADDENDUM

FIGURES AND TABLES

(The figures and tables contained on the following pages have been extracted from Chapters 2 through 9 of the parent report.)

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8-1	Location of Proposed Disposal Sites	8-8
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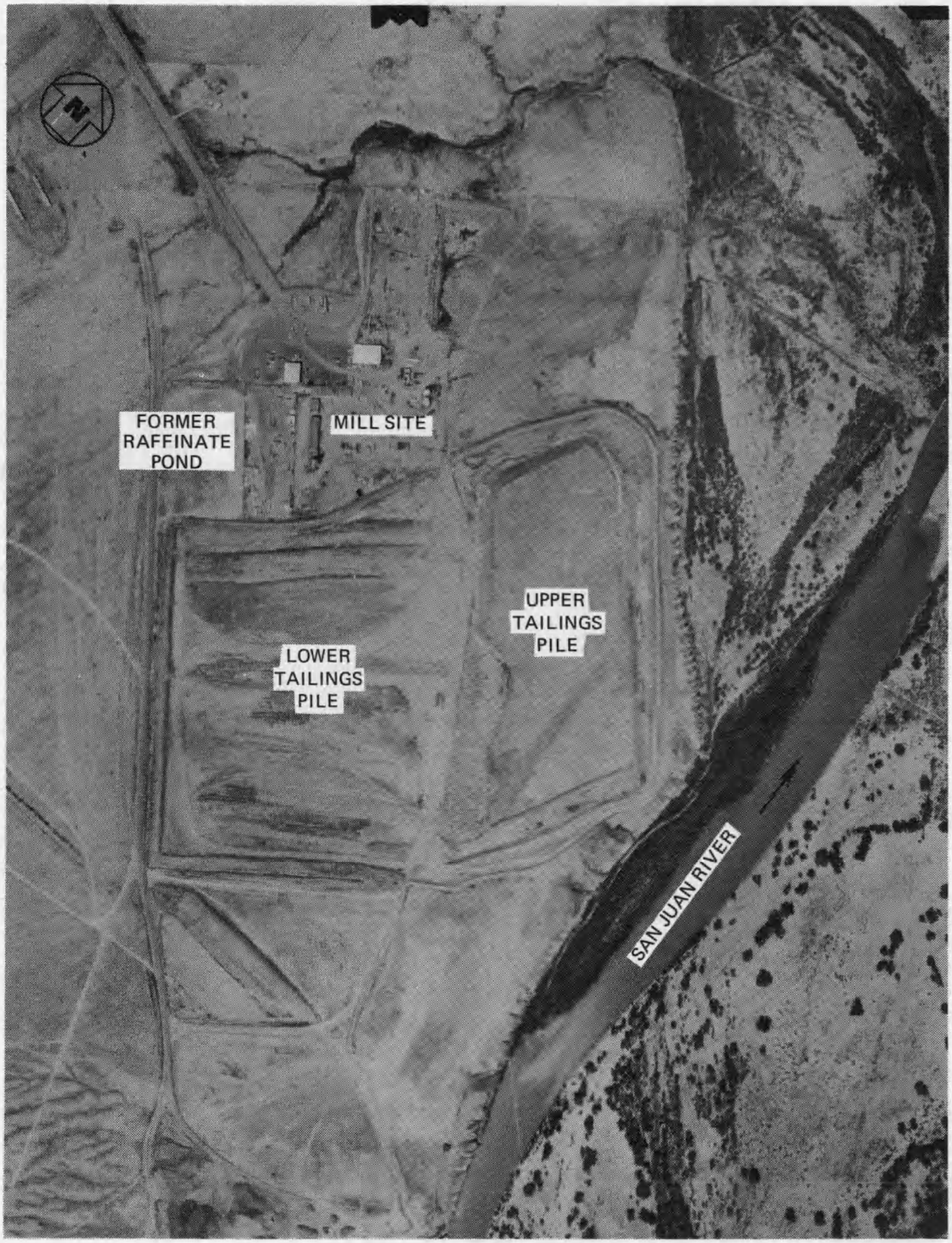

FIGURE 2-1. AERIAL PHOTOGRAPH OF SITE

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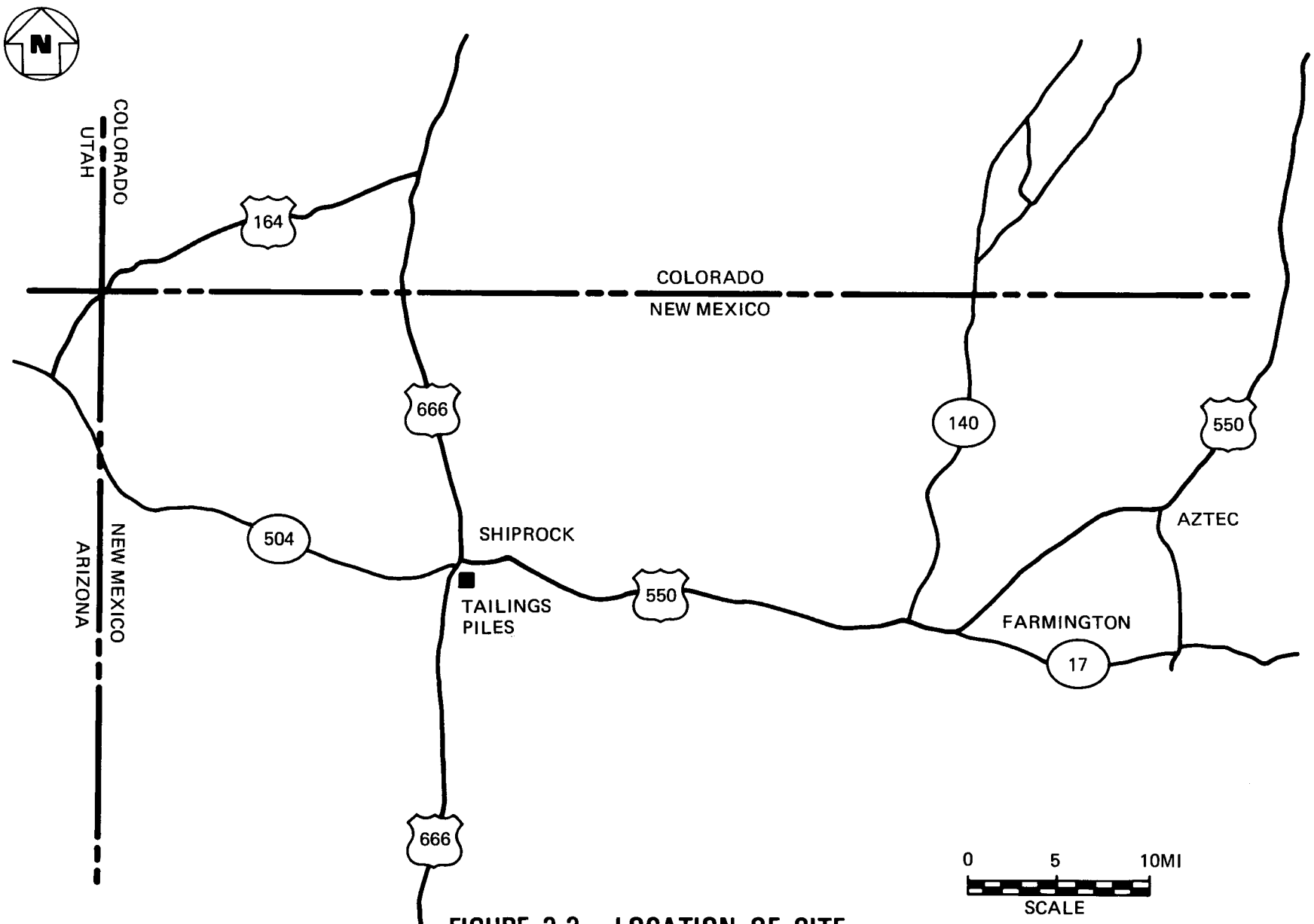

FIGURE 2-2. LOCATION OF SITE

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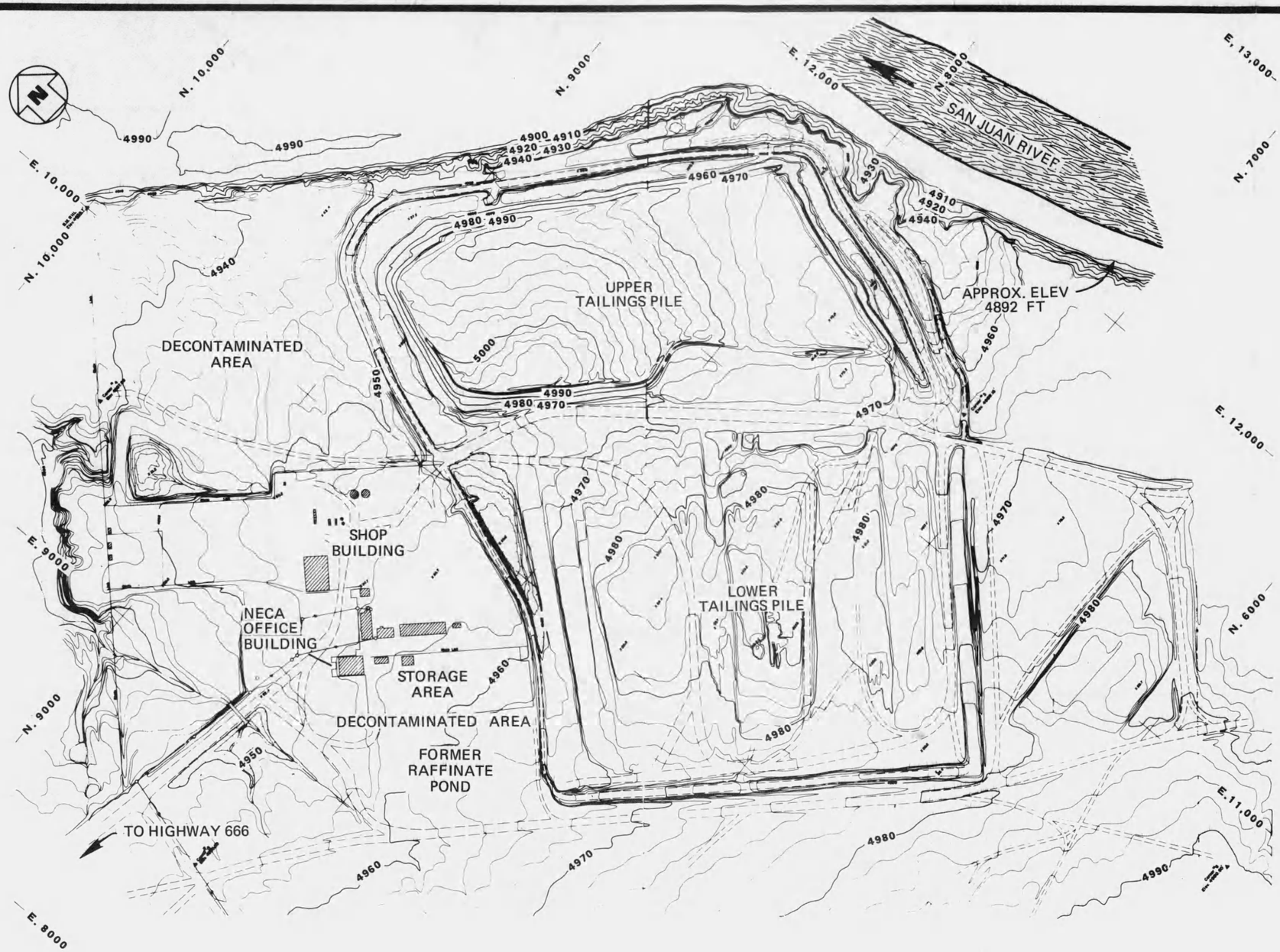

0 200 400 600 800FT

SCALE
CONTOUR INTERVAL 2 FT

FIGURE 2-3. TOPOGRAPHIC MAP

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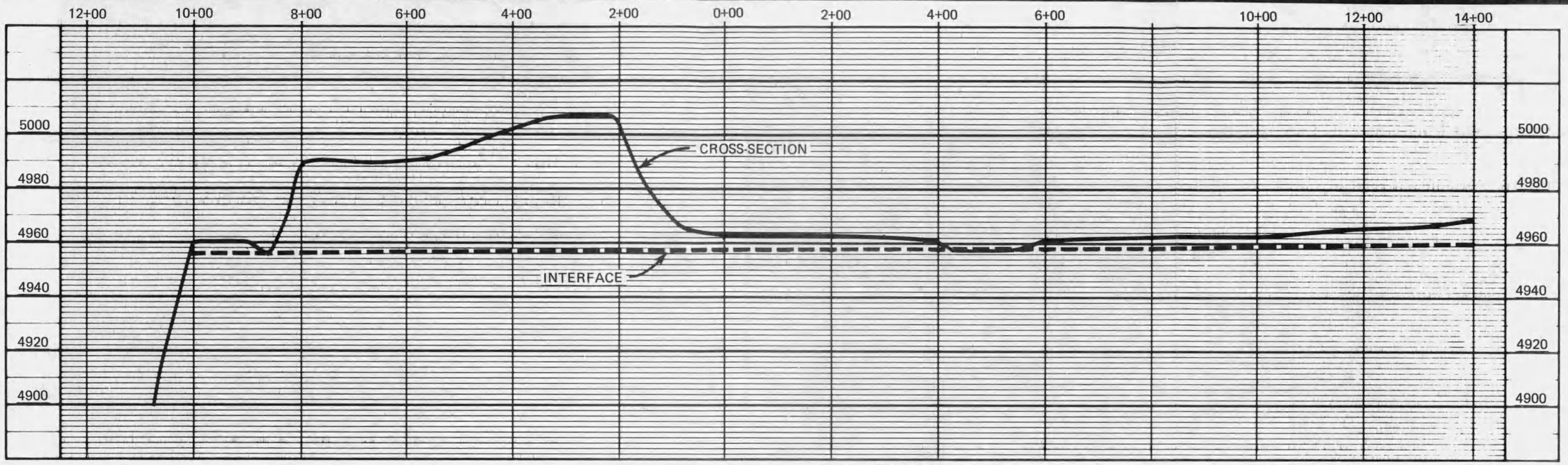
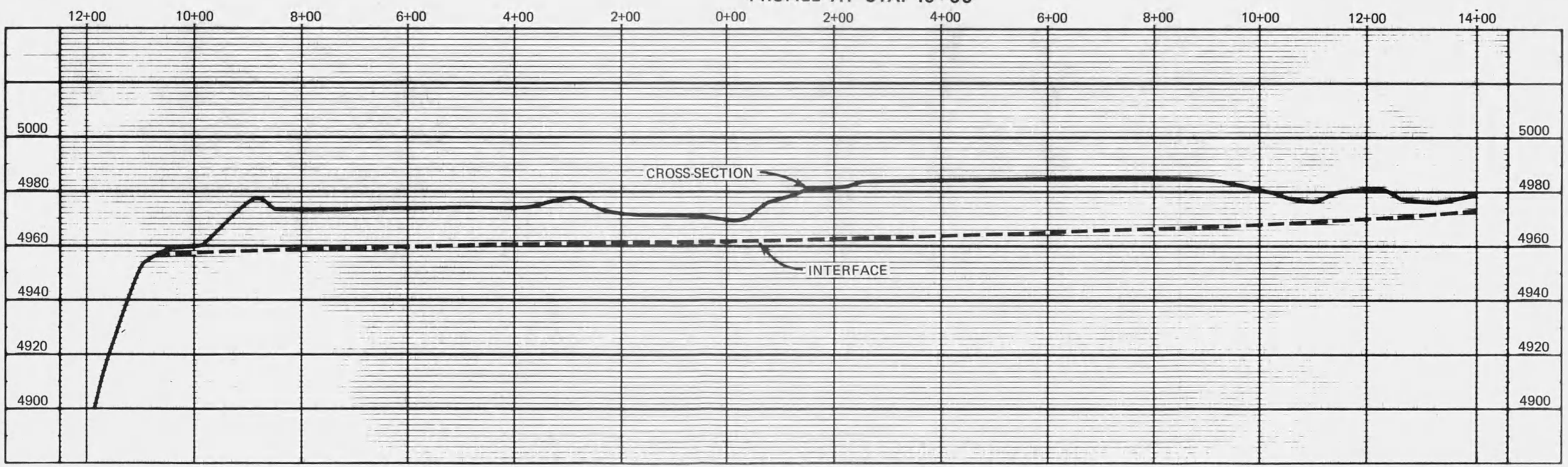


PROFILE AT STA. 15+00



PROFILE AT STA. 24+50

FIGURE 2-5. CROSS-SECTIONS AT STATIONS 15+00 AND 24+50

NOTE: SEE FIGURE 2-6. DESCRIPTIVE MAP FOR PLAN

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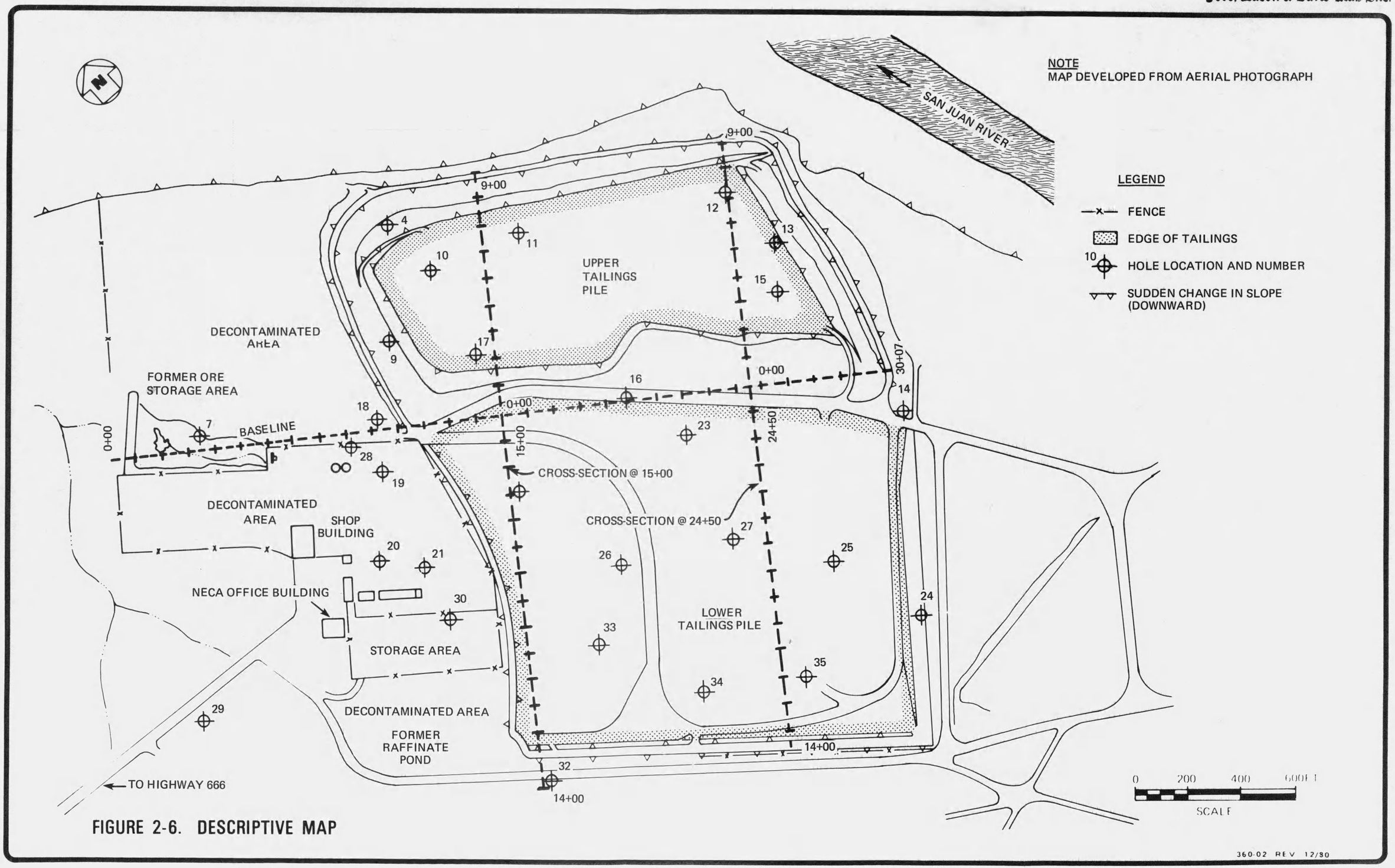

FIGURE 2-6. DESCRIPTIVE MAP

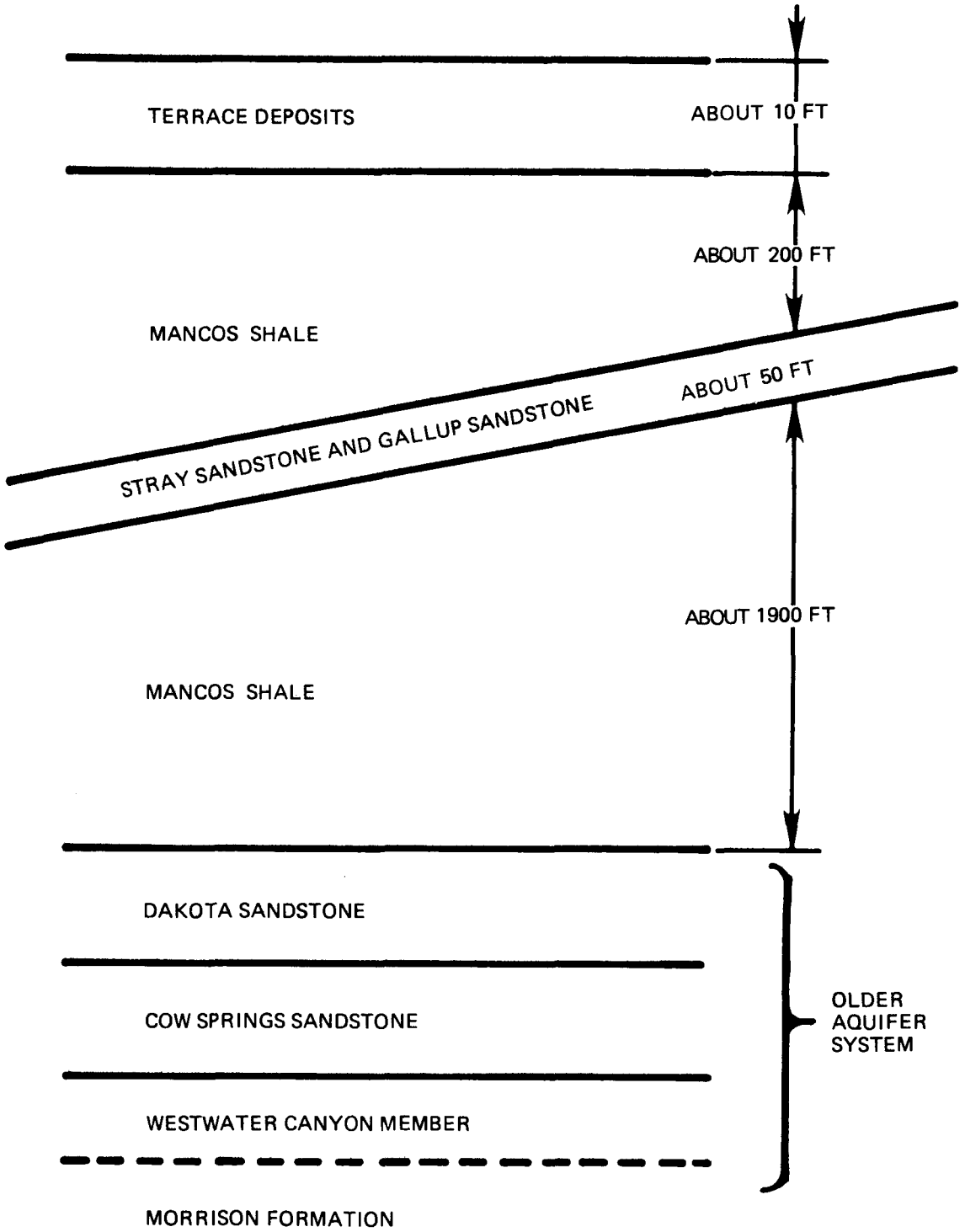

FIGURE 2-9. SIMPLIFIED STRATIGRAPHIC CROSS-SECTION

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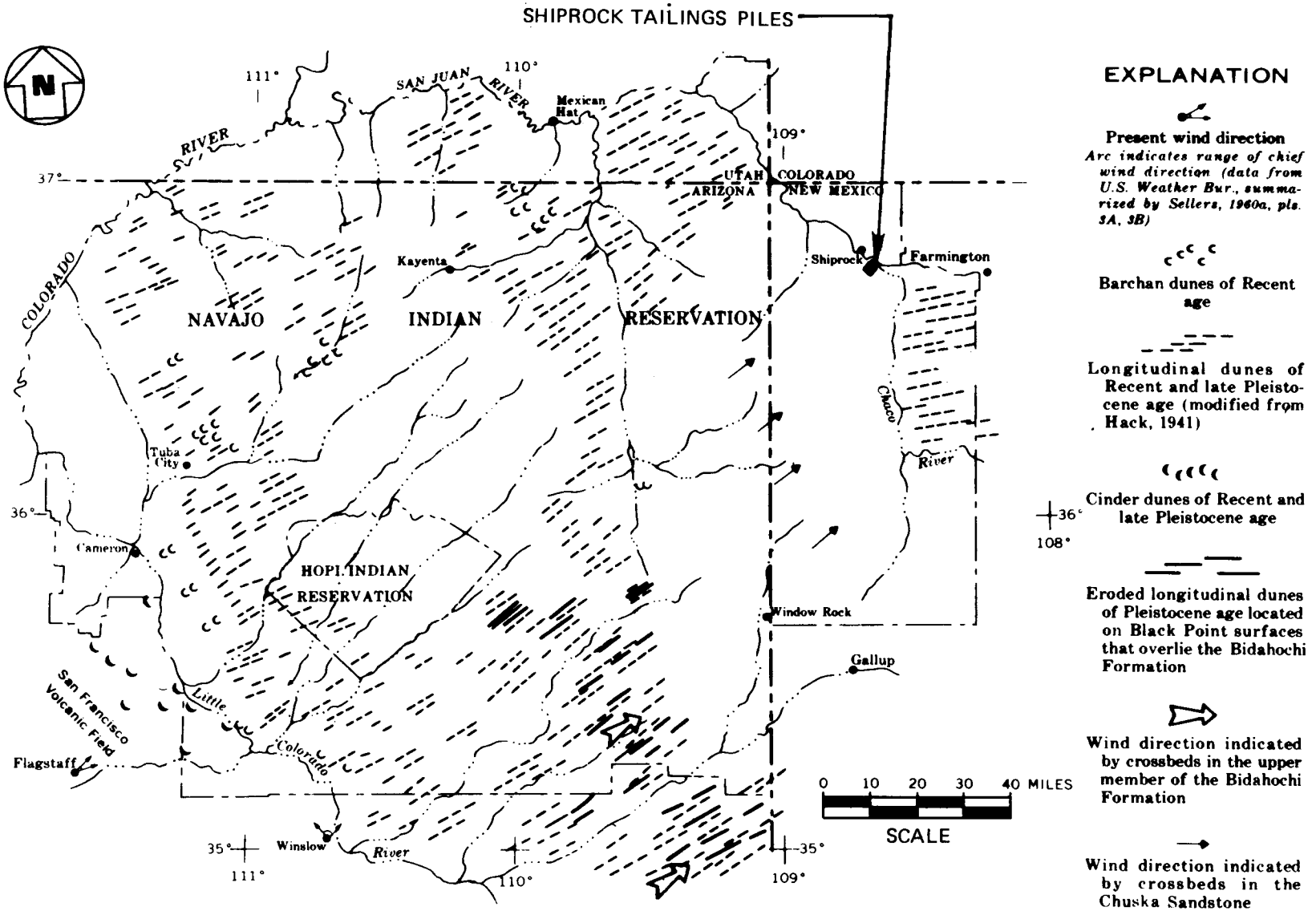

MAP SHOWING PAST AND PRESENT PREVAILING WIND DIRECTIONS

NOTE:
FROM REFERENCE 7

FIGURE 2-10. PREVAILING WIND MAP

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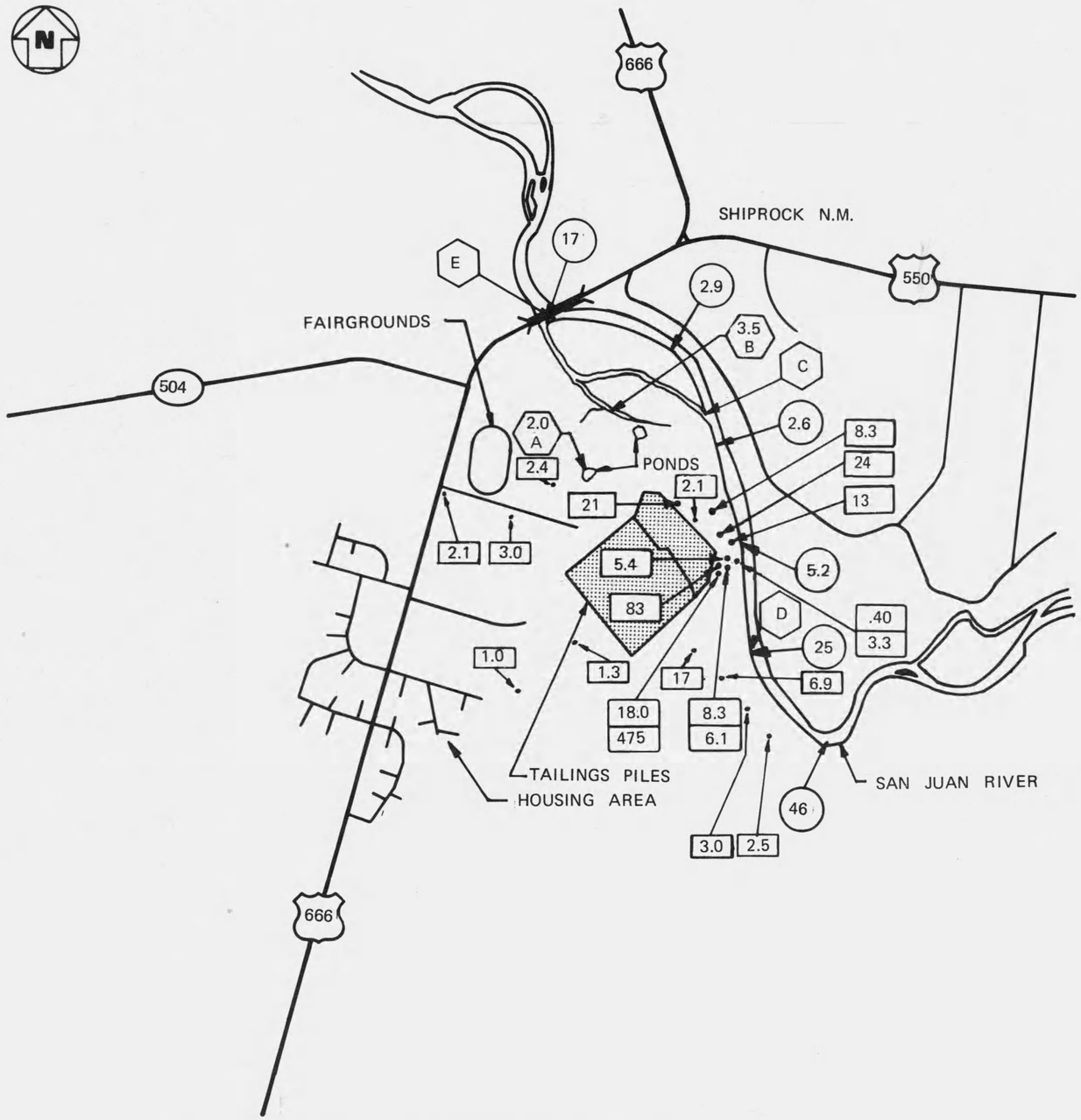

LEGEND

- SEDIMENT SAMPLES MEASURED IN pCi/g
- WATER SAMPLES MEASURED IN pCi/l
- SURFACE SAMPLE MEASURED IN pCi/g
  SAMPLES TAKEN SIX INCHES DEEP pCi/g
- SURFACE SAMPLE MEASURED IN pCi/g
  DATA FROM REFERENCE 1
- 504 STATE HIGHWAY
- 550 U.S. HIGHWAY

0 1/2 1MI
SCALE

FIGURE 3-13. SURFACE AND SUBSURFACE RADIUM CONCENTRATIONS

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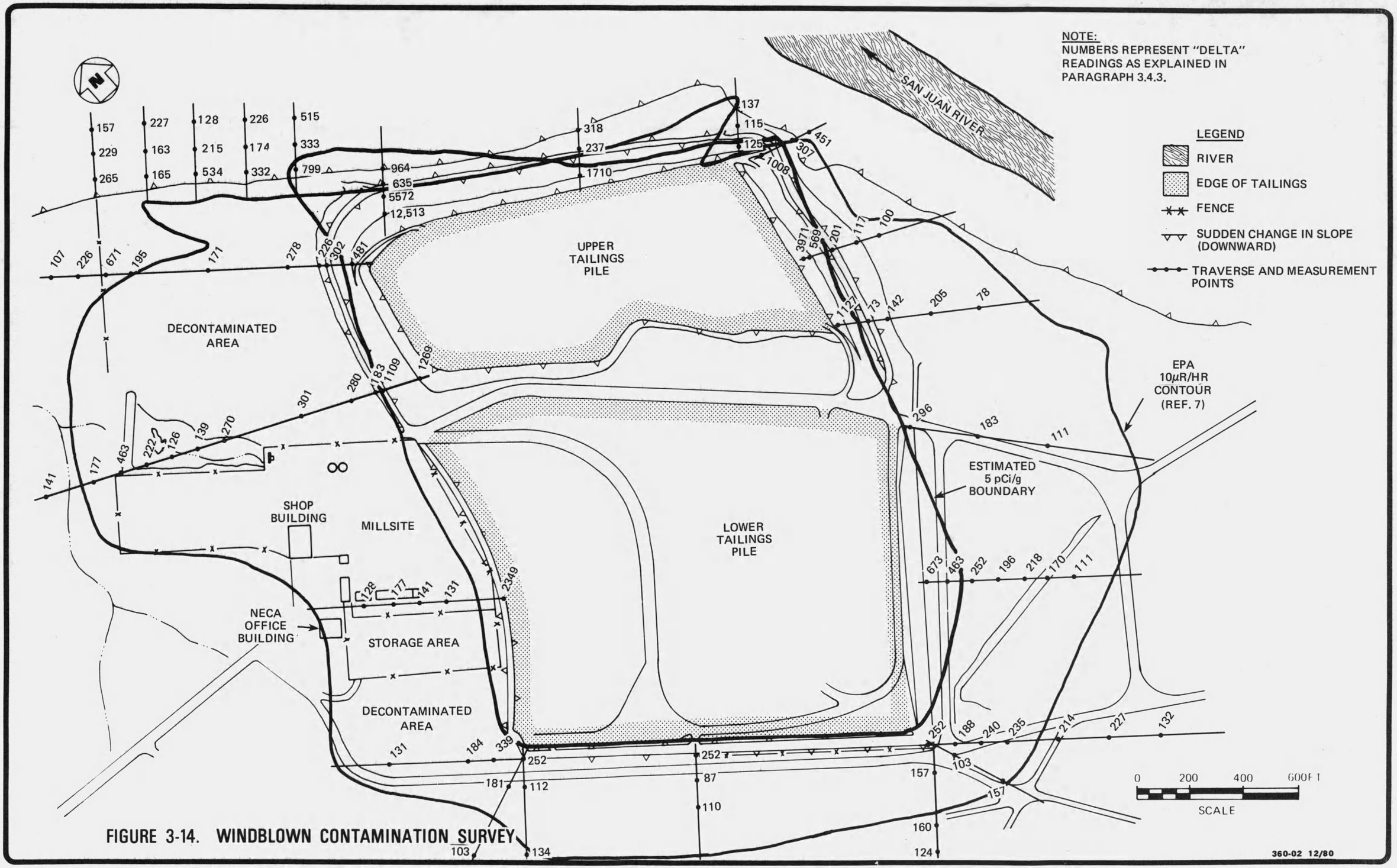

FIGURE 3-14. WINDBLOWN CONTAMINATION SURVEY

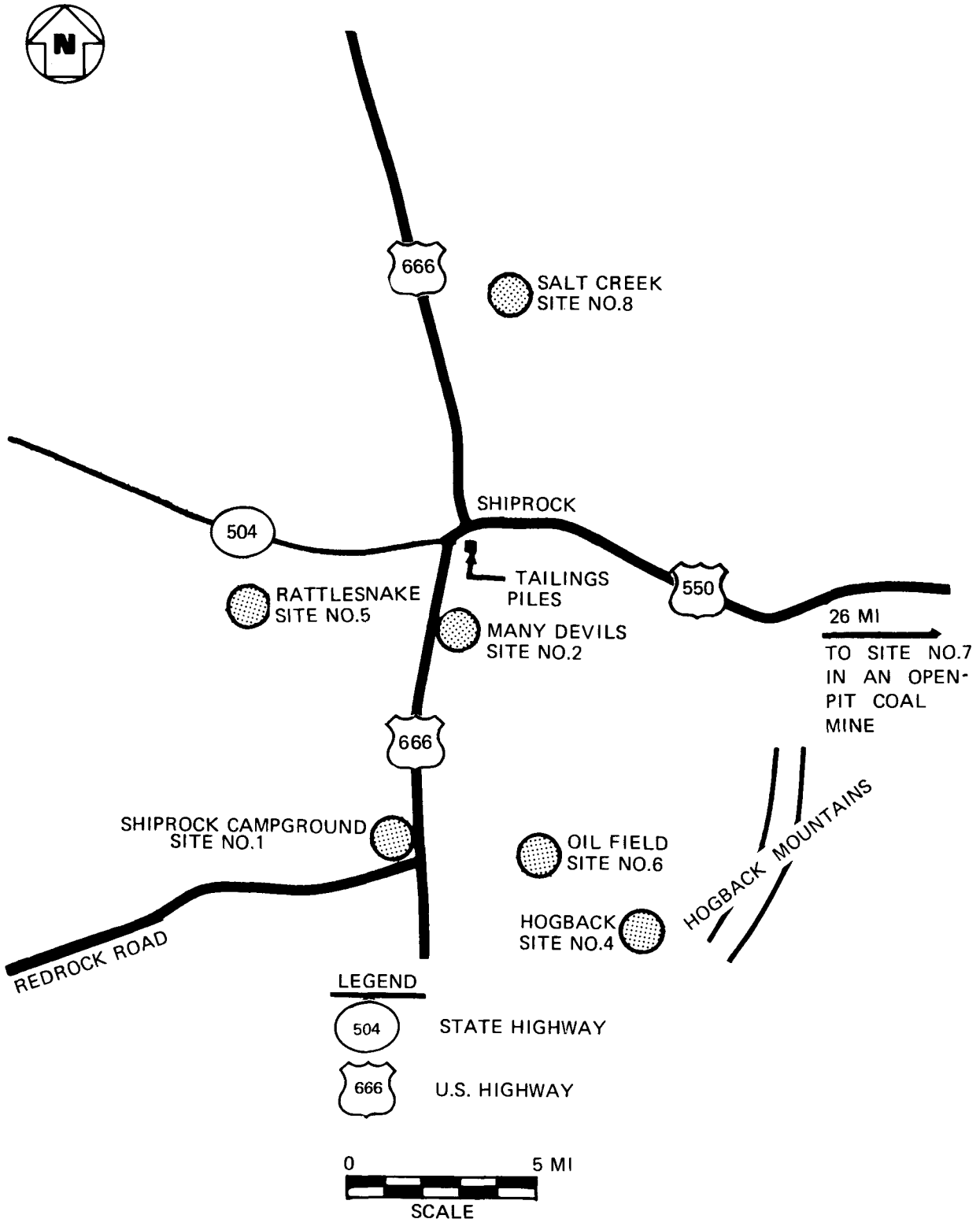

FIGURE 8-1. LOCATION OF PROPOSED DISPOSAL SITES

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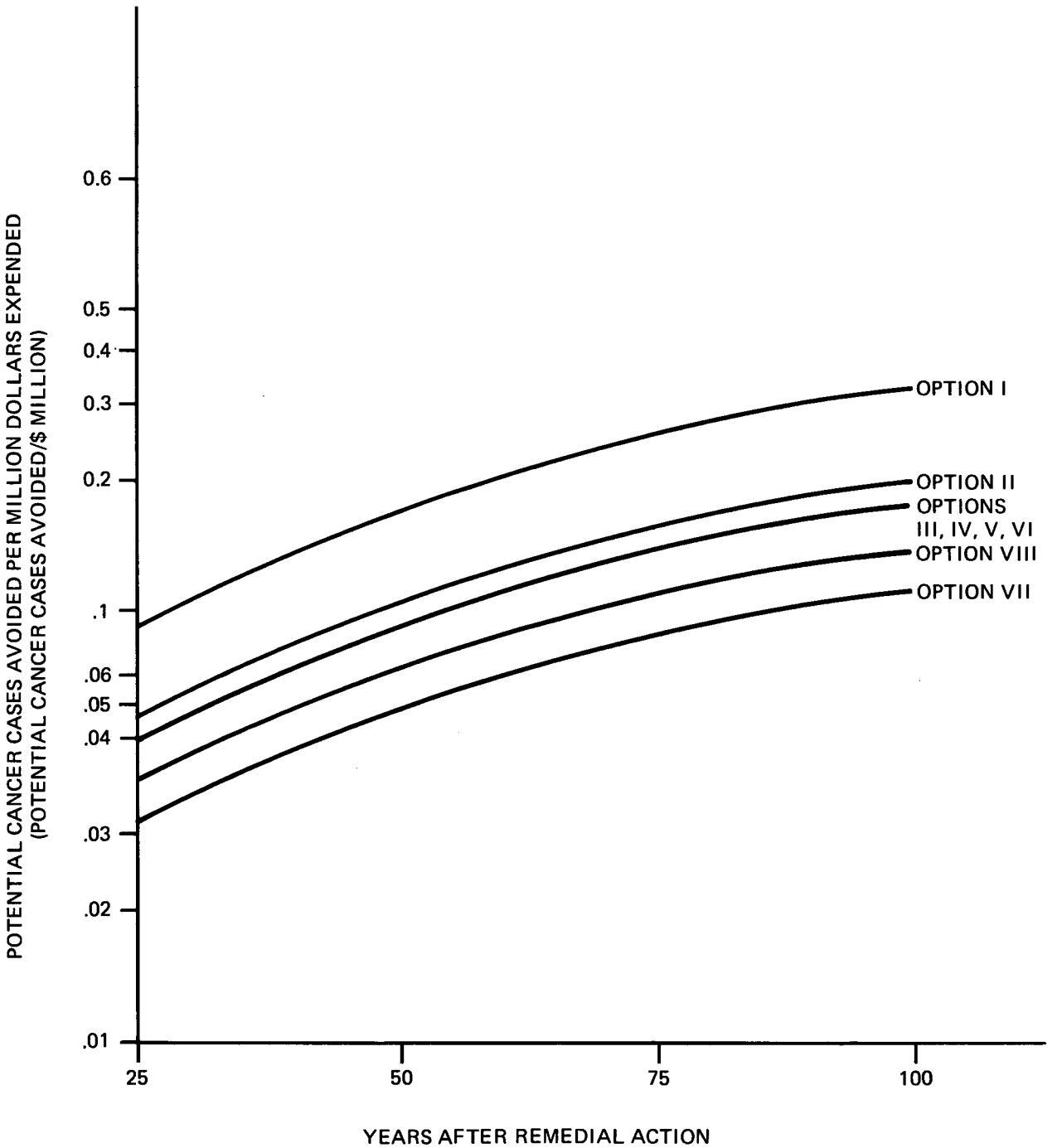

FIGURE 9-2. POTENTIAL CANCER CASES AVOIDED PER MILLION DOLLARS EXPENDED

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LIST OF TABLES

Number	Title	Page
8-1	Sites Evaluated for Disposal of Shiprock Tailings.	8-9
9-1	Summary of Stabilization and Disposal Costs	9-10
9-2	Potential Cancer Cases Avoided and Cost Per Potential Case Avoided.	9-11

TABLE 8-1

SITES EVALUATED FOR DISPOSAL OF SHIPROCK TAILINGS

Site No.	Option No.	Road Distance from Shiprock (mi)	Site Name
2	II	4.0	Many Devils
1	III	6.8	Shiprock Campground
5	IV	8.3	Rattlesnake
8	V	8.5	Salt Creek
6	VI	8.5	Oil Field
4	VII	16.0	Hogback
7	VIII	26.0	Operating Open-Pit Coal Mines
3	--	6.0	Shiprock Airport

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TABLE 9-1

SUMMARY OF STABILIZATION AND DISPOSAL COSTS[a]

		I	II	III	IV	V	VI	VII	VIII
1.	Tailings Site Costs	7.4	5.2	5.2	5.2	5.2	5.2	5.2	5.2
2.	Off-Site Remedial Action	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
3.	Windblown Area Remedial Action	--	--	--	--	--	--	--	--
4.	Transportation								
	a. Capital Costs	--	0.1	0.1	0.1	0.2	0.1	0.7	0.2
	b. Haul Costs	--	3.7	6.6	7.1	8.3	7.2	13.0	13.2
5.	Disposal Site	--	6.4	6.3	4.9	6.0	6.0	6.0	3.3
6.	Total Cleanup[b] (sum of lines 1 through 5)	7.9	16.0	18.7	17.8	20.3	19.1	25.4	22.4
7.	Engineering Design and Construction Management (30% of lines 1 through 6, except line 4b)	2.4	3.7	3.6	3.2	3.6	3.6	3.7	3.7
8.	Total[b] (sum of lines 6 and 7)	10.3	19.7	22.3	21.1	23.8	22.7	29.2	26.2
9.	Contingency (30% of line 8)	3.1	5.9	6.7	6.3	7.1	6.8	8.7	7.9
10.	GRAND TOTAL[b] (sum of lines 8 and 9)	13.4	25.6	29.0	27.4	30.1	29.5	37.9	34.1

[a]Costs are presented in millions of year 1980 dollars.

[b]Totals may differ from the sum of component costs because of round-off.

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TABLE 9-2

POTENTIAL CANCER CASES AVOIDED
AND COST PER POTENTIAL CASE AVOIDED

A. Number of Potential Cancer Cases Avoided

Options:	I	II	III	IV	V	VI	VII	VIII
Option Cost (million $)	13.4	25.6	29.0	27.4	30.1	29.5	37.9	34.1
Years After Remedial Action								
25	<1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
50	<2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
75	<3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
100	<4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0

B. Cost Per Potential Cancer Case Avoided (Million $)

Options:	I	II	III	IV	V	VI	VII	VIII
Option Cost (million $)	13.4	25.6	29.0	27.4	30.1	29.5	37.9	34.1
Years After Remedial Action								
25	11.2	21.3	24.2	22.5	25.1	24.6	31.6	28.4
50	6.4	12.2	13.8	12.9	14.3	14.0	18.1	16.3
75	4.3	8.3	9.4	8.7	9.7	9.5	12.2	11.0
100	3.4	6.4	7.3	6.8	7.5	7.4	9.5	8.5

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25	<1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
50	<2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
75	<3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
100	<4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0

B. Cost Per Potential Cancer Case Avoided (Million $)

Options:	I	II	III	IV	V	VI	VII	VIII
Option Cost (million $)	13.4	25.6	29.0	27.4	30.1	29.5	37.9	34.1
Years After Remedial Action								
25	11.2	21.3	24.2	22.5	25.1	24.6	31.6	28.4
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75	4.3	8.3	9.4	8.7	9.7	9.5	12.2	11.0
100	3.4	6.4	7.3	6.8	7.5	7.4	9.5	8.5

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