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Project Chariot Site Assessment and Remedial Action Final Report

August 1994

Environmental Restoration
Division

U.S. Department of Energy
Nevada Operations Office

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Project Chariot Site Assessment and Remedial Action Final Report

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ACZMP	Alaska Coastal Zone Management Program
ADEC	Alaska Department of Environmental Conservation
ADFG	Alaska Department of Fish and Game
ADGC	Alaska Division of Governmental Coordination
ADNR	Alaska Department of Natural Resources
AEC	U.S. Atomic Energy Commission
Am-241	Americium-241
amsl	above mean sea level
ATV	All Terrain Vehicles
BLM	U.S. Bureau of Land Management
Bq/g	becquerels per gram
Bq/kg	becquerels per kilogram
cm	centimeters
cpm	counts per minute
CRZ	Contaminant Reduction Zone
Cs-137	Cesium-137
DERP-FUDS	Defense Environmental Restoration Program for Formerly Used Defense Sites
DOE	U.S. Department of Energy
DoD	U.S. Department of Defense
DOT	Department of Transportation
EA	Environmental Assessment
EG&G/EM	EG&G Energy Measurements, Inc.
EPA	U.S. Environmental Protection Agency
EZ	exclusion zone
FONSI	Finding of No Significant Impact

FSP	Field Sampling Plan
ft	feet
FWS	Fish and Wildlife Service
FY	fiscal year
g	grams
gal	gallons
GPS	Global Positioning System
HDPE	High-density polyethylene
I-131	Iodine-131
in.	inches
IT	IT Corporation
keV	kiloelectron volts
kg	kilograms
km	kilometers
km^2	square kilometers
LLD	lower limit of detection
m	meters
m^3	cubic meters
MCA	Multichannel Analyzer
mCi	millicuries
MDA	minimum detectable activity
mi	mile
mi^2	square miles
ml	milliliter
mph	miles per hour
R/hr	microroentgens per hour
mR/hr	milliroentgens per hour
mrem/yr	millirems per year
NaI	Sodium iodide
NARL	Naval Arctic Research Laboratory

NIST	National Institute of Standards and Technology
NTS	Nevada Test Site
NWP	nationwide permit
OA	observational approach
oz	ounces
PIC	Pressurized Ion Chamber
pCi/g	picocuries per gram
pCi/l	picocuries per liter
PPE	Personal Protective equipment
QA	quality assurance
QAPjP	Quality Assurance Project Plan
QC	quality control
RWMS	Radioactive Waste Management Site
SAP	Sampling and Analysis Plan
SOP	Standard Operating Procedures
Sr-85	Strontium-85
Sr-90	Strontium-90
SSHSP	Site-Specific Health and Safety Plan
TLDs	Thermoluminescent dosimeters
USGS	United States Geological Survey
yd^3	cubic yards
°C	degrees Celsius
°F	degrees Fahrenheit

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Glossary

abraded - eroded by scouring, as by rocks tumbling down stream

actinides - a chemical compound that begins with actinium or thorium and ends with lawrencium

aliquot - a quantity of a sample

alpha radiation - caused by a radioactive nucleus emitting high-speed positively charged nuclear particles, consisting of two protons and two neutrons

alluvian fan deposits - gravel and dirt deposited at the base of a slope by a stream usually in an arid or semiarid region where a stream issues from a narrow canyon onto a plain or valley floor

analyte - unofficial term for an element that is the subject of inquiry. In other words, the element being analyzed in a particular situation

anomalies - deviation from what is common, abnormal

aquifer - a groundwater reservoir. A body of rock that is capable of holding or conducting a significant amount of groundwater

background radiation - the radiation in man's natural environment, including cosmic rays and radiation from the naturally radioactive elements, both outside and inside the bodies of humans and animals

background samples - samples taken of known "normal" or "undisturbed" areas that will be used to compare against samples taken in a nearby contaminated area

bedrock knobs - a rounded hill or mountain, usually isolated, that consists of the solid rock that underlies the local soil and gravel

beta radiation - caused by a radioactive nucleus emitting high-speed electrons due to beta decay

biota - the plants and animals of a region

biomass - the amount of living matter, plant and animal matter

bipod - a stand that has two legs

braided channel - a channel that divides into an interlacing network of branching and reuniting shallow channels separated from each other by small islands or channel bars

byte - units used by a computer to represent an alphanumeric character

calibrate - to check or correct the accuracy of a measuring instrument to assure proper operational characteristics

clinometer - an instrument for measuring angles of elevation or inclination

closure - the closing of a project by returning the environment to its pre-disturbed state

collimate - to make parallel

colluvium - a general term applied to loose and incoherent deposits, usually at the foot of a slope or cliff and brought there chiefly by gravity

contaminant reduction zone - the controlled area between the Exclusion Zone and the Support Zone used primarily for decontamination and entry/exit

cosmic rays - penetrating ionizing radiation, both particulate and electromagnetic, originating in space

count rate - to measure radiation; counts per minute (cpm)

cross contamination - contamination from one sample that is transferred onto other samples by accident. For example, if a tool is not washed between samples, then the tool would transfer small amounts of the last sample to the next sample

diatomaceous earth - large amounts of silicified skeletal remains of algae or plankton that form a light soil that is commonly used as a filter material

electrodeposit - a deposit formed by a chemical change induced by an electrical current

excelsior™ blankets - erosion control/revegetation blanket consisting of smolder resistant curled and barbed aspen wood, covered with a photodegradable plastic mesh

exclusion zone - the controlled area of a hazardous waste site where the hazardous waste activity takes place

ephemeral pond - a pond having water flow only in direct response to precipitation in the immediate vicinity and is at all times above the watertable

gamma radiation - caused by a radioactive substance emitting high-energy photons

gamma spectroscopy - a method for determining and measuring gamma radiation

germanium detector - a detector for measuring gamma radiation

geology - the study of the history of the earth and its life as recorded in rocks, description of the rocks and soils of an area

geotextile fabric - heavy, black, plastic tarpaulins

global positioning system - a method of determining a location on earth by using satellites in earth's orbit that can pinpoint exact locations through communication with computers on the earth's surface

grab sample - a sample taken from a general location that is representative of that location, as opposed to a sample taken at precise measurements

half-life - time required for half of the atoms of a radioactive substance to become disintegrated

hand auger - a tool used to bore a hole; it is twisted by hand

head waters - the source of a stream; where a stream begins

homogenized - to blend different elements into a uniform mixture

humus - organic soil formed by the partial decomposition of plant and animal matter

hydrology - dealing with the properties, distribution, and circulation of water on and below the earth's surface and in the atmosphere

in situ - in place, in the natural or original position

incinolet toilet - portable toilet that burns feces

injection slug - a known volume of water or a solid that is rapidly placed into a water system and the resultant water properties measured

integrity of samples - chain-of-custody procedures used to protect against tampering or cross contamination

isoradiation contour map - a map showing the radiation levels of the ground surface in which each contour line represents a unique level of radiation

isotope - one of two or more atoms with the same number of protons, but different numbers of neutrons in their nuclei

lanthanides - chemical compounds containing lanthanum or cesium, and lutetium

matrix - the material making up a sample (gas, liquid, or solid)

matrix spike - a material added to the sample that will reflect the accuracy of the analysis to be performed

microdrainage - very small scale drainage area of a stream or tributary

milling - to grind up with machinery

mudstone - mud that has turned to stone by process of drying and compression

node - a point at which a wavelength has a height of zero

oxalates - a salt or ester containing $(C00H)_2$ or $H_2C_20_4$, which is a strong poisonous acid

percent moisture - the relative amount of moisture with respect to dry air. Amount of water in soil openings (pores) given as a percentage of the total soil volume

percolation - infiltration, slow smooth movement of water through small openings within a porous material

permafrost - permanently frozen soil or subsoil

permeable - rock, sediment, or soil capable of transmitting fluid

polyethylene sheeting - lightweight plastic sheeting that is resistant to chemicals and moisture and has good insulating properties

polymer - man-made synthetic material

process knowledge - deciding what is in the waste by looking at the operation that produced the waste, as opposed to determination through sampling and analysis

progeny - daughter isotopes and related elements that result from the decay of radioactive elements. A radioactive element will lose energy and become a different element or isotope.

proportional counter - an instrument used to measure alpha or beta radiation

radiation field - any area where radiation is being emitted

radioactivity - the property possessed by some elements, such as uranium or isotopes, such as carbon 14, of spontaneously emitting energetic particles by the disintegration of their atomic nuclei

radioecology - the study of effects of radiation on the natural environment

radioisotopes/radioactive isotopes - radioactive isotopes spontaneously emit energetic particles (as alpha or beta particles) by the disintegration of their atomic nuclei

radioactive tracers - because radioactive elements are easily traced, they can be used in studies to observe the movements of stable elements that are not traceable. The radioactive tracers mimic the movements of their stable counterparts.

reconnaissance - a general exploratory examination or survey of the main features of a region, usually done before a more detailed survey

remedial action - action taken to correct or counteract a problem

replicate quadrate sampling - a sampling method that samples all the plants in marked square areas

sediment transport - movement of soil carried in water downstream

silt - soil that is finer grained than sand

slurry - a highly fluid mixture of water and finely divided material

talus - rock fragments, usually coarse and angular, lying at the base of a cliff or steep slope from which they have been derived

terrace deposits - step-shaped ledges on the sides of a valley; each ledge was a former streambed that has been cut by a smaller stream

terrestrial - contained in the earth

topography - a description of the land's surface with regards to the height and position of major features, such as hills and valleys

trap-night - a term used to define one 24-hour period of trapping effort by one trap

tundra - a level or undulating treeless plain, having a black muck soil and permanently frozen subsoil

uni-mat - portable stable foundations; safe road systems that support heavy haul loads and traffic flow of machinery equipment and personnel

upgradient - groundwater does not necessarily flow downhill; it flows downgradient, i.e., to places with less pressure. Relative to any given point in a groundwater basin, upgradient is any direction groundwater will not flow.

volatile organic compounds - organic compounds that evaporate at relatively low temperatures

water table aquifer - a groundwater reservoir that interacts with the atmosphere because it is not sealed by solid rock on top

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Executive Summary

Project Chariot Site

The U.S. Department of Energy (DOE), through its Nevada Operations Office, conducted a site assessment and remedial action at the Project Chariot Site from July 29 through September 5, 1993. The Project Chariot Site is a remote and isolated area located in the Ogotoruk Valley along the Ogotoruk Creek in the Cape Thompson region of northwest Alaska. This region is approximately 200 miles north of the Arctic Circle and is bounded on the southwest by the Chukchi Sea. Extreme weather conditions make the site inaccessible for ten months of the year. The closest populated areas are Point Hope (population 639), which is 32 miles northwest of the Project Chariot Site, and Kivalina (population 317), which is 41 miles to the southeast.[1] The Cape Thompson area is used for subsistence hunting and fishing by local natives.

Experimental Studies

The U.S. Atomic Energy Commission's (AEC) Plowshare Program was created in the 1950s to study peaceful uses for nuclear explosives. Project Chariot was part of this program. One aspect of the Plowshare Program was to demonstrate to scientists whether nuclear explosives could be used to excavate a harbor. Project Chariot began in July 1958 when a scientific field party chose Cape Thompson as a potential site to develop nuclear excavation technology.

Scientists studied the environment at Cape Thompson between 1958 and 1962 to determine if any nuclear devices could be used. They studied land and sea mammals, freshwater and marine fish, birds, vegetation, land, and weather. They also explored the historical and cultural background of the site. They determined the natural background levels of radiation in the soils and also collected information on the underground temperatures of the permafrost.

One of the studies conducted was a U.S. Geological Survey (USGS) radioactive tracer experiment. The experiment was designed to study the movement of radioisotopes through native soil and water. The AEC granted the USGS a license to conduct this experiment and allowed fallout soil from Project Sedan, a Plowshare Program experiment in Nevada, to be brought to the site.

The 1962 USGS experiment involved twelve test areas, which included 10 rectangular test plots for an overland-transport tracer study, a sediment-transport experiment, and an 18-hour percolation test. The overland-transport tracer studies measured the movement of Project Sedan fallout or individual radioisotopes through the soil by simulating rainfall to produce temporary runoff. Scientists performed a sediment transport study to measure the movement of contaminants through water. The 18-hour percolation test was designed to measure the movement of radioisotopes in Sedan soil through silt and clay. After each test, samples were collected and analyzed to determine any radioactivity present.

The ten rectangular test plots designed for the overland-transport studies ranged from 0.6 meters (m) by 0.6 m to 1.5 m by 2 m (2 feet [ft] by 2 ft to 5 ft by 7 ft). The radioisotopes used in the research were 6 millicuries (mCi) of cesium-137 (Cs-137), 5 mCi of iodine-131 (I-131), 5 mCi of strontium-85 (Sr-85), and 10 mCi of various radioisotopes contained in Project Sedan soil. When the tests were completed, the USGS removed the tracer-contaminated soil from the various test areas and placed the soil over two of the plots. The contaminated soil was mixed with native Alaskan soil and finally covered with a four-foot layer of clean soil, forming a mound. This disposal mound and the former test plot areas became the focus of the DOE site assessment and remediation.

In November 1962, AEC closed the camp without completing the harbor excavation experiments, and no nuclear explosives were taken to the site. Commission officials cancelled the program. Much of the information they had hoped to obtain from Project Chariot was already available from earlier tests conducted elsewhere or would be obtained through other experiments.

1992 Levels of Radioisotopes at the Project Chariot Site

In 1992, while preparing a paper on Project Chariot, a researcher from the University of Alaska, Fairbanks, obtained two letters written in the 1960s from the USGS to the AEC, discussing the use of radioactive isotopes at the Project Chariot Site. The information stated that some radioactive isotopes were buried at the site without proper permits. The researcher informed the U.S. Army Corps of Engineers and the media of the presence of radioisotopes remaining at the site. Responding to the publication of these findings, the public asked Alaskan officials to take action.

In response to public concern, the Alaska Department of Environmental Conservation (ADEC) and the U.S. Army Corps of Engineers conducted an investigation of the Project Chariot Site from September 10 through 13, 1992. A surface radioactivity survey indicated that the radioactive materials in the mound remained intact since there were no surface radiological readings above background levels. However, the survey showed a slight increase in radiation level when the detector was placed at the bottom of a three-foot hole drilled into the soil disposal mound. The slightly elevated level was suspected to be the result of natural radioactivity. In addition, ADEC placed the site on the State Hazardous Waste Site List. Later, ADEC and DOE resurveyed the site. The survey results showed no elevated readings.

Of the radioisotopes left at the disposal site from the 1962 studies, I-131 and Sr-85 have half-lives of less than 70 days and had decayed away before this remedial action. The man-made isotope, Cs-137, has a half-life of 30 years, and certain isotopes in the Sedan soil have half-lives of three years or more. Calculations indicated that approximately 3 mCi of Cs-137 remained in the disposal mound in 1993, with an average concentration of 30 picocuries per gram (pCi/g).

Although risk assessments indicated that neither the 1993 level of radioactivity nor the activity present in 1962 posed a risk to human health or the environment, DOE was prompted by public concern to reexamine the Project Chariot Site. The Secretary of the U.S. Department of Energy accepted responsibility for the removal of the waste from the Project Chariot Site since the waste had been created by DOE's predecessor, AEC. The site assessment and remedial action focused on removing the soil containing radioactive materials from the former test plot area and the disposal mound.

Site Preparations

Preparations for the site assessment and remediation began 10 months before the actual site assessment and remediation team arrived at the Project Chariot Site. Timing was crucial in the preparations. The site assessment and remediation were scheduled for a six-week period from July to September to avoid disturbing local subsistence hunting. If adverse weather conditions occurred, remediation activities would be severely inhibited.

These preparation activities involved numerous agencies and included obtaining 8 permits, issuing 14 different support contracts, preparing an Environmental Assessment and a Wetlands and Floodplains Notice, substantiating a Finding of No Significant Impact under the National Environmental Policy Act, and preparing a Site Assessment and Remediation Plan. In addition, the public was involved throughout the planning process. Public meetings were held in the northern Alaskan villages of Point Hope, Kivalina, Kotzebue, and Barrow, giving area residents an opportunity to participate in activities taking place at the Project Chariot Site.

Eight permits were needed before site operations could begin. For example, DOE had to obtain permits to land on the beach, place a culvert within Snowbank Creek, use water for campsite operation, discharge treated graywater, and obtain samples.

In addition, 14 different support contracts were issued. A contractor was hired to provide a full-service campsite large enough for 60 people. Since the main travel route to the Chariot Site consisted of jet travel to Kotzebue and propeller plane to Cape Thompson, a private plane was contracted to transport supplies and individuals. A separate contract was issued to a barge company to transport larger equipment and to remove the boxes containing the waste soil. Other contracts involved equipment and personnel to run global positioning equipment and to set up the radiation and biota laboratories.

DOE prepared a site assessment and remedial action plan with technical expertise provided by IT Corporation, an environmental consulting firm under DOE contract. The Alaska Department of Environmental Conservation, the U.S. Fish and Wildlife Service, other concerned agencies, and the public provided advice and comments on the plan.

Environmental impacts of the remediation activities at the Project Chariot Site were studied. One area, Crowbill Point, was the possible nesting site of a pair of peregrine falcons. To avoid any interference with the nesting pair, an exclusion zone was established within a half-mile radius of Crowbill Point. This exclusion zone banned all surface- and air-disturbing activities to ensure compliance with the Endangered Species Act. In addition, revegetation requirements for the Project Chariot Site were established to ensure that the site would be restored when activities were completed.

Equipment and materials were leased or purchased to meet specific requirements, e.g., construction equipment weight was limited to no more than three pounds per square inch to protect the tundra. No viable roads were available to transport personnel, equipment, and supplies to the site, so arrangements were made to transport them by either sea or air.

Before field activities could begin, a remediation clean-up level for the Project Chariot Site was determined based on an exposure and risk analysis. The clean-up level of 0.4 becquerels per gram (Bq/g) (10 pCi/g) was established for Cs-137. Soils that showed Cs-137 contamination levels above this clean-up level were removed from the site.

Site Assessment and Remediation

The objectives of the assessment and remedial activities at the Project Chariot Site were to:

- remediate the soil disposal mound in accordance with the DOE-prepared and ADEC-approved Site Assessment and Remedial Action Plan
- excavate and package the soil from the mound and test-plot area to attain the established clean-up level
- perform a radiological survey and confirmatory sampling of the excavated soil mound and the test-plot area to verify that the tracer-study radioisotopes had been removed and to secure on-site ADEC approval of final closure
- perform sediment and surface water sampling and analysis of Snowbank Creek to assess any potential transport of radioisotopes
- obtain samples of selected biological organisms from the Project Chariot area to make an informed decision as to the radiological significance of the tracer study on the biota
- collect background soil and biota samples from undisturbed locations in Ogotoruk Valley that displayed soil and vegetation characteristics similar to the area of the disposal mound
- perform the remedial action in a safe, environmentally sound, and cost-effective manner.

All activities at the Project Chariot Site were conducted with full public disclosure, oversight, and review. Oversight of characterization and remediation activities was provided by:

- Alaska Department of Environmental Conservation
- U.S. Fish and Wildlife Service
- Alaska Department of Natural Resources
- Point Hope Representatives
- North Slope Borough Representatives (Foster-Wheeler Corporation)
- Kivalina Representatives
- Native Village of Point Hope Representatives.

The assessment and remedial activities at the Project Chariot Site required an approach that provided for conducting characterization and remediation at the same time in order to complete field activities within one season. A streamlined method of decision making, called the Observational Approach was used. The Observational Approach is a technique for:

- managing uncertainty in the field
- obtaining an adequate quantity of quality data for characterization
- focusing characterization to support field decisions for remediation
- enabling remedial action decisions to be made in the field at early stages of the process
- evaluating remedial alternatives based on probable site conditions
- identifying reasonable deviations from realistic site conditions
- allowing for the design of contingency plans to address reasonable deviations.

The use of DOE's Observational Approach allowed the remediation to occur in a cost-effective and efficient manner by directing the characterization and remediation efforts to follow parallel paths.

The characterization and remedial activities at the Project Chariot Site were divided into nine specific tasks, some of which were done simultaneously:

Task I: Aerial Photographic and Radiological Surveys

Task II: Soil Sampling

Task III: Surface Water and Sediment Sampling

Task IV: Ground Radiological Survey

Task V: Biota Sampling

Task VI: Pre-Excavation Sampling and Analysis

Task VII: Soil Excavation and Packaging

Task VIII: Postexcavation Sampling and Analysis of the Excavated Area and Closure

Task IX: Waste Transportation and Disposal.

In June 1993, aerial photographs were taken to support the aerial radiological surveys conducted at the Project Chariot Site and surrounding area. The aerial radiological surveys were conducted in July 1993 to screen the area for the potential existence of unnaturally elevated levels of radioactivity, that is, elevated levels of man-made radioactivity. No such elevated levels were detected during the aerial radiological surveys.

The aerial radiological surveys were conducted to address the public's concern that 5 curies of radioactive material were brought to and remained in the Cape Thompson area. The USGS, in a license issued by the AEC, was authorized to use up to 5 curies of mixed fission products in its tracer experiments. However, only 26 millicuries of radioactive materials were actually brought to the Project Chariot Site.

Background samples were collected and analyzed to compare site conditions to the surrounding environment. All selected background sampling locations were outside the areas of past activities conducted by AEC. Selection of the criteria for defining an acceptable accuracy for background determination was based on the natural variations of background levels occurring in the environment.

During the USGS studies, personnel identified the tributaries of Snowbank Creek numerically as they traveled away from Ogotoruk Creek with Tributary 1 as the first branch off Snowbank Creek. USGS personnel designated a very small branch of Snowbank Creek as Tributary 2. This branch was several inches wide and several feet long.

During site reconnaissance and during the surface water and sediment sampling, it was noted that what was once considered Tributary 2 was no longer identifiable. To prevent confusion concerning the naming of the upper tributaries (2 and 3) of Snowbank Creek, it was decided that sample locations on the creek would be identified as being either on the upper or lower reaches. The section of Snowbank Creek between Ogotoruk Creek and the first tributary is referred to as the "lower reach of Snowbank Creek." The section of Snowbank Creek from the first tributary traveling away from Ogotoruk Creek is referred to as the "upper reach of Snowbank Creek."

Surface water, sediment, and soil samples were collected to determine if residual tracer-study isotopes remained at the site. All soil samples were analyzed at the on-site laboratory using gamma spectroscopy.

Biological sampling was performed to evaluate radioisotope concentrations of selected animals and plants in the vicinity of the Project Chariot Site. Samples of plants, mammals, and birds were collected and analyzed to measure radioisotopic concentrations in the samples, to compare current results to past measurements, and to make an evaluation of the radioecological significance of the results. Biota samples were also collected in Kisimilok Valley to conduct intervalley biota comparisons. Analytical results indicated that concentrations of Sr-90 and Cs-137 in biota samples were essentially uniform over the area. The concentrations indicated that most radioisotopes detected had their origins in natural sources or from worldwide fallout. Strontium-90 and Cs-137 concentrations in food items of local importance were well within acceptable limits.

Radiological surveys were performed to locate the original tracer-study test plots, to determine whether any radioisotopes remained from the 1962 excavation of the plots, and to characterize the surface radiation levels along Snowbank and Ogotoruk Creeks. In addition, a radiation survey was conducted to identify radioactive contamination between each lift of soil removed from the mound. The radiation survey and screening process at the mound continued until clean soil was reached at the bottom of the excavation.

Radiological survey work included measurements of gamma radiation using an Eberline ESP-2 ratemeter with sodium-iodide scintillation detectors; a Canberra Multichannel Analyzer (MCA), used with a 3-in. by 3-in. sodium-iodide scintillation detector; and a GE Reuter-Stokes pressurized ion chamber. The ESP-2 ratemeter was used for walkover surveys. The ESP-2 and the MCA were used during excavation of the disposal mound to determine the presence of radioactive contamination.

The two areas at the Project Chariot Site requiring remedial activities were the disposal mound and one test-plot area. On August 7, 1993, the disposal mound was excavated in one-foot increments, or lifts. Seven lifts were required to complete excavation of the disposal mound. Two spots under Lift 7 were removed manually with shovels. Approximately 115 cubic meters (m^3) (150 cubic yards [yd^3]) of contaminated soil (including water in the soil matrix) were removed from the mound and placed in B-25 containers.

Excavation of the test-plot area containing three individual test plots began on August 17, 1993. The test-plot area was located using photographic records and historical information and was confirmed by the radiological survey. The photographs showed Test Plots 105, 106, and 107 to be close together and near willows by Snowbank Creek. The size of the test-plot area was approximately 6 m by 5 m by 0.3 m (19.5 ft by 16 ft by 1 ft). The contaminated soil was removed from this area manually with shovels. Approximately 9 m^3 (12 yd^3) of soil (including vegetation and water in the soil matrix) were removed and placed in B-25 containers.

A fourth test plot (Test Plot 112) was located on Tributary 1 of Snowbank Creek using photographic records, observed ground disturbance, and the original sign identifying the plot. No residual soil contamination was found, so Test Plot 112 was not excavated.

Final closure samples of soil from the mound and test-plot area were analyzed at both the on-site and off-site laboratories to ensure that concentrations of Cs-137 were below the clean-up level.

Contaminated soil from the disposal mound and the test-plot area was excavated, packaged in B-25 containers, and then transported to the Radioactive Waste Management Site at the Nevada Test Site (NTS) for disposal. In order to dispose of low-level radioactive waste at the NTS, specific waste acceptance criteria must be met. Waste acceptance criteria address issues such as packaging, shipping, hazardous and radioactive constituents, external package radiation levels, and the control of free liquids. Procedures were put in place, and appropriate personnel performed surveillances and inspections to ensure that all requirements were met.

In addition to characterization and remedial activities, site restoration was completed after final closure notice was received from ADEC. Disturbed areas were reseeded and fertilized with direction from the Alaska Department of Natural Resources. Excelsior™ blankets were placed over the revegetated areas for protection. A trip to inspect the reseeded areas took place in early August 1994.

All remediation personnel had left the site by September 3, 1993. The camp was dismantled and removed by the camp operator. The barge with its Project Chariot cargo left Cape Thompson, Alaska, on September 5, 1993. The waste containers arrived intact at the NTS in October 1993.

Conclusions

All activities at the Project Chariot Site were performed according to procedures and guidelines defined in the Quality Assurance Project Plan (QAPjP).[2] Appropriate personnel were appointed to conduct surveillances for compliance with the QAPjP requirements.

The primary contaminants of concern at the Project Chariot Site were Cs-137 and Sedan fallout radioisotopes, which were used in the 1962 tracer-study experiments. Therefore, the site assessment and remediation action focused on removing radioactive contamination from the former test-plot area and disposal mound. Based on the analytical data provided for surface water samples, only one sample taken from the ephemeral pond, was above the state of Alaska Drinking Water Criteria for either gross alpha or gross beta activity. The remedial activity at the disposal mound removed the potential source of the contamination. In addition, the ephemeral pond was regraded and revegetated to eliminate potential future ponding of water in the same area.

Analytical results of sediment samples show that the radioisotopes and the detected activity levels were at background level. The activity levels were consistent with the geologic makeup of the Ogotoruk Valley.

Analysis of animal samples showed that radioisotopes detected had their origin in natural sources or worldwide fallout, deposited during and following the 1961 to 1963 period of atmospheric nuclear weapons testing.

Compared to biota samples collected at other locations in Ogotoruk and Kisimilok Valleys, no unusual amounts of Sr-90; plutonium-238, 239, and 240; and americium-241 were detected in comprehensive sampling of animals and plants from the disposal mound. Strontium-90 and Cs-137 concentrations in food items of local importance were well within acceptable limits.

Following the 1962 USGS study, the study team measured the radiation levels to verify that they were below 0.1 mR/hr (100 microroentgens per hour [μR/hr]), the "allowable level" at the time. In 1993, utilizing more sophisticated equipment, the actual radiation level measured was 18 μR/hr.

No radioactive contamination was found at a depth greater than 6 in. at the test-plot area, with the highest concentrations usually near the surface. No contamination was found by a surface scan outside the excavated area. The test-plot area was excavated to below the established clean-up criteria, with the highest closure sample containing 2.55 pCi/g of Cs-137.

The exposure rate and risk at the test-plot area from surface contamination would not have been significant over the 30 years from the Cs-137 test plots. The exposure rate at the Cs-137 test-plot area immediately after the 1962 studies was no more than 100 μR/hr at the center. This exposure rate would have been at background levels 30 ft away from the center. Assuming a worst-case scenario in 1962, a dose of 1 millirem (mrem), about 1 percent of the annual dose due to background radiation, would have required standing in the exact center of the test-plot area for 10 hours. At the time of the 1993 excavation, a 1-mrem dose would have required standing in the exact center of the highest exposure rate for 55 hours.

The expected dose from the test-plot area to a single individual is less than 1 mrem over the last 30 years and surely less than 10 mrem. In comparison, an individual would receive approximately 8 mrem from a chest X-ray.[3] The past risk to any individual from the test-plot contamination is well within the range of national and international guidance. The yearly dose allowable to the public in the United States is 100 mrem/yr.[4] Since the test-plot contamination was removed to below the established clean-up criteria, no future exposure or risk is expected.

The disposal mound received 99 percent of the residual material from the USGS tracer tests, as estimated from the factor of 1,000 reduction in the exposure rate at the test plots. There was no measurable exposure rate above background on or near the disposal mound nor was any Cs-137 indicated by measurement with the MCA system. Soil, vegetation, and small mammal samples taken on the surface of the mound indicated no Cs-137 contamination.

The Cs-137 contamination at the disposal mound was found to be approximately 4 ft below the surface. The Cs-137 was not uniformly mixed but ranged in concentration up to 6,000 pCi/g. The disposal-mound area was excavated to below the established clean-up criteria, with the highest closure sample containing 3.16 pCi/g of Cs-137.

The lack of measurable exposure rate above background and the absence of Cs-137 contamination in the surface soil and in the vegetation and small mammal samples indicates that it is highly unlikely that any individual received above-background exposure or dose from the material in the disposal mound. The past risk from the disposal mound is essentially zero because the 4-ft soil cover acted as a shield. Any future risk from the disposal-mound area is expected to be zero.

During remedial activities at the Project Chariot Site, materials that showed Cs-137 contamination above the established clean-up level were packaged in B-25 containers and shipped to the NTS for storage and disposal.

ADEC authorized clean closure of the disposal mound and former test-plot area on August 23 and 26, 1993, respectively.

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[1] U.S. Census, 1990

[2] U.S. Department of Energy, 1993, *Project Chariot: 1962 Tracer Study Site Assessment and Remedial Action Plan,* Las Vegas, Nevada.

[3] National Council of Radiation Protection and Measurements, 1993, *Exposure of the U.S. Population from Diagnostic Medical Radiation,* NCRP Report No. 100, Bethesda, Maryland.

[4] National Council on Radiation Protection and Measurement, *Limitation of Exposure to Ionizing Radiation,* NCRP Report No. 116, Bethesda, Maryland.

Chapter

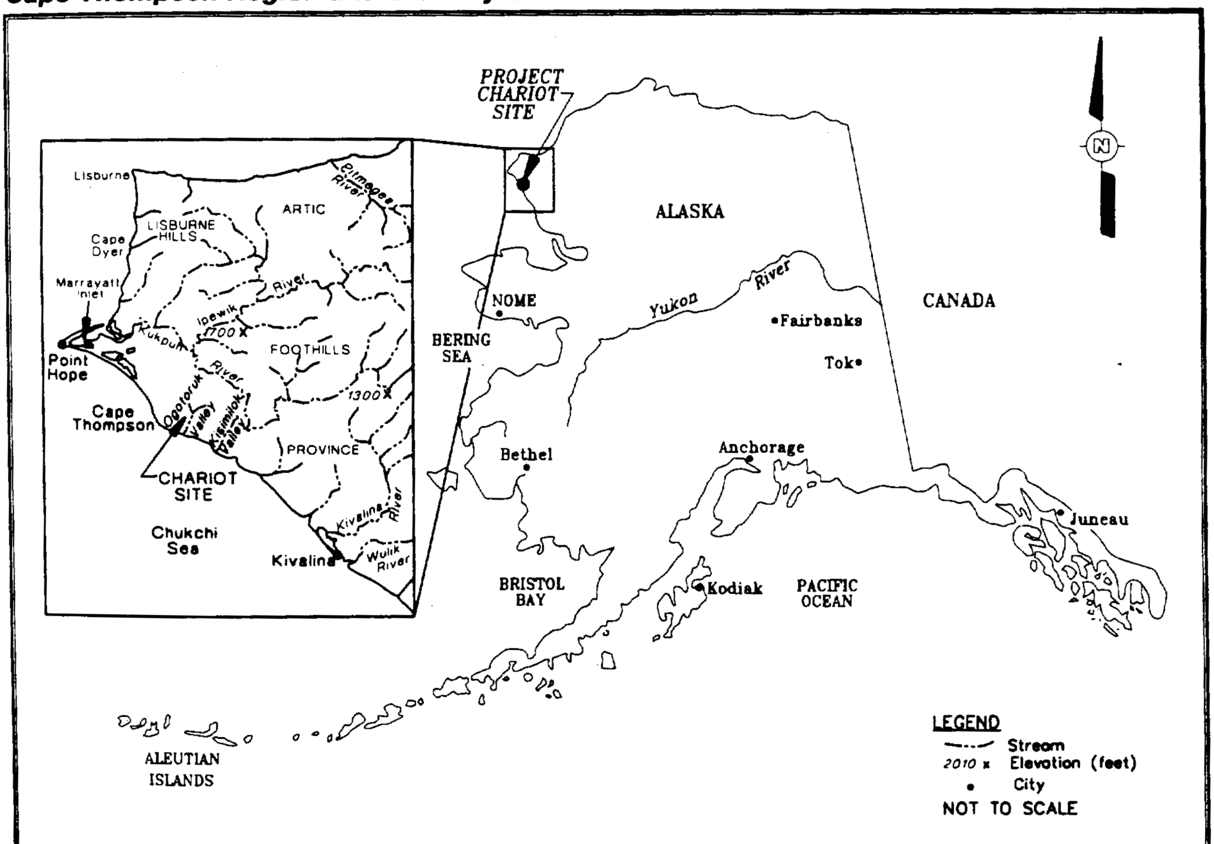
1.0 Background

1.1 Introduction

The Project Chariot Site is a remote and isolated area located in Ogotoruk Valley along the Ogotoruk Creek in the Cape Thompson region of northwest Alaska. This region is approximately 200 miles (mi) north of the Arctic Circle and is bounded on the southwest by the Chukchi Sea (Figure 1-1).

The U.S. Atomic Energy Commission (AEC) selected the Project Chariot Site for experimental harbor excavation studies in 1958. In 1962, as part of those studies, the U.S. Geological Survey (USGS) conducted a radioactive tracer experiment. Soil contaminated with radioisotopes as a result of the tracer experiments was removed from the test plots and mixed with native soil. This soil was then covered with 1.2 meters (m) (4 feet [ft]) of clean top soil,

Figure 1-1
Cape Thompson Region and the Project Chariot Site



forming a mound (Figure 1-2). This disposal mound and a former test-plot area became the focus of the remedial action reported herein.

In 1992 and 1993, the U.S. Department of Energy (DOE), through its Nevada Operations Office and its contractor IT Corporation (IT), performed site inspections, site reconnaissance, site assessment, and remedial action of the Project Chariot Site. In addition, three control sites in the neighboring Kisimilok Valley (approximately 10 mi southeast of Ogotoruk Valley) were sampled to establish background levels for natural and man-made radioactive constituents. This report details the operations and findings of the site assessment and remedial activities conducted at the Project Chariot Site in the summer of 1993.

1.2 History and Use of the Site

Table 1-1 outlines the history of the Project Chariot Site. AEC selected the site for Project Chariot in 1958 in order to plan and study an experimental harbor

Figure 1-2
Project Chariot Site Location

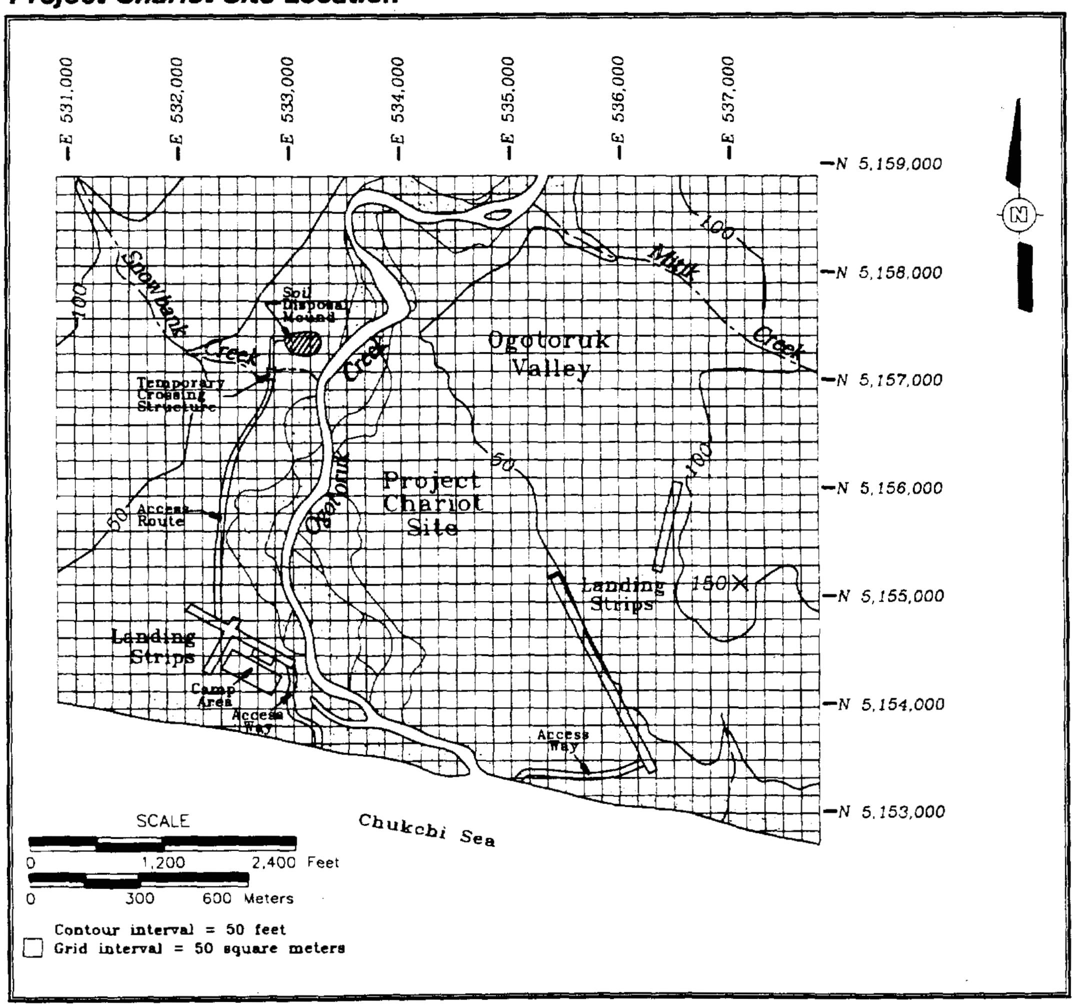


Table 1-1
History of the Project Chariot Site

Date	Activity
1958	Atomic Energy Commission (AEC) selects Project Chariot Site for experimental harbor excavation studies
1959 - 1962	40 separate environmental studies conducted by the AEC, university researchers, and Canadian Government
1962	U.S. Geological Survey conducts five-day radioactive tracer experiment
1962	Project Chariot and associated environmental studies suspended
1963	Site transferred to Naval Arctic Research Laboratory
1970	Site returned to U.S. Bureau of Land Management
1980	Site transferred to Fish and Wildlife Service (FWS) (with exception of two individual Native allotments)
1988	U.S. Department of Defense (DoD) approves site for Defense Environmental Restoration Program for Formerly Used Defense Sites
1990 through 1992	Remedial Action contract awarded for cleanup of unsafe debris and buildings, petroleum containers, and contaminated soils; DoD, Corps of Engineers completed remedial action
1992 (Sept. 10-14)	Alaska Department of Environmental Conservation (ADEC) and the U.S. Army Corps of Engineers conduct site investigation of disposal mound
1992	ADEC puts Project Chariot Site on State Hazardous Waste Site List
1992 (Early October)	Public meeting held in Point Hope to discuss Project Chariot
1992 (Late October)	DOE, ADEC, and Point Hope and Barrow residents perform site inspection; Alaska submits request to the President to clean up site and the DOE Secretary decides to accept responsibility
1992 (December)	Public meeting held in Barrow to discuss remediation of Project Chariot Site and conduct radiological training
1993 (February)	Public meetings held in Point Hope, Kivalina, and Kotzebue to discuss Remediation of Project Chariot Site
1993 (February)	Project Chariot Remedial Action Plan Draft reviewed in Washington
1993 (May)	DOE, ADEC meet with Science Advisory Committee hired by North Slope Borough to review plan
1993 (June)	DOE, ADEC, FWS, and the Native allotment holder representative perform site reconnaissance
1993 (June)	DOE performs photo survey of Project Chariot Site
1993 (July 28)	Findings of No Significant Impact signed; final permits approved as part of Environmental Assessment process
1993 (July)	DOE performs aerial gamma survey of Ogotoruk Valley and part of Kisimilok Valley
1993 (July-Sept.)	DOE performs site assessment and remedial action of Project Chariot Site
1993 (August)	ADEC approves clean closure of soil disposal mound and test-plot area

excavation in Alaska using nuclear explosives. The experimental harbor excavation was part of the AEC Plowshare Program designed to test the use of nuclear explosives for peaceful purposes. The primary purpose of Project Chariot was to investigate technical issues and to develop nuclear-excavation technology. At the same time, other nuclear excavation studies were being conducted at various sites, including the Nevada Test Site (NTS), where a cratering experiment called Sedan was conducted (Figure 1-3).

The AEC, with the assistance of other agencies, university researchers, and the Canadian Government, conducted pretest environmental studies in the Cape Thompson area to assess the potential environmental effects of the proposed project and to ensure that it could be conducted safely. More than 40 separate environmental investigations were conducted between 1959 and 1962.[5]

By late 1962, much of the desired nuclear-excavation engineering data originally planned to be obtained from Project Chariot activities had become available or would be available from experiments at other sites. In addition, there was increasing public concern from local communities to discontinue the experiments. Therefore, the AEC decided in 1962 to suspend Project Chariot and to end the associated environmental studies. No nuclear devices were taken to the Project Chariot Site.

Figure 1-3
Sedan Crater, Nevada Test Site

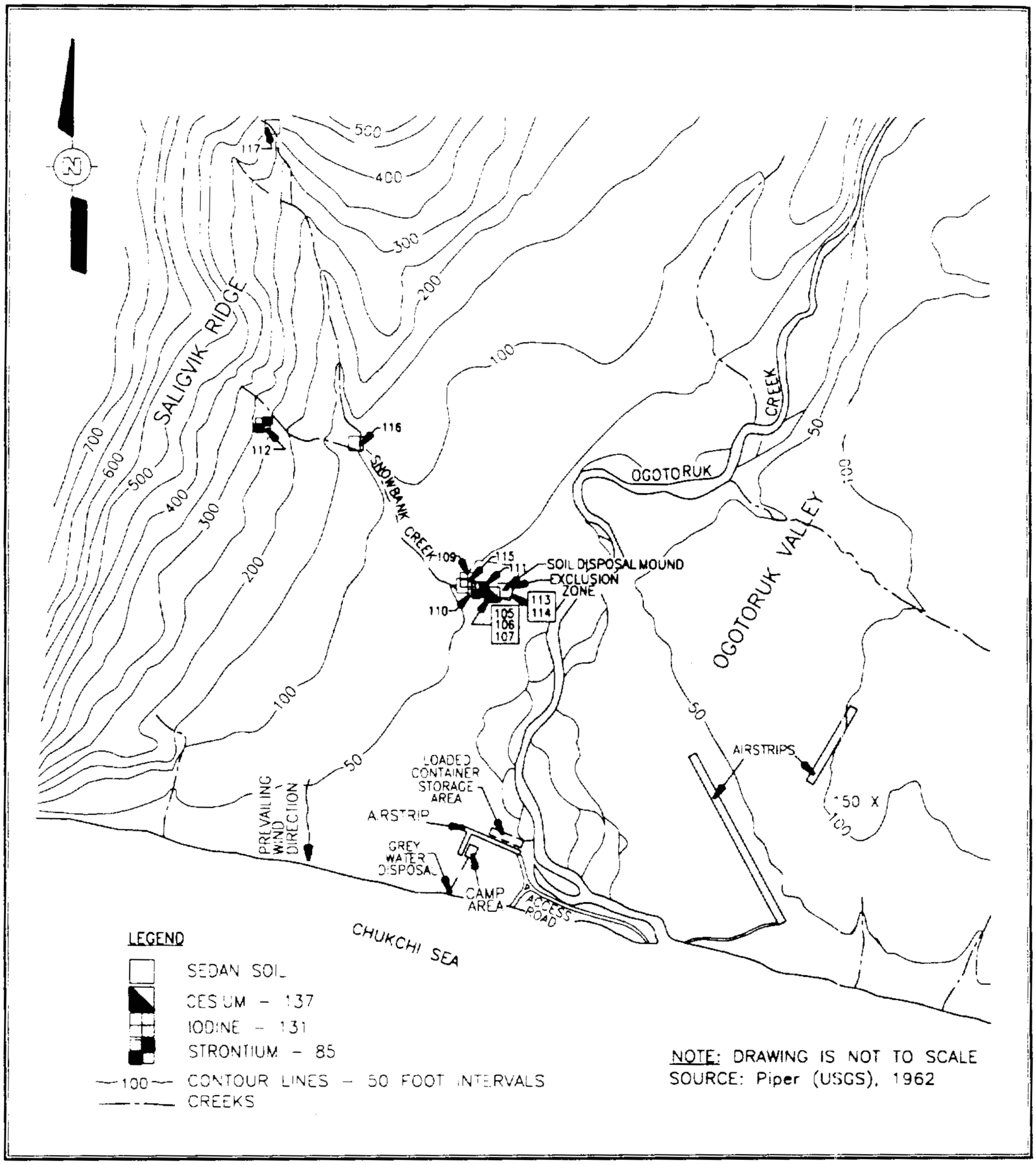
Just before Project Chariot Site activities were suspended, the USGS, under a license granted by the AEC, conducted a radioactive tracer experiment on the soils at the Project Chariot Site from August 20 through 25, 1962. This experiment was to provide information about the possible movement of radioisotopes through native soil and water. Small amounts of radioactive tracer material and soil containing radioactive fallout from the Sedan cratering experiment were used for tests. Ten plots were specifically designed to represent a variety of microdrainage patterns and were located along Snowbank Creek, approximately 1.2 km (0.75 miles) from the base camp (Figure 1-4). The test-plot areas ranged in size from 0.6 by 0.6 m (2 by 2 ft) to 1.5 by 2 m (5 by 7 ft). The radioisotopes used in the tracer studies were 6 millicuries (mCi) of cesium-137 (Cs-137), 5 mCi of iodine-131 (I-131), 5 mCi of strontium-85 (Sr-85), and 10 mCi of various radioisotopes contained in Project Sedan soil.[6, 7]

The USGS plot experiments for the overland-transport tracer study involved four basic steps. Step 1 was to enclose each test plot with boards wrapped in polyethylene sheeting. The boards were then set edgewise and inset into the ground surface to cut off both surface flow and shallow seepage through the soil. Figure 1-5 shows a 1962 test plot. In Step 2, a single tracer was distributed uniformly on the surface of each plot. Step 3 simulated rainfall by using water drawn from Snowbank Creek supplied to the plots through a hose and spray nozzle. Enough water was applied to saturate the surface soil of the plots and to generate temporary runoff (Figure 1-6). Flow measurements indicated that the intensity of the simulated rainfall was substantially greater than would be expected to occur naturally. The final step in the experiment was to collect and analyze samples of the runoff to measure radioactivity in the water.

In addition to the overland-transport tracer study, underground transport of radioisotopes was evaluated by a simple 18-hour percolation test on a hillside above Snowbank Creek. A small pit was dug through the surface layer of humus-rich soil into underlying silt and clay (Figure 1-7). The pit was filled with a slurry of Sedan soil mixed with creek water. The pit was refilled three times with additional water. This water percolated through the soil and traveled downslope. The resultant percolate was sampled downslope from the pit to determine the extent of radioisotopes absorbed or exchanged from percolating or infiltrating water.

A sediment-transport experiment was conducted at a small tributary of Snowbank Creek. A single injection slug of Sedan soil was introduced into the tributary to study the movement of contaminants through the water. During the experiment, the stream bottom at the point of introduction was vigorously agitated to disperse any of the slurry that may have been absorbed or settled on the stream bottom. Samples were collected and analyzed for contaminant concentrations.

Figure 1-4
Radioisotope Test-Plot Locations



Following completion of each test-plot experiment and the percolation test, the tracer-contaminated soil was removed and transported in half-filled 55-gallon (gal) drums to a designated area. The excavated soil was poured from the drums and mixed with the native soils present (in situ site soils). The boards and polyethylene sheeting were disposed with the soils. The soils, boards, and polyethylene sheeting were then covered with 1.2 m (4 ft) of clean soil, forming a small mound.

On April 28, 1963, the Project Chariot Site was transferred to the Naval Arctic Research Laboratory (NARL). The buildings, airstrip, and structural

Figure 1-5
Project Chariot 1962 Test Plot

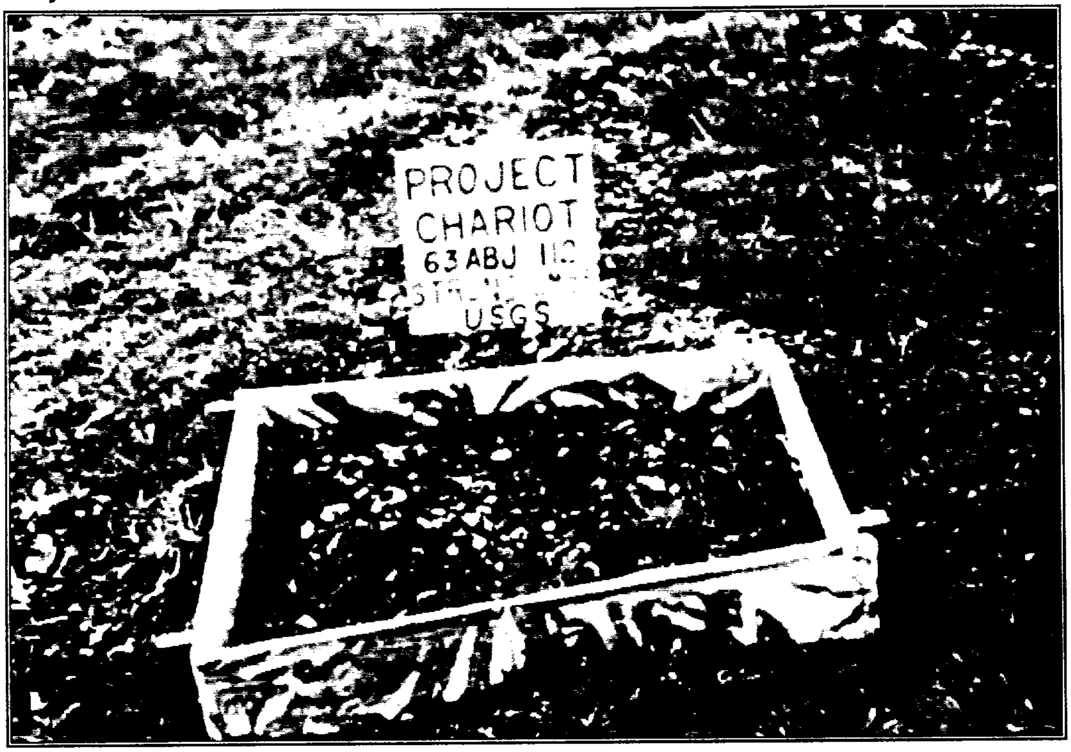


Figure 1-6
Water Applied to Test Plot to Generate Runoff

Figure 1-7
Eighteen-Hour Percolation Test

improvements placed at the site were used by the U.S. Navy as a logistical support base. The NARL ceased operations at the site in 1970, and the site was returned to the U.S. Bureau of Land Management (BLM). In 1980, the site was transferred to the Fish and Wildlife Service (FWS).

To comply with new regulations regarding the review of formerly used defense sites, the U.S. Army Corps of Engineers performed the first field investigation at the site in 1988. Areas of potential environmental concern were identified, including debris, structures, and domestic waste materials.

Based on the U.S. Army Corps of Engineers' findings, the site was identified for possible inclusion in the Defense Environmental Restoration Program for Formerly Used Defense Sites (DERP-FUDS). The Department of Defense (DoD) approved this site for inclusion in the DERP-FUDS program on August 8, 1988. A remedial action contract was awarded in fiscal year (FY) 1990 for the cleanup of unsafe debris and buildings, petroleum containers, and contaminated soils at the site. The remedial action was performed and completed during the summer of 1992, but did not include the contaminated soil mound.

In 1992, a researcher preparing a paper on Project Chariot at the University of Alaska at Fairbanks obtained early 1960s correspondence between AEC and USGS. The letters focused on the use of radioactive tracers during the investigations at the Project Chariot Site. The letters also addressed the radioisotopes remaining at the site at the end of the experiment. The researcher informed the U.S. Army Corps of Engineers and the media of the presence of radioisotopes at the site. The letters were published by the media, and local residents became concerned that the radioisotopes posed a hazard to human health and the environment.

In response to public concern, the Alaska Department of Environmental Conservation (ADEC) and the U.S. Army Corps of Engineers conducted a site investigation from September 10 through 14, 1992. No visible signs of stressed vegetation were observed. A surface radioactivity survey indicated no readings above background levels. This survey did, however, show a slight increase in radiation level when the detector was placed at the bottom of a three-foot hole drilled into the soil disposal mound. The slightly elevated level was suspected to be the result of natural radioactivity. However, ADEC subsequently placed the Project Chariot Site on the State Hazardous Waste Site List.

A DOE review of a video tape of the site investigation concluded that the measurement results should only be used for qualitative information.

Both I-131 and Sr-85 have half-lives of less than 70 days. Therefore, both of these radioisotopes would have essentially decayed away prior to the remedial activity in 1993, leaving only the longer half-life Cs-137 (30 years) and the components of the Sedan soil radioisotopes with half-lives of 3 years or more. It was calculated that approximately 3 mCi of Cs-137 remained in the disposal mound in 1993, with an average concentration of 30 picocuries per gram (pCi/g). Other radioisotopes would have decayed to an undetectable level.

Based on the risk assessment reviews performed by Oak Ridge Institute for Science and Education and the Alaska Department of Health and Social Services, neither the 1993 level of radioactivity nor the activity present in 1962 posed a risk to human health or the environment. However, public concern regarding subsistence hunting in the area and political pressure prompted DOE to reexamine the Project Chariot Site. DOE's position was that the soil disposal mound has never presented, nor would it ever present, a hazard to the public or the environment.

However, local residents still expressed concern that the radioisotopes used in the 1962 studies may have migrated and contaminated the food supply of animals used in subsistence hunting by local residents. Upon evaluation of potential costs for further investigations at the site, complicated logistic issues, sensitivity to Native concerns, and the potential that removal of the disposal mound would be required in any case, DOE (in consultation with ADEC) determined that a site assessment and mound removal was the best and most cost-effective approach. The Secretary of the U.S. Department of Energy accepted responsibility for removal of the contaminated soil from the Project Chariot Site since the contaminated soil had been generated by DOE's predecessor, AEC. Therefore, plans for remedial activities at the Project Chariot Site were initiated.

The public was involved throughout the remediation operation. From 1992 through 1993, public meetings were held in the northern Alaskan villages of Point Hope, Kivalina, Kotzebue, and Barrow to give area residents an opportunity to participate in activities associated with the Project Chariot Site. On October 21, 1992, representatives from DOE, ADEC, and Point Hope and Barrow residents performed a site inspection. The objectives of the inspection were to assess the soil disposal mound, to perform a radiation survey of the mound surface, and to inspect and assess logistically important facilities (e.g., airfields) and buildings at the site for potential use.

The draft Project Chariot Remedial Action Plan was released for review in February 1993. Review of the document was held in Washington to address any concerns noted by the reviewers. In May 1993, DOE and ADEC met with members of the Science Advisory Committee. The North Slope Borough residents' Science Advisory Committee provided expertise and comments on the clean-up activities at the Project Chariot Site.

Representatives from DOE, ADEC, FWS, and the affected Native allotment holder performed a site reconnaissance on June 22, 1993. The additional site reconnaissance achieved the following objectives:

- assessment of site conditions after snowmelt
- measurement of the mound and runway
- inspection of the terrain and disturbed areas
- evaluation of the access from the camp to the mound
- attempt to locate the former tracer test plots with the help of one of the original USGS researchers who conducted the tracer-study experiments
- assessment of conditions for biota sampling
- documentation of the condition of the site prior to site assessment and remedial action.

Before starting the site assessment and remedial action of the Project Chariot Site, the following activities were completed:

- preparation of an Environmental Assessment (EA) by the FWS for the proposed radioactive soil removal from the Project Chariot Site at Cape Thompson to satisfy requirements of the National Environmental Policy Act
- issuance of a Finding of No Significant Impact (FONSI) based on independent review of the EA, public comments, and DOE responses to public comments
- issuance of federal, state, and local permits
- completion of aerial photography of the Project Chariot Site and surrounding area on June 19, 1993 (Attachment A)
- completion of an aerial gamma-radiation survey over the site and adjacent valley during the period of July 13 through July 24, 1993 (Attachment A).

Between July 29 and September 3, 1993, the site assessment and remedial action of the Project Chariot Site were performed by DOE. Soils containing Cs-137 at levels above the established clean-up level were removed and transported to the DOE low-level waste disposal facility at the NTS. The soil disposal mound and former test-plot area (the site of the Cs-137 studies) received on-site approval for final clean closure by ADEC on August 23 and August 26, 1993, respectively. More detailed discussions of the site investigations and remedial activities are presented in later sections.

1.3 Environmental Conditions

The environmental conditions at the Project Chariot Site were taken into consideration when determining the appropriate assessment and remedial activities to be performed. The climate, topography, geology, and hydrology of the site were factors that influenced the type of remedial action taken.

Climate

Extreme weather conditions occur at the Project Chariot Site and limit access to approximately two months per year in the summer. Most noticeable in northwestern Alaska are the high-velocity surface winds. The wind speeds for Ogotoruk Valley in July and August range from 12 and 15 knots (14 and 17 miles per hour [mph]), respectively.[5] Much higher winds were observed at times during the remedial action period. The most frequent wind direction is from the north-northeast.

The monthly precipitation in Ogotoruk Valley for the months of July and August ranges from 2.87 to 6.12 centimeters (cm) (1.13 to 2.41 inches [in.]). Daily high temperatures range from 10 to 13 degrees Celsius (°C) (50 to 56 degrees Fahrenheit [°F]) in July and August. Daily low temperatures range from 2 to 4°C (37 to 40°F) in July and August.[5] The July-August monthly average percentage of cloud cover from sunrise to sunset is from 58 to 91 percent to 68 to 82 percent, respectively. Sunlight ranges from approximately 24 hours in July to 22 hours in August.

Topography

The Ogotoruk Creek is located in the southwest-trending Ogotoruk Valley. The valley floor rises from a few feet above mean sea level (amsl) at the coast to about 84 m (275 ft) amsl at a poorly defined divide that separates Ogotoruk Valley from Saligvik Valley. Saligvik Ridge is the western boundary of Ogotoruk Valley. The elevation of the ridge crest ranges from a low of about 129.5 m (425 ft) to highs of 270 m (886 ft) at Crowbill Point on the coast and 258 m (847 ft) at a point south of the Kukpuk River.[5] Pumaknak Pond, Ikaknak Pond, and other ponds on the divide drain both south into Ogotoruk Creek and north into tributaries of the Kukpuk River (Figure 1-8). The west side of Ogotoruk Valley is steeper than the east.

Geology

Frozen mudstone of the Ogotoruk Formation underlies the Project Chariot Site. The mudstone is covered by Quaternary Age unconsolidated deposits that consist of ancient beach deposits, colluvium, flood-plain deposits, alluvial-fan deposits, swamp deposits, silt deposits, and terrace deposits.[5] Although the alluvium is locally as much as 9 m (30 ft) thick, it generally is only a thin layer ranging from 1.5 to 3.7 m (5 to 12 ft) thick.

The Project Chariot Site is underlain by permafrost. Ice wedges and lenses are extensive in the unconsolidated deposits. A peat layer, which covers most of the valley, is an excellent insulator and has maintained the permafrost at shallow levels.

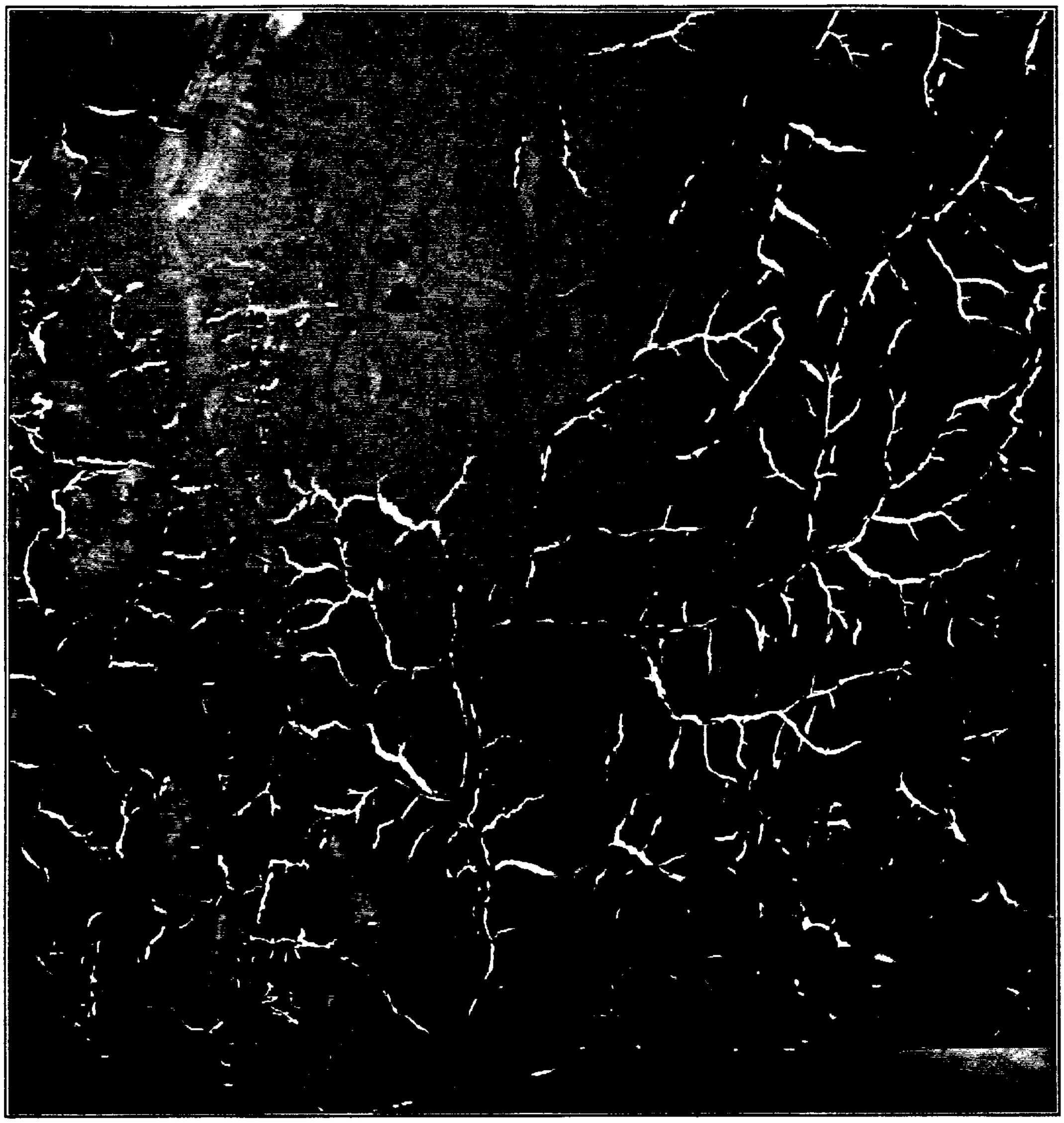
Hydrology

Groundwater in areas surrounding the Project Chariot Site occurs in two distinct environments: shallow aquifers associated with stream floodplains and deep aquifers associated with major fault systems in the limestone and dolomitic rocks. Local surface water drains into the Ogotoruk Creek, which flows into the Chukchi Sea.

Shallow Aquifer

Previous geologic investigations indicate that, except for the stream floodplains and terraces, only a thin layer of weathered material overlies the bedrock. Permanently frozen ground prevents water-bearing zones from occurring in this thin mantle. Relatively thick beach deposits from a higher stand of the sea are also permanently frozen, except where streams dissect them and occasionally thaw adjacent portions. The shallow aquifers are, therefore, only present adjacent to the major streams.

Figure 1-8
Aerial Photo of Ogotoruk Valley Showing Pumaknak, Ikaknak, and Other Ponds



The lower reach of Ogotoruk Creek flows in a moderately broad valley that has a bedrock floor covered by a thin layer of unconsolidated material. The flood-plain aquifer is a water table aquifer, and recharge is directly related to streamflow and precipitation. In spring, meltwater usually floods the plain and recharges the porous deposits. Rainfall also contributes to recharge once the seasonal frost has thawed. If it is not already saturated, the coarse aquifer readily absorbs the rainfall.

Ogotoruk Creek usually maintains a thin year-round aquifer, provided that (1) late autumn rains provide a high creek stage, which creates full bank storage of groundwater; (2) severe freezing does not set in early; and (3) a thick snow cover develops over the aquifer and stream to slow the penetration of frost.

Deep Aquifer

Deep aquifers may occur within consolidated rocks either below or within the zone of permafrost. Beneath Ogotoruk Valley, the bedrock is primarily mudstone. Limestone, chert, and sandstone occur principally west of Ogotoruk Creek.

Aquifers may be present in the unfrozen permeable portions of the limestone and sandstone, particularly along fracture and fault systems. Arctic bedrock aquifers are believed to be recharged only where streams flow across the strike of the beds, such as along the east-trending course of Kukpuk River north of the Project Chariot Site. Recharge directly by precipitation appears to occur only locally because of the permanently frozen ground.

Surface Water

Ogotoruk Creek flows into the Chukchi Sea about 10 kilometers (km) (6 mi) southeast of Cape Thompson and about 51 km (32 mi) southeast of Point Hope. The creek flows westward for the first 10 km (6 mi) and southward for the remaining 6 km (4 mi). The drainage area of the upper reach, 1.9 km (1.2 mi) upstream of the mouth of Ogotoruk Creek, is approximately 98 square kilometers (km^2) (38 square miles [mi^2]). The drainage area of the lower reach of the creek is a broad valley, but the remainder is a rolling to hilly area.

With its fairly well-developed tributaries, the fan-shaped basin provides an efficient drainage system. The streambed consists of highly permeable fine gravel, and the channel is abraded throughout most of its length. The floodplain is about 300 m (1,000 ft) wide and is underlain by gravel, sandstone, and mudstone. Except for the floodplain, most of the drainage is covered by a protective mat of vegetation, which is underlain by permafrost.

Chapter 2.0

Site Assessment and Remedial Action Scope of Work

The scope of the site assessment and remedial action included:

- aerial photographic and radiological surveys
- soil sampling
- sampling and analysis of surface water and sediment
- surface radiological surveys
- biota sampling
- pre-excavation sampling and analysis
- soil excavation and packaging
- post-excavation sampling and analysis, including site restoration
- waste transportation and disposal.

Prior to initiating the site assessment and remedial action, a remediation clean-up level of 0.4 becquerels per gram (Bq/g) (10 pCi/g) was established for Cs-137. The clean-up level was established based on the results of a risk analysis performed for the Project Chariot Site. The risk analysis is presented in the Project Chariot 1962 Tracer Study Site Assessment and Remedial Action Plan, Appendix C.[2] This level was well below normal clean-up guidelines, under the As Low as Reasonably Achievable doctrine, and was reachable and verifiable. Materials that showed Cs-137 contamination levels above the clean-up level were removed from the site.

All activities at the Project Chariot Site were conducted with full public disclosure, oversight, and review. Oversight of characterization and remediation activities was provided by:

- ADEC
- FWS
- Alaska Department of Natural Resources (ADNR)
- Point Hope Representatives
- Kivalina Representatives
- North Slope Borough Representatives (Foster-Wheeler Corporation)
- Native Village of Point Hope Representatives.

The overall site assessment process is shown in Figure 2-1, and the overall remedial-action process is shown in Figure 2-2. The site assessment and remedial action consisted of the following tasks, which are discussed in more detail in Sections 5.0 and 6.0 of this report. Some of these tasks were conducted simultaneously.

Task I: Aerial Photographic and Radiological Surveys
Aerial photographic and radiological surveys were conducted to establish naturally occurring levels of radioisotopes in soils of Ogotoruk and Kisimilok Valleys and to verify that no other radioactive materials were disposed at the Project Chariot Site during the 1950s and 1960s. The aerial radiological survey was conducted using a sodium-iodide (NaI) gamma-ray detection system mounted on a Messerschmitt-Bolkow-Blohm BO-105 helicopter (Figure 2-3).

Task II: Soil Sampling
Background soil samples were collected to (1) determine the naturally occurring background levels of radioactivity in soil to allow for a distinction to be made between noncontaminated overburden soil and soil impacted by Project Chariot activities and (2) assist the surface radiological survey in locating the tracer-study test plot locations. The soil samples were analyzed at the on-site

Figure 2-1
Site-Assessment Process

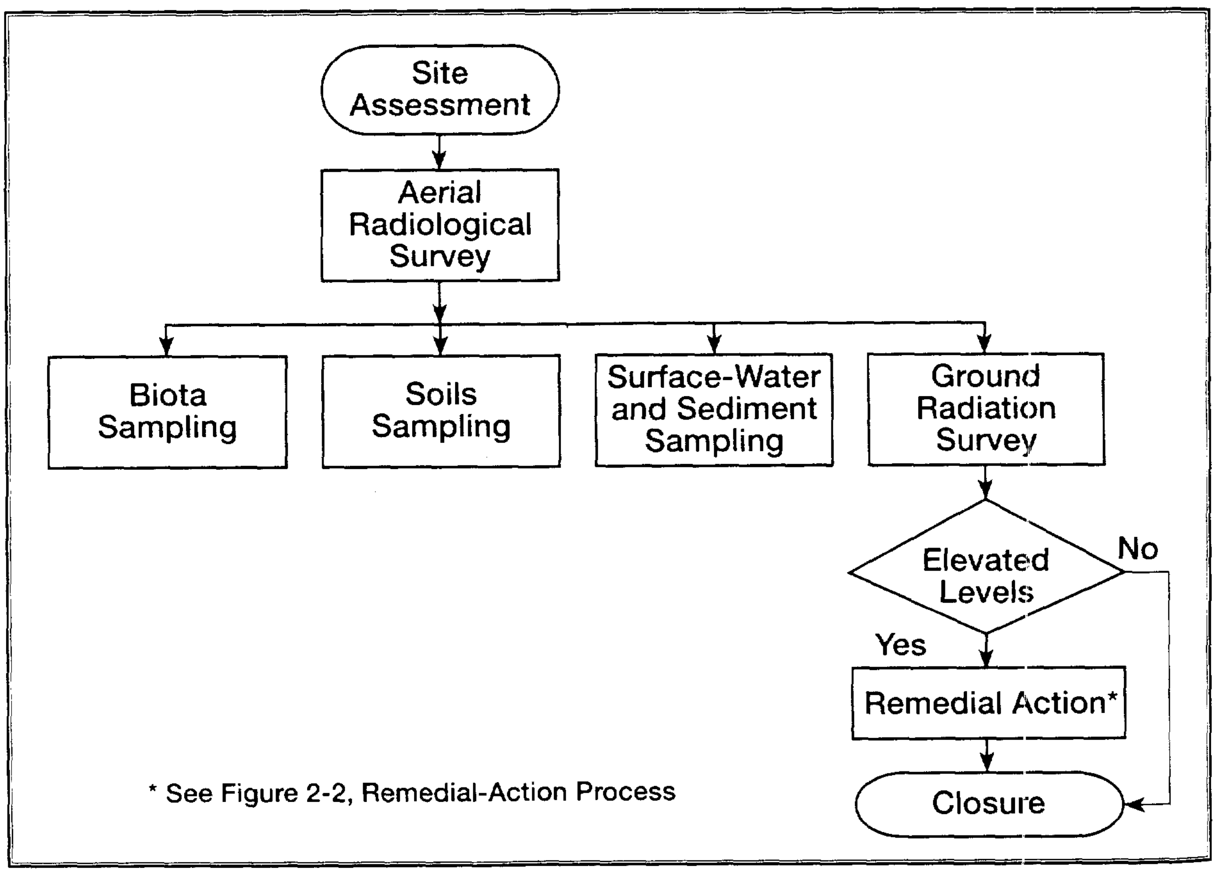


Figure 2-2
Remedial-Action Process for the Disposal Mound and Test-Plot Area

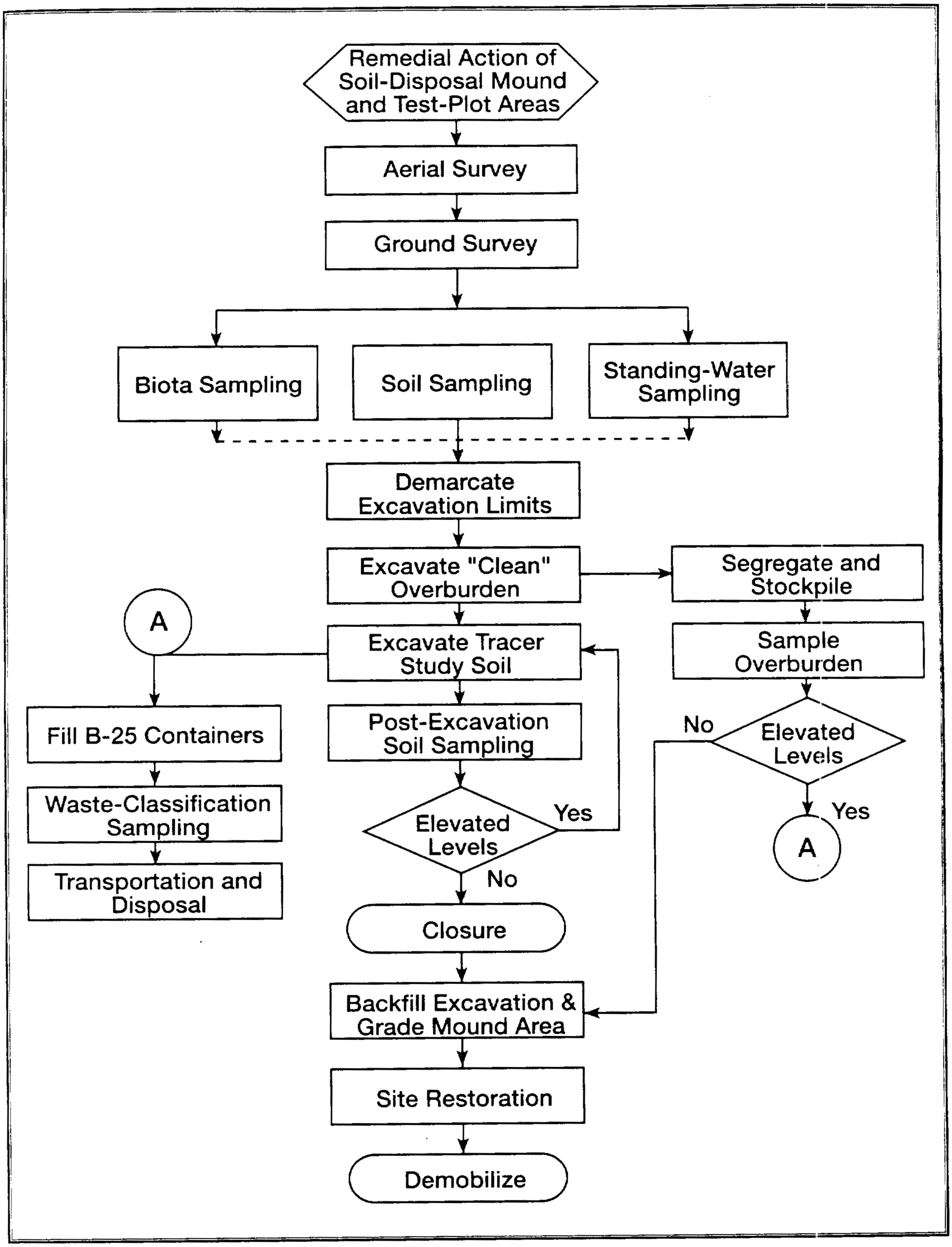


Figure 2-3
Helicopter Used for Aerial Radiological Survey

laboratory, and 10 percent of the samples were also analyzed at the off-site laboratory.

Task III: Surface Water and Sediment Sampling

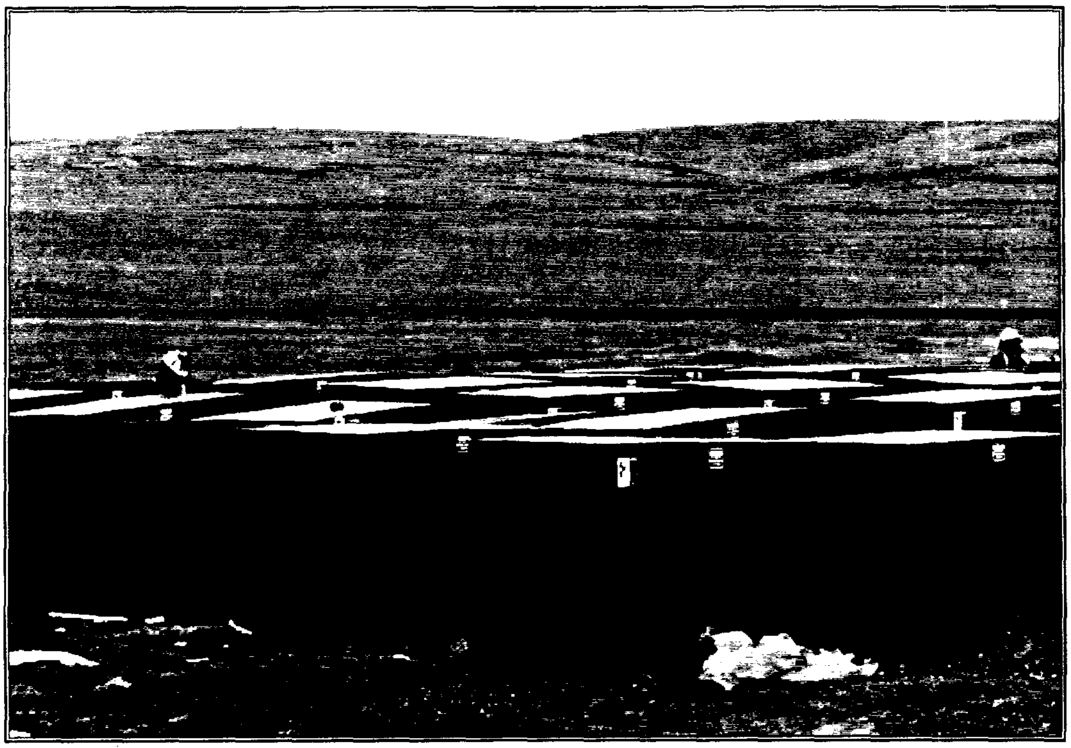
Surface water and sediment from Snowbank and Ogotoruk Creeks, as well as standing water adjacent to the disposal mound, were sampled and analyzed at an off-site laboratory. The results were used to assess any potential transport of radioisotopes from the tracer study.

Task IV: Radiological Survey

A ground-based radiological survey of the area was performed to locate the historic test plots, as well as to verify that the radioisotopes used in the tracer study had been removed. When the survey results indicated that radioisotopes remained at levels above the established clean-up level, the soil within the area was manually excavated and placed into U.S. Department of Transportation (DOT)-approved B-25 containers for disposal. A B-25 container is made of double-wall steel and is 6 ft long by 4 ft wide by 4.3 ft deep (Figure 2-4).

Additional surveys were performed to verify that radiation levels were consistent with background readings throughout the area near the mound.

Figure 2-4
B-25 Containers Used to Hold Contaminated Soil



Task V: Biota Sampling

Selected plants and animals of the Ogotoruk and Kisimilok Valleys were collected and analyzed for radioisotopes at the off-site laboratory (Figure 2-5). Samples of lichens, sedges, and shrub species were obtained from seventeen sampling locations in Ogotoruk Valley. Small animals were trapped in Ogotoruk and Kisimilok Valleys, and caribou samples were obtained from Point Hope and Kivalina residents. Additional sites on and near the disposal mound were sampled to evaluate potential migration of radioisotopes from the disposal mound into soils and vegetation near Snowbank Creek. Three control sites were established for sampling in Kisimilok Valley.

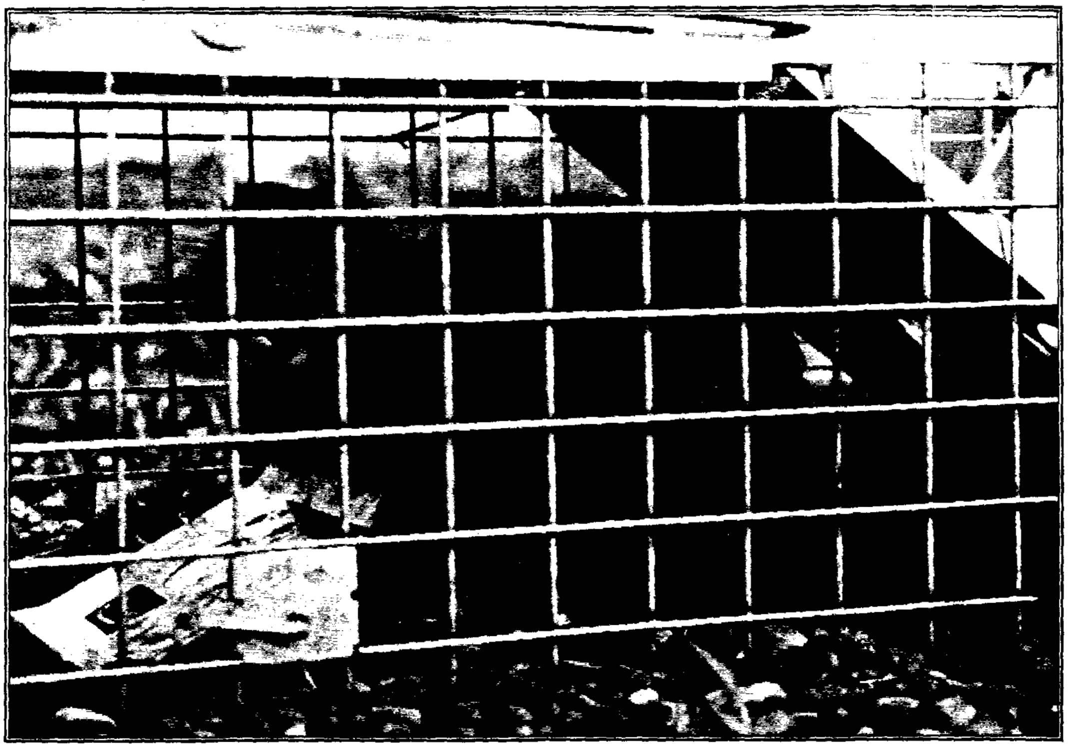
Task VI: Pre-Excavation Sampling and Analysis

The disposal mound was radiologically surveyed, and soil samples were collected for waste disposal classification prior to the excavation of each lift. Analytical results were used to determine both transportation and disposal requirements.

Task VII: Soil Excavation and Packaging

The disposal-mound soil was excavated and placed in DOT-approved B-25 containers. During the excavation activity, an on-site laboratory equipped with radiological instruments was used to analyze soil samples and to certify the decontamination of the B-25 containers. Based on measurements taken during

Figure 2-5
Ground Squirrel Collected for Radioisotope Analysis



the site assessment and remedial action, approximately 124 cubic meters (m^3) (162 cubic yards [yd^3]) of contaminated soil were removed and packaged from the disposal mound and former test-plot area.

Task VIII: Postexcavation Sampling and Analysis of the Excavated Area

After all contaminated soil was judged to be removed from the disposal mound, soil samples were collected from the base and sides of the excavation for laboratory analyses. Both on-site and off-site laboratory analyses were performed to confirm that the established clean-up levels had been achieved. When laboratory results indicated that additional soil removal was required, soil from the area of concern was removed, and the remaining soil was sampled until the clean-up level was achieved. After obtaining the clean-up level and receiving ADEC's approval of final clean closure, the excavated area was restored to natural grade using clean soil surrounding the excavation and the stockpiled clean soil cover from the former disposal mound. The area was reseeded in accordance with an ADNR-approved revegetation plan, fertilized, and covered with Excelsior™ blankets to protect emerging seedlings.

Task IX: Transportation and Disposal

The B-25 containers of soil were transported by barge and truck in accordance with DOT regulations for disposal at the Radioactive Waste Management Site (RWMS) at the NTS.

Chapter
3.0 Preremedial Activities

A great deal of planning and preparation was necessary before site assessment and remedial action could begin at the Project Chariot Site. The Project Chariot 1962 Tracer Study Site Assessment and Remedial Action Plan was prepared. Permit requirements were identified and the acquisition process completed. An EA for the site activities was prepared and a FONSI was issued by FWS and DOE. Subcontracts were issued for services and equipment needed during the field activities. Camp facilities were set up before remedial action field personnel arrived at the site, and EG&G Energy Measurements, Inc. (EG&G/EM), a maintenance and operations contractor to DOE, performed aerial photographic and radiological surveys of the area.

3.1 Preparation of the Site Assessment and Remedial Action Plan

Before field activities could begin, it was necessary to prepare the Project Chariot 1962 Tracer Study Site Assessment and Remedial Action Plan. The objectives of the Site Assessment and Remedial Action Plan were to:

- present a concise approach and scope of work for the remediation of the tracer-study soil disposal mound and test-plot areas
- provide procedures that were consistent with the regulatory requirements
- provide a "working" document based on logical decisions that enabled project personnel to perform in accordance with governing regulations and guidelines
- provide a strategy for post excavation soil sampling of the mound area to verify completeness of the excavation to the site's established clean-up level, which enabled an in-field approval of final closure by ADEC
- provide strategies for conducting background soil sampling, surface water and sediment sampling, biota sampling, and radiological surveys
- gather information and requirements from local stakeholders and incorporate them into the final action plan.

Appendices to the Site Assessment and Remedial Action Plan included the Sampling and Analysis Plan (SAP), Site-Specific Health and Safety Plan (SSHSP), and the Risk Analysis for the Project Chariot Site. The objectives of the SAP were to (1) define procedural and documentation requirements for all data collection activities that were to be conducted during the remedial action;

(2) define the quality assurance (QA) requirements for all data collection, tests, and analyses; and (3) serve as a working document for use by field sampling personnel at the site.

The objectives of the SSHSP were to (1) identify possible health and safety hazards that might be present during the remedial action; (2) present methods to prevent the risk to personnel; and (3) provide plans to deal with emergency situations, if necessary. In addition to the health and safety issues discussed in the SSHSP, special precautions were taken to prevent injury from bear attacks. Specified personnel attended bear-guard training classes. Bear guards were present throughout all field activities, and an electric fence that was activated nightly was installed around the perimeter of the camp. Personnel leaving the camp boundaries were required to log in and out of camp and to maintain periodic radio communication with the base camp while outside the camp perimeter.

3.2 Permits

A concerted effort was made to ensure that the proposed activities at the Project Chariot Site were performed in accordance with all applicable federal, state, and local regulations. Due to the singular nature of proposed project activities, there was no precedent for regulatory compliance. Therefore, the regulatory compliance effort began with informal discussions between DOE, U.S. Army Corps of Engineers, FWS, and Alaska Division of Governmental Coordination (ADGC) personnel in March 1993. These discussions served to inform and involve responsible regulatory agencies in the early stages of project development. Early and frequent interactions with regulatory agencies simplified the permitting and compliance effort by enabling the regulatory agencies to keep a very concerned and interested public well-informed, while ensuring that relevant information on which to base permitting and approval decisions was provided to the regulatory agencies.

Federal Requirements

Federal permitting requirements were mandated by both the U.S. Army Corps of Engineers and FWS. DOE and the U.S. Army Corps of Engineers agreed that proposed project activities were subject to the requirements of nationwide permit (NWP) #38, Cleanup of Hazardous and Toxic Wastes. The NWP #38 addresses concerns regarding the impact of any proposed activities on aquatic environments and applies to specific activities required to

> *...effect the containment, stabilization or removal of hazardous or toxic waste materials that are performed, ordered, or sponsored by a government agency...*[8]

Project activities also included the discharge of fill materials to waterways to construct stream crossings for equipment and personnel movement. This is a permitted activity regulated through Section 404 of the Clean Water Act (33 U.S.C. 1344). In addition to standard requirements, the permit application submitted to the U.S. Army Corps of Engineers included information pertinent to the discharge of fill materials to comply with Section 404 requirements.

The FWS identified three project activities requiring FWS Special Use Permits. The FWS required a separate letter report application for each activity. FWS was able to issue Special Use Permits for site inspection and biological sampling before the completion and approval of the project Work Plan because these activities did not "individually or cumulatively have a significant effect on the human environment." [8] Since site-assessment activities had the potential to have a significant impact on the human environment, the issuance of the Special Use permit for site assessment was linked to the completion, evaluation, and approval of the EA for Project Chariot.

FWS also determined that a Section 810 Subsistence Determination was required for proposed project activities. Alaska Maritime National Wildlife Refuge personnel took care of this requirement and did not request any action from DOE on the matter.

State Requirements

The ADGC was contacted regarding the required state permits and approvals needed for the proposed project activities. The ADGC is a state clearinghouse for the dissemination of information and provides a consistency determination for permit applicants to ensure that all state agencies affected by the proposed activity are involved in the processes required by the Alaska Coastal Zone Management Program (ACZMP). ADGC personnel provided guidance on Alaska environmental regulatory agencies and requirements and acted as the point of contact for the coordination of compliance activities.

The Federal Coastal Zone Management Act was enacted in October 1972 (Public Law 92-583) and reauthorized in 1990 to encourage states to preserve, protect, develop, and where possible, restore or enhance water resources. State participation is voluntary. The state of Alaska is a participant and has an Ocean and Coastal Resource Management-approved program that can be used to deny and/or restrict any development that may be inconsistent with the state coastal-zone management program. The Alaska Coastal Project Questionnaire was completed as the first step in obtaining the necessary state permits and approvals. This questionnaire is used as a screening tool by the ACZMP to determine if proposed project plans are consistent with the state program and to identify applicable state permits and approvals required for initiation and completion of proposed project activities.

In addition to the above state requirements, ADEC requested a report describing proposed solid waste management practices at the project site. ADEC also served in a review and approval role for the NWP #38 application received from the U.S. Army Corps of Engineers.

ADNR required the completion of an Applicant Environmental Risk Questionnaire to help clarify the types of activities associated with the remedial action and to identify the level of environmental risk associated with the activities. ADNR also required the completion of a Tideland Permit Application to describe the proposed use of tidelands in the vicinity of proposed project activities and a Land Use Permit Application to describe land-based activities at the project site. These requirements were in addition to an ADNR review and approval of the NWP #38 application received from the U.S. Army Corps of Engineers.

The Alaska Department of Fish and Game (ADFG) issued Scientific Permit No. 93-102 for the biological sampling of small mammals, caribou, and ptarmigan. These requirements were in addition to an ADFG review and approval of the NWP #38 application received from the U.S. Army Corps of Engineers.

Local Requirements

Project activities were to occur in a region under the jurisdiction of the North Slope Borough. As a federal agency, DOE is exempt from local fees and requirements. However, wherever possible, DOE's policy is to maintain consistency with local land-use regulations. For this reason, DOE completed the North Slope Borough Land Management Regulation Permit Application.

3.3 Environmental Assessment

An EA for the proposed site assessment and remedial actions at the Project Chariot Site was prepared and released by the FWS in June 1993. Based on the information presented in the EA, DOE and FWS issued FONSIs regarding the proposed activities at the Project Chariot Site. The following statement was included in DOE's FONSI:

> *Based on the analysis in the EA, the proposed remedial action, including sampling, excavating, transporting, and disposing of the soils, closing and revegetating the site, and conducting the environmental sampling program does not constitute a major Federal action significantly affecting the quality of the human environment within the meaning of the National Environmental Policy Act. Therefore, an environmental impact statement for the proposed action is not required.*[9]

3.4 Subcontracts

Fourteen subcontracts were procured during the preparation stages for the remedial activities at the Project Chariot Site. Two major subcontracts were issued for the barge services and camp operations. A competitive procurement process was used to award both subcontracts. Bid lists were developed by researching the northwest market for ocean shipping and remote camp contractors.

Five subcontracts were issued for equipment to support the field effort. A competitive procurement process was used when more than one source could be identified. A wide variety of equipment was obtained, which included radiological survey equipment, B-25 containers, global positioning equipment, heavy construction equipment, and gamma-spectroscopy analytical equipment.

Seven subcontracts were issued for other services. These services included trucking services, air charters, legal services, surveying, and technical consulting services. A competitive procurement process was used when more than one source could be identified. As appropriate, individual contracts were awarded on a time and material, labor hour, or fixed unit cost basis. Air charter services were obtained from local companies when possible because of the local pilots' knowledge regarding the geography and weather conditions of the area. In addition, the use of local air charter services was cost effective and allowed the DOE to use small, disadvantaged companies. Whenever possible, support personnel, such as bear guards, were hired from the local areas.

3.5 Camp Setup

Before remedial-action personnel arrived at the site, an advance crew from Taiga Ventures arrived on site to set up the camp. Work included erecting the tents, assembling plumbing and electrical components, and preparing the camp for full habitation by July 29, 1993. The camp was comprised of 28 canvas and nylon tents with plywood floors (Figure 3-1), including a dining tent, a cooking tent, sleeping tents, a storage tent, laboratory tents, and office tents. The completed camp also included full laundry facilities, a showering/washroom/toilet area, and additional equipment, such as generators and incinerators. All tents were insulated and provided with oil stoves. The generators were necessary to provide not only the energy required for lighting and electrical construction equipment, but also the energy for the detector systems and computers in the on-site laboratories.

Figure 3-1
Tents at the Project Chariot Camp

3.6 Aerial Photographic and Radiological Surveys

An aerial photographic survey of the site and surrounding area was conducted on June 19, 1993. The aerial photographs were later used as base maps to plot the results of the aerial radiological survey. A half-mile-radius exclusion zone was established by the FWS around Crowbill Point because it is the possible nesting site of a pair of peregrine falcons. The half-mile-radius no-fly zone was maintained during all aerial photographic and radiological surveys. The aerial radiological surveys were conducted to screen the area for the potential existence of unnaturally elevated levels of radioactivity, that is, elevated levels of man-made radioactivity. Additional information regarding the aerial photographic and radiological surveys is presented in Attachment A.

Chapter 4.0

Chronological Summary of Site Activities

On-site activities for the Project Chariot Site assessment and remedial action were conducted from July 29 through September 5, 1993. Agencies and groups present during or participating in field activities included the following:

- DOE
- IT (DOE contractor)
- ADEC
- FWS
- ADNR
- Point Hope, Kivalina, North Slope Borrough, and other local officials and residents
- Foster-Wheeler (consultant to the North Slope Borough)
- News media.

The site assessment and remedial action was completed in 39 days. Daily meetings were held to provide the project status to the above agencies and groups. Daily reports were also prepared to document all field activities. Table 4-1 lists the major activities that occurred at the Project Chariot Site. Brief descriptions of the activities for each week are presented in this section.

Week 1 - July 29 through August 4, 1993

The first week at the Project Chariot Site was used to organize and mobilize operations. Personnel arrived on July 29 and July 30, 1993, and proceeded to set up camp operations, including the office, laboratory, and communication systems (Figure 4-1), as well as to establish project logistics and schedules. A temporary crossing at Snowbank Creek was installed. The Exclusion Zone (EZ) and Contaminant Reduction Zone (CRZ) at the disposal mound were established. Figure 4-2 shows the work zones at the Project Chariot Site. Near completion of the project, the EZ boundary was expanded to make loading of B-25 containers at the staging area easier. Teams began biota, surface water and sediment sampling, and radiological surveys at areas around the disposal mound. Radiation surveys and biota sampling were performed at the disposal mound first so that disposal-mound removal activities would not interfere with the sampling effort. Mobilization of the excavating equipment to the mound began as soon as a trail across the tundra (from the base camp to the mound) was identified and approved by the FWS Representative. Uni-mats were placed on the trail to minimize damage to the fragile tundra (Figures 4-3 and 4-4).

Table 4-1
Summary of Activities at Project Chariot Site
(Page 1 of 2)

Week	Activity
Week 1 July 29 through August 4, 1993	• Arrival of personnel • Camp setup • Temporary crossing at Snowbank Creek installed • Exclusion Zone (EZ) and Contaminant Reduction Zone (CRZ) at disposal mound established • Radiation survey and biota, surface water, and sediment sampling began at disposal mound • Uni-mats placed on trail • Cs-137 activity detected in Snowbank Creek area • DOE presented information at public meeting in Point Hope • Point Hope residents visited Project Chariot Site • Four Eberline instruments damaged • High winds caused delay in unloading barge
Week 2 August 5 through August 11, 1993	• Damaged Eberline instruments replaced • Disposal mound measured • Two high-volume air samplers set up in the EZ and one outside to monitor for airborne radioactive particulates • Mound excavation began • Lifts 1, 2, 3, and 4 were excavated, surveyed, and sampled • Lift 5 soil had slightly elevated radiological activity • Soil placed in seven B-25 containers • Surface water and sediment samples collected from the upper reach of Snowbank Creek Station Nos. 1 through 7, lower reach of Snowbank Creek Station Nos. 1 through 3, and Ogotoruk Creek Station No. 05-01 • Two public relations events held and DOE hosted press day on August 10 • News media filmed work at the excavation and in the laboratory
Week 3 August 12 through August 18, 1993	• Project Chariot disposal site confirmed during mound excavation • Project remained on schedule despite heavy rains and strong winds • Lift 6 soil contaminated; soil loaded into 27 B-25 containers • Lift 7 soil contaminated; soil placed in 18 B-25 containers. • 90 percent of soil from the test-plot area removed and loaded into two B-25 containers • Mammal sampling completed in Kisimilok Valley • All vegetation samples collected from Ogotoruk and Kisimilok Valleys • Trail to disposal mound closed due to heavy rain

Table 4-1
Summary of Activities at Project Chariot Site
(Page 2 of 2)

Week	Activity
Week 4 August 19 through August 25, 1993	• All sampling activities completed • Manual excavation of former test-plot area completed (final 10 percent) • Caribou samples collected from Native hunters • On August 23, 1993, ADEC approved clean closure of the disposal mound • Background radiation sampling completed • Remedial action team completed work at disposal mound • Disposal mound excavation backfilled • EZ and CRZ disassembled • Equipment, fencing, and temporary structures removed • Excavator and front end loader taken back to camp • Tour of laboratory operations and site operations visit held for teachers
Weeks 5-6 August 26 through September 5, 1993	• Site restored • ADEC approved clean closure of Cs-137 test-plot area on August 26, 1993 • With coordination from the ADNR and FWS, remedial action team completed revegetation activities • Equipment packed and sampling teams departed • Public meetings held in Point Hope and Kivalina to discuss Project Chariot Site cleanup • Remaining Project Chariot Site Remediation Team personnel left Cape Thompson on September 3, 1993; camp dismantling began • Barge loading began on September 3, 1993; winds forced interruption of barge loading until September 5, 1993; excavator and front end loader transported onto barge, thus completing barge-loading activities • Camp operator dismantled and removed camp

Vegetation sampling was completed along North Saligvik Ridge and around the disposal mound in the EZ. Soil sampling began at Snowbank Creek west of the disposal mound, and surface water and sediment sampling was completed at Snowbank Creek Stations and initiated at Ogotoruk Creek Stations.

Cesium-137 activity was detected in a small area in soil next to Snowbank Creek. This area was flagged with markers for further radiological survey work.

DOE presented information and answered questions at a public meeting with local residents in Point Hope on July 30, 1993. At the end of the week, Point Hope residents visited the Project Chariot Site.

Figure 4-1
Office Setup

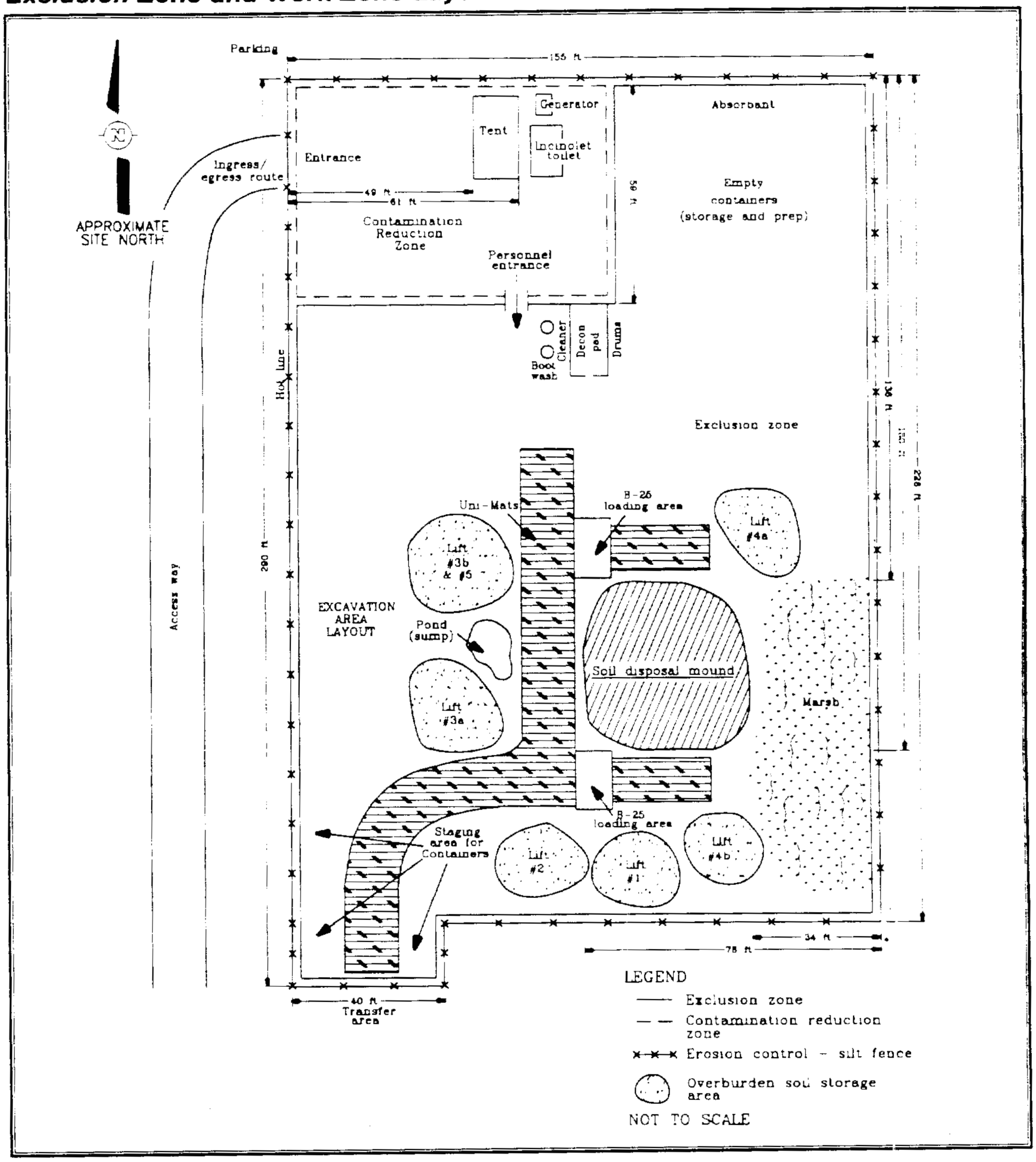
The sea-land container with all of the electronic equipment was dropped by the barge company during unloading. The Eberline ratemeters sustained the most damage with four units rendered useless. Other pieces of equipment were salvaged. High winds forced the barge out to sea and delayed complete unloading until the night of August 2, 1993.

Week 2 - August 5 through August 11, 1993

Site assessment and remediation activities progressed well through the second week. The weather was accommodating and allowed much work to be accomplished. The damaged Eberline instruments were replaced. The excavator, loader, and B-25 containers were mobilized to the disposal mound. The CRZ at the disposal mound was set up; two high-volume air samplers were placed downwind in the EZ, and one was placed outside the EZ to monitor airborne radioactive particulates. The disposal mound was surveyed and measured before the excavation operation began.

The excavation operation at the disposal mound began during the second week. The disposal mound was excavated in 0.3-m (1-ft) increments, referred to as "lifts" (Figure 4-5). Lifts 1, 2, 3, and 4 were excavated, surveyed (Figure 4-6 and 4-7), and sampled (Figure 4- 8). At least four soil samples were taken from each lift, composited, and analyzed in the on-site laboratory. An additional lift, Lift 5, was needed before reaching the previously disposed contaminated soil. The upper portion of Lift 5 soil was not contaminated. Radiological surveys indicated that the lower portion of the Lift 5 soil had slightly elevated

Figure 4-2
Exclusion Zone and Work Zone Layout



activity. Soil from this lower portion was immediately put in seven B-25 containers. All waste certification sampling and required documentation were performed as these B-25 containers were filled. Radiological surveys were conducted at the disposal mound throughout the excavation activities.

Surface water and sediment sampling (Figure 4-9) was completed in the upper reaches of Snowbank Creek (Station Nos. 1 through 7), the lower reaches of Snowbank Creek (Station Nos. 1 through 3), and the Ogotoruk Station. (Plate I, Sampling Site Locations). These samples were sent to the off-site laboratory for analysis. Vegetation sampling was completed throughout Ogotoruk Valley, and vegetation samples were processed. The ground radiation survey was initiated along the north side of Snowbank Creek.

Figure 4-3
Uni-mat Placement on Trail

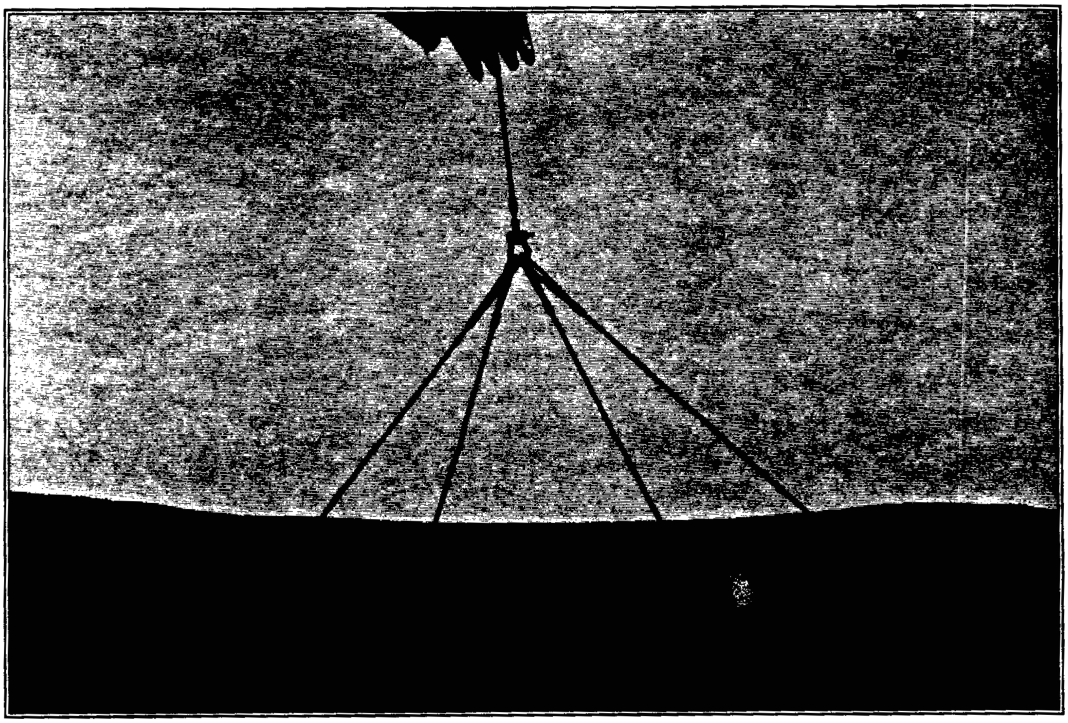


Figure 4-4
Uni-mat Placement Using Leap-Frog Method

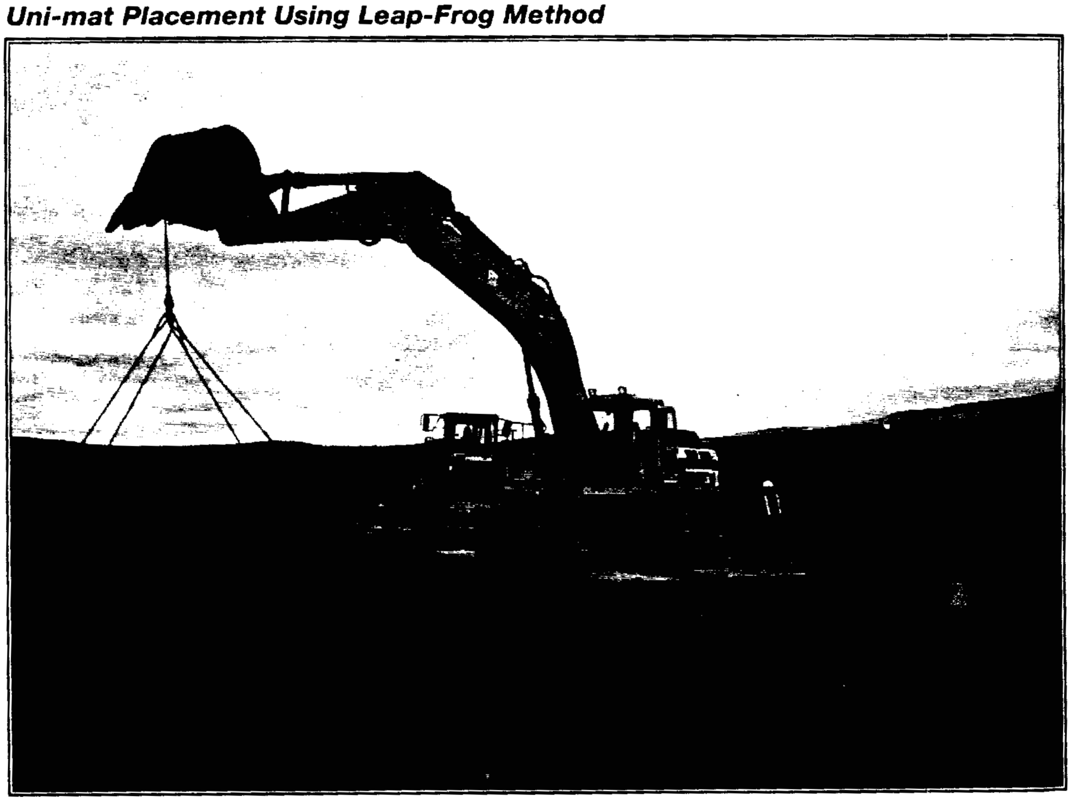
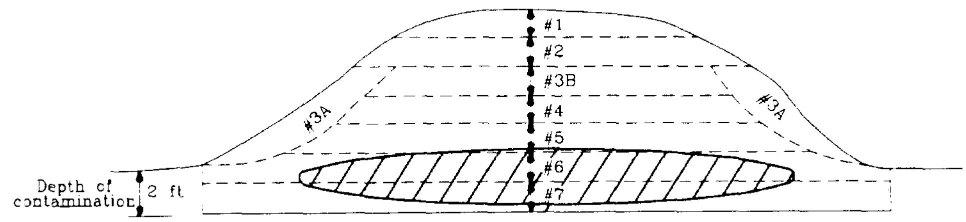


Figure 4-5
Soil Disposal Excavation Procedure



Sequence of Soil Disposal Mound Excavation

1. The soil disposal mound was surveyed to establish approximate one-foot vertical increments (lifts) over the entire mound.
2. The soil-erosion and sediment control measures were installed, in accordance with the soil erosion and sediment control plan.
3. The surface of the mound was surveyed utilizing radiological survey instruments, and soil samples were collected in accordance with the Sampling and Analysis Plan.
4. Excavation of the mound was performed utilizing a track excavator equipped with a regular digging bucket.
5. Excavation of the uppermost lift proceeded over the entire mound and the clean soil was stockpiled on high-density polyethylene (HDPE) liners. The stockpiled soil was covered with HDPE liners secured with sandbags.
6. Once contaminated soil was encountered, the exposed mound was covered with sheeting secured with sandbags during nonoperation hours.
7. Prior to the excavation of each subsequent lift, the surface of the newly exposed mound was surveyed with radiological survey instruments.
8. Composite soil samples were collected from each of the stockpiles and analyzed on site, in accordance with the Site Assessment and Remedial Action Plan. Based on the laboratory analysis results, stockpiled soil that exceeded the established clean-up level was subsequently placed into the B-25 Low Specific Activity (LSA) containers for disposal. Overburden soils that were determined to be below the established clean-up level were utilized to fill the mound area to grade after the completion of the removal activities.
9. At the excavation level where the soil from the tracer study existed the soil was excavated and loaded directly into the B-25 LSA containers for disposal.
10. Post-excavation soil samples were collected from the base and sidewalls of the excavation and analyzed in the on-site laboratory. Upon approval by the Alaska Department of Environmental Conservation for final clean closure, the removal activity was completed.
11. The clean overburden soil was graded into the open excavation.
12. The disturbed areas were revegetated in accordance with Chapter 9.0, Soil Erosion, Sediment Control and Revegetation, of the Remedial Action Plan.
13. The soil-erosion and sediment control structures were then removed.

Additional visitors from Point Hope stayed on site, and DOE hosted a press day on August 10, 1993. News media were on site to film work at the excavation and in the laboratories.

Week 3 - August 12 through August 18, 1993

The majority of the disposal-mound excavation was completed during the third week. The disposal mound was confirmed to be the location of the historic disposal activities when wood and plastic from the former test plots were excavated with Lift 6 (Figure 4-10). The project remained on schedule even though heavy rain and strong winds limited field operations at the end of the week.

Figure 4-6
ESP-2 Survey Procedure of Lifts 1, 2, 3, and 4

Figure 4-7
Multichannel Analyzer Survey Procedure of Lifts 1, 2, 3, and 4

Figure 4-8
Soil Sampling at the Disposal Mound

Figure 4-9
Sediment Sampling

The soil from Lift 6 had elevated radioactivity levels. This soil was removed from the disposal mound and placed into 27 B-25 containers. A soil sample was taken from the center of Lift 6 for on-site analysis. A radiological survey was performed on the mound to delineate any area of elevated readings. It was determined that another lift would be necessary to ensure the removal of all contaminated soil. Lift 7 removed another foot of soil from the area. Eighteen additional B-25 containers were filled before reaching the bottom of the contaminated zone. Another radiation survey was performed. This survey indicated that very localized areas of slightly elevated activity remained at the bottom of the excavation. This soil was removed manually by shovel and placed in B-25 containers. All waste certification requirements were completed throughout the removal activities in accordance with the approved Waste Management Plan. The only part of the disposal mound not yet excavated was the west end; it was believed that this end consisted of clean soil. To verify this, a sampling trench was dug to ensure that contaminated soil was not buried below the clean surface soils in the area. No Cs-137 activity was detected in that area; therefore, the soil at the west end of the disposal mound was determined to be clean soil that had been used as cover material in 1962.

Soil samples were collected from the excavated area in accordance with the approved plan and analyzed in the on-site laboratory. All readings were either

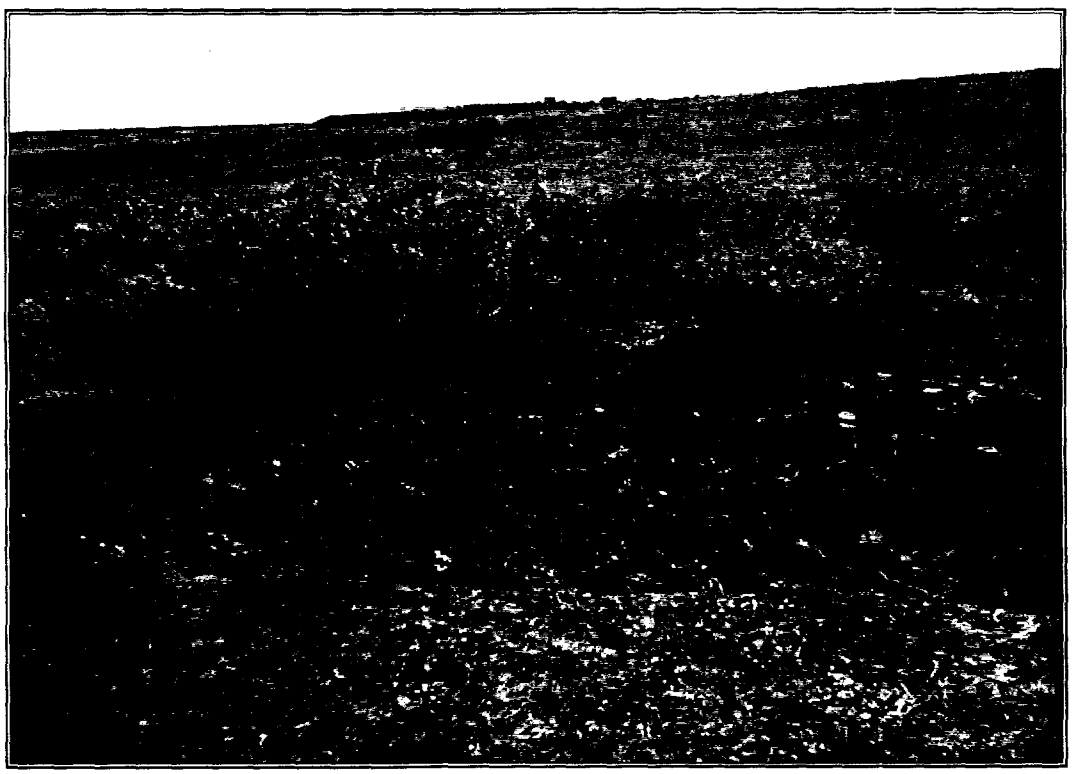
Figure 4-10
Wood and Plastic in Disposal Mound

below detection limits for Cs-137 or were below the clean-up level of 0.4 Bq/g (10 pCi/g). At this point, a grid was set up for closure sampling of the mound area. Another area of contamination was identified by the radiation team in the vicinity of a former test-plot area, which was the site of three test plots used as part of a Cs-137 study conducted in 1962 (Figure 4-11).

The ground-radiation survey team completed all stations on the north side of Snowbank Creek and initiated the survey on the south side of the creek. Mammal sampling was completed in Kisimilok Valley, and all vegetation samples were collected from both valleys. Animal and vegetation samples continued to be collected and processed, although rodents in Ogotoruk and Kisimilok Valleys were in a low activity cycle.

An odor originating from the disposal mound was associated with irritation of skin, eyes, and throat of the remediation crew. It was believed that a sulfonated compound was being released by the biological decay processes in the newly exposed organic-rich soils, which in turn formed a weak sulfuric acid upon contact with moisture in the mouth or eyes. To remedy the situation, it was decided that excavation personnel would work upwind and take breaks if the irritation persisted. This problem ceased once the excavation activities were completed. The trail to the disposal mound was closed to motorized vehicles on August 17 because of heavy rain.

Figure 4-11
Test-Plot Area



Week 4 - August 19 through August 25, 1993

A Native villager expressed concern about radiation in areas other than the disposal mound and test-plot area. A series of boreholes that were drilled during the original experiment were of particular concern. DOE, ADEC, and Foster Wheeler examined these areas with survey meters. No elevated levels of radiation were detected. Site remediation work progressed on schedule, but periodic rainstorms and cold winds gusting above 35 knots (40 mph) hindered site activities. The trail to the disposal mound remained closed except for foot traffic, access by the bear guards, and emergency support.

Caribou samples were collected from Native hunters in Point Hope and Kivalina. A sample was collected from a dead bear with permission from the FWS. The samples were processed for off-site radioisotopic analysis.

Soil samples from the disposal mound were analyzed at the on-site laboratory. All samples analyzed by the on-site laboratory were at concentrations below the action level. The containers filled with water pumped from a ponded area near the mound also tested clean. After receiving analytical results from the off-site laboratory, ADEC approved clean closure of the soil disposal mound on August 23, 1993 (Attachment B).

Sampling was also completed at the test-plot area. The radiation survey team surveyed the area throughout the test-plot excavation work, samples were collected, and split samples were taken by ADEC and Foster-Wheeler. Composite samples were prepared for waste characterization and closure sample analysis at the off-site laboratory. The manual excavation at the test-plot area was completed during the fourth week.

The radiation survey team surveyed the area around Snowbank Creek (Figure 4-12); no elevated readings were detected. By the end of the week, all sampling activities were completed, and the sampling and analysis teams began to dismantle and pack the laboratory and field instruments.

In total, 59 B-25 containers were filled with low-level waste (soil, debris, and remediation-derived waste) from the mound and the former test-plot area, and two B-25 containers were filled with slightly contaminated water from the test-plot area. There were an additional 13 B-25 containers filled with sanitary trash; the rest of the sanitary trash was burned in the incinerator on site.

The disposal-mound excavation was backfilled after a Native Village of Point Hope Representative surveyed the area and agreed that the remediation goals had been achieved. The heavy equipment (excavator, bucket, and cab), the B-25 containers, and the excavation area (EZ and CRZ) were surveyed and sampled for possible radiological constituents. Everything was found to be contaminant free, so the EZ and CRZ were

Figure 4-12
Backpack Survey Equipment

"turned off" and dismantled. The entire area was then graded using clean stockpiled soil, and the area above the excavation received an additional foot of soil to compensate for possible subsidence.

The following activities were conducted during demobilization of the disposal mound area: (1) equipment, fencing, and temporary structures were removed; (2) all remediation-derived waste was put in B-25 containers; (3) the B-25 containers were transported to the holding area near the camp (Figure 4-13); (4) support tents were broken down; (5) the Uni-mats were repaired for transportation of the equipment to the camp; and (6) the excavator and front end loader were transported back to camp on the Uni-mats.

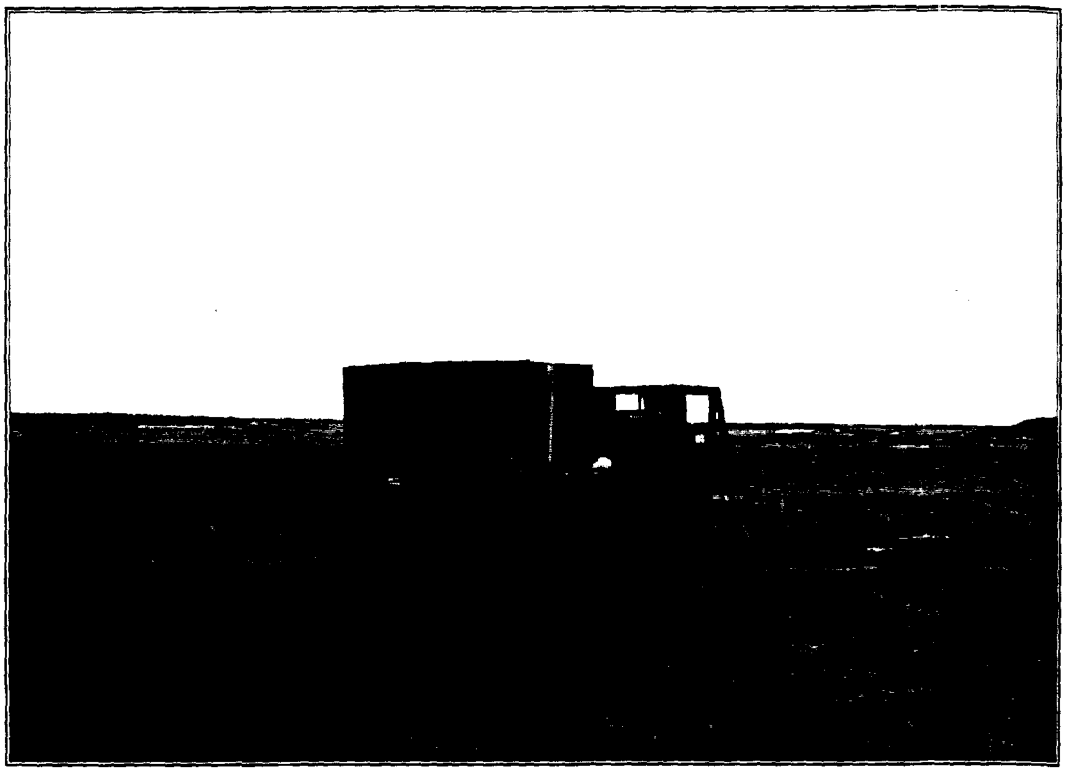
Three teachers from Point Hope toured the Project Chariot Site on August 22, 1993. The teachers were shown laboratory operations, as well as the disposal-mound and test-plot-area excavations. Before leaving, they were given additional information and materials to share with their students.

Weeks 5 and 6 - August 26 through September 5, 1993

The site was restored during the fifth week. ADEC approved the clean closure of the test-plot area on August 26, 1993 (Attachment B).

Heavy equipment was returned to camp, the test-plot area was backfilled, the crossing at Snowbank Creek was removed, and the disturbed areas of

Figure 4-13
B-25 Containers Transported to Holding Area



the site were revegetated. With coordination from ADNR and FWS, the remedial action team successfully accomplished the revegetation activities (spreading seed, fertilizer, and Excelsior™ blankets) on the trail and disposal mound.

The equipment was packed, and the sampling teams departed. A substantial part of the week was spent preparing and reviewing permit requirements and paperwork for shipping purposes.

Public meetings were held in Point Hope and in Kivalina to discuss the remediation process and results of the Project Chariot Site cleanup. Many of the local concerns were addressed and resolved. Local residents expressed their appreciation for the clean-up effort.

The barge arrived on September 3, 1993. The weather changed in late afternoon, and the barge-loading operations were discontinued. The barge was able to return to shore on September 5, 1993, and the excavator and front end loaders were transported onto the barge, completing barge-loading activities. The remaining DOE Project Chariot Site remediation personnel left Cape Thompson on September 3, 1993. The camp was then dismantled and removed by the camp operator.

Chapter 5.0

Environmental Studies

The existing environmental conditions at the Project Chariot Site and surrounding area were assessed by performing:

- aerial photographic and gamma surveys
- sampling and analysis of surface water, soil, and sediment
- radiological ground surveys of the tracer test plots
- sampling and analysis of biota.

Each of these activities was conducted in accordance with quality assurance (QA) and quality control (QC) requirements to ensure sample and data integrity (Section 10.0).

Assessment of the existing environment included investigation of background radiation sources and levels. Natural radiation and radioactivity in the environment provide the major source of human radiation exposure.[10]

There are several sources of radiation that occur naturally. The radiation emitted from these sources is identical to the radiation that results from man-made sources. The four major sources of naturally occurring radiation exposures are cosmic, terrestrial, internal, and radon.

Cosmic radiation comes from the sun. Terrestrial radiation comes from natural sources of radiation in the ground, rocks, building materials, and drinking water supplies. Sources of internal radiation are from food and water. The radioactive materials in food and water can be deposited in the body. Radium is a naturally occurring element in soil and becomes radon as it decays. Radon is a gas that can travel through the soil and collect in basements and other areas of buildings. Table 5-1 shows the total average annual dose to the general population from the various types of natural and man-made background radiation.

In addition to the naturally occurring sources of radiation, the population is exposed to radiation from man-made sources: medical radiation sources, such as x-rays, diagnosis, and therapy; atmospheric testing of nuclear weapons; and consumer products.

5.1 Aerial Surveys

Aerial photographs of the Project Chariot Site and surrounding area were taken on June 19, 1993. The photographs were used as base maps to plot the results

Table 5-1
Total Average Annual Dose to the General Population from the Various Types of Natural and Man-Made Background Radiation

Cosmic Radiation	28	millirems per year (mrem/yr)
Terrestrial Radiation	28	mrem/yr
Internal Sources	40	mrem/yr
Radon	200	mrem/yr
X-Rays	40	mrem/yr
Diagnosis and Therapy	14	mrem/yr
Atmospheric Testing	<1	mrem/yr
Consumer Products	10	mrem/yr
Total	360	mrem/yr

of the aerial radiological survey. An aerial radiological survey was conducted over the Project Chariot Site during the period of July 13 through July 24, 1993, to determine the natural radiation environment (background) and to determine if additional man-made radioisotopes were disposed at the site. The survey was conducted by EG&G/EM Remote Sensing Laboratory. The information presented in this section is derived from the *Chariot Site Aerial Radiation Survey Report* (Attachment A).

The aerial gamma-radiation survey was conducted in two areas: a 93-km^2 (36-mi^2) area of the Ogotoruk Valley, which included the Project Chariot Site, and, for comparison, a 10-km^2 (4-mi^2) area centered on the Kisimilok Creek in Kisimilok Valley, south of the Project Chariot Site. A 1.3-km^2 (0.5-mi^2) area near the Kotzebue Airport was also surveyed during equipment checkout and could be used as a comparison to the primary survey areas.

The aerial radiological survey was conducted using a sodium-iodide (NaI) gamma-ray detection system mounted on a Messerschmitt-Bolkow-Blohm BO-105 helicopter (Figure 2-3). The system was flown at an altitude of 46 m (150 ft) along parallel flight lines spaced 76 m (250 ft) apart; the helicopter speed was 70 knots (80 mph). The FWS required that precautions be taken to remain 0.8 km (0.5 mi) from Crowbill Point, a seabird habitat (Figure 5-1). These precautions included a half-mile no-fly zone around Crowbill Point to protect a potential nesting site for peregrine falcons. Gamma-radiation data were collected in 1-second intervals over an area encompassing about 100 km^2 (40 mi^2).

The objectives of the data processing and analysis were to (1) generate contour maps that establish the spatial distribution of the terrestrial gamma radioactivity, (2) identify the gamma-emitting radioisotopes present, and (3) estimate the quantity of radioisotopes present. The count rate produced by gamma rays was evaluated for each data point (1 point approximately every 37 m [120 ft] of flight), and the results were contoured to generate radiation profile maps of the

Figure 5-1
Seabird Habitat

surveyed areas. Count-rate contour maps were generated for total terrestrial natural activity and total terrestrial man-made source activity.

Data processing was initially conducted at the Kotzebue base of operations using a smaller version of the analysis system used at the EG&G/EM Remote Sensing Laboratory in Las Vegas, Nevada. As a quality control check, the data were again processed in Las Vegas prior to generating the final radiation contour plots.

Isoradiation contour maps, showing radiation levels at various locations, were generated for total terrestrial and total man-made activity. To relate the terrain with its corresponding radiation contours, the scale of the contour maps was adjusted to correspond to the aerial photographs taken on June 19, 1993. The contour maps were then overlaid on the aerial photographs. Gamma-energy spectra were also generated over various locations within each of the areas surveyed to identify the gamma-emitting radioisotopes present. This was done because Cs-137 is a man-made radioisotope that emits gamma radiation.

Within the approximately 100 km^2 (40 mi^2) surveyed, only activity from naturally occurring gamma emitters (uranium-238 and progeny, thorium-232 and progeny, and potassium-40) and worldwide fallout were detected. No other man-made radiation anomalies were detected. Figures 1 through 4 in the *Chariot Site Aerial Radiation Survey Report* (Attachment A) summarize the results of the survey. Figure 1 shows the flight lines flown over the primary survey area covering Ogotoruk Valley and the Project Chariot Site. Flight lines were flown at a nominal line spacing of 76 m (250 ft). Figures 2 through 4 (Attachment A) show the results from processing the total count rate data, converted to units of exposure rate, over the Ogotoruk and Kisimilok Valleys, and an area near Kotzebue, respectively. No contour maps were generated for man-made activity since none was detected.

Within the Ogotoruk survey area (Figure 2 [Attachment A]), the exposure rate values in the hills to the north were as low or lower than the valley floor values, with exposure rates mostly in the 5 to 7 microroentgens per hour (μR/hr) range. (This and all other exposure rate values given are total exposure rates, which include the estimated 4 μR/hr cosmic-ray contribution.) The exposure-rate values in the hills to the south, however, were higher than the typical valley floor values, mostly in the 9- to 13-μR/hr range. The typical valley floor exposure rates, outside the creek bed, were in the range of 5 to 9 μR/hr for the first 6.4 to 8 km (4 to 5 mi) inland and then increased to 7 to 11 μR/hr further inland. The Ogotoruk Creek bed was primarily in the 9- to 11-μR/hr range.

The results over the Kisimilok Valley (Figure 3 [Attachment A]) were similar to those over the Ogotoruk Valley. Most of the area was in the range of 7 to 11 μR/hr, with exposed rocky areas slightly higher, in the 11 to 13 μR/hr range. The small area surveyed near Kotzebue (Figure 4 [Attachment A]) was over wet tundra and showed exposure rates of 5 to 9 μR/hr. As shown on Table 5-2, the normal tundra radiation level in this area of Alaska ranges from 7 to 9 μR/hr.

Several areas were flown at lower altitudes and slower speeds to increase the sensitivity of the aerial system, in particular, Snowbank Creek, the disposal mound, and portions of Ogotoruk Creek. Hovers were also made in these areas to further increase system sensitivity. No man-made radioisotopes were detected under these survey conditions. The most noticeable overall difference in the areas surveyed was that the radiation levels were normally higher in bare spots and creek beds (generally with little or no vegetation) than the vegetated areas, a finding that is consistent with surveys in other areas of the country.

Table 5-2 summarizes the results of the survey. The gamma-energy spectra, taken at various locations throughout the survey areas, revealed the identity of naturally occurring radioactive sources (uranium-238 and progeny thorium-232 and progeny, and potassium-40) and small levels of worldwide fallout. The increased levels of exposure rate in the Ogotoruk Creek bed were determined to be due to higher levels of naturally occurring thorium and potassium in the area.

The exposure rates measured during the aerial gamma-radiation survey are not considered harmful. These exposure rates are due almost entirely to naturally occurring radioactive rocks.

Table 5-2
Area Coverage and Total Exposure
Rate Estimates at One Meter above Ground Level

Area	Exposure Rate Typical Range (μR/hr)	μR/hr Range (maximum)	Coverage
Ogotoruk Valley	7 - 11	5 - 13	93 km^2 (36 mi^2)
Kisimilok Valley	7 - 11	7 - 13	10 km^2 (4.0 mi^2)
Kotzebue	5 - 9	5 - 9	1.3 km^2 (0.5 mi^2)
Burial Mound	7 - 9	7 - 9	Hovers*
Snowbank Creek	7 - 9	7 - 9	Several low passes*
Ogotoruk Creek	9 - 11	9 - 11	Several low passes*
Special Areas	7 - 9	5 - 11	Several Passes*
Typical Tundra	7 - 9	5 - 11	

*These flights were made in addition to the normal survey flights.

5.2 Global Positioning System Survey

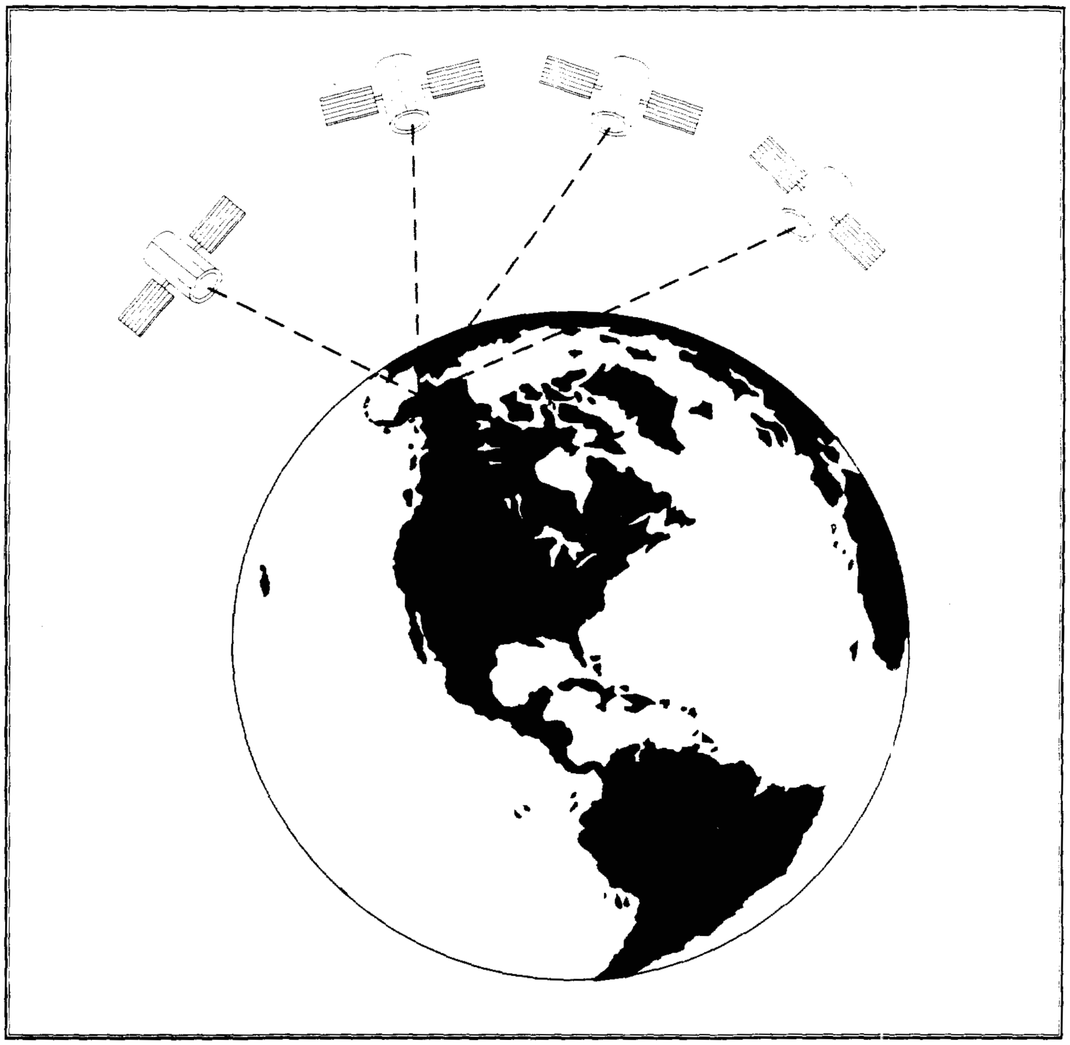
All sampling points were plotted on a map using data collected from a Global Positioning System (GPS) survey. The GPS uses a hand-held unit and an antenna mounted on a bipod to receive information from satellites (earth-orbiting radio stations). Information received from the satellites was stored in a computer linked to the GPS unit and then copied and stored on computer disks following completion of the session. Information received from the satellites was used to determine the location and elevation of sampling points on the earth's surface (Figure 5-2).

The GPS equipment was separated into two operating and control systems before the survey began. The purpose was to track locations and operating problems more efficiently. One system, designated as the base control unit, was set up at a known global position, such as a National Geodetic Survey Marker. The second system, designated as the remote unit, was then set up at the global position to be identified.

In order to determine the latitude, longitude, and elevation, signals from four satellites were required. Both the base unit and remote unit use the same four satellites. Prior to initiating a GPS session, the two operators selected which four of the 24 satellites orbiting the earth would be used. This selection process was based on the satellite position relative to the location of each unit.

Each GPS session lasted at least 7.5 minutes of uninterrupted signal reception. For more accurate information, extended periods of data collection were used. The maximum session was 20 minutes, and the average session, which consisted of approximately 500,000 bytes of data gathered by each unit, lasted about 13 minutes. Both the base and remote unit operators monitored their

Figure 5-2
Satellite Signal Processing for Global Positioning System



units for loss of satellite reception. If the signals were interrupted before 7.5 minutes, the session was restarted.

Postprocessing of the data collected from a GPS session was accomplished using a computer program that analyzed information collected from both GPS units. The program was designed to match certain segments of information collected from the satellite signals. Because the global position of the base unit was known, the program could then calculate the position of the remote unit. The positions were then plotted on a topographical map using AUTOCAD® version 12 (Plate 1). Data diskettes were labeled with the project name, location, date the data were collected, and the names of the files contained on the diskette. Hardcopy material, including data printouts, GPS session information, and GPS field survey forms, was kept in folders.

5.3 Field Radiological Survey Instrumentation

Several types of instrumentation were used for field radiological surveys:

- GE Reuter-Stokes Pressurized Ion Chambers (PICs)
- Canberra Portable Plus Multichannel Analyzers (MCAs)
- Eberline ESP-2 ratemeters with NaI detectors.

Pressurized Ion Chambers

The PICs were used to measure the gamma-ray exposure rate in units of μR/hr at selected locations. The PICs were selected for use during the Project Chariot remediation because they are a complete, ultrasensitive, gamma-ray-exposure monitoring system designed to measure and record low-level exposure rates, such as those due to natural background radiation. The PIC measurements were taken at the background locations, at the mound, and at the Cs-137 test-plot area prior to excavation.

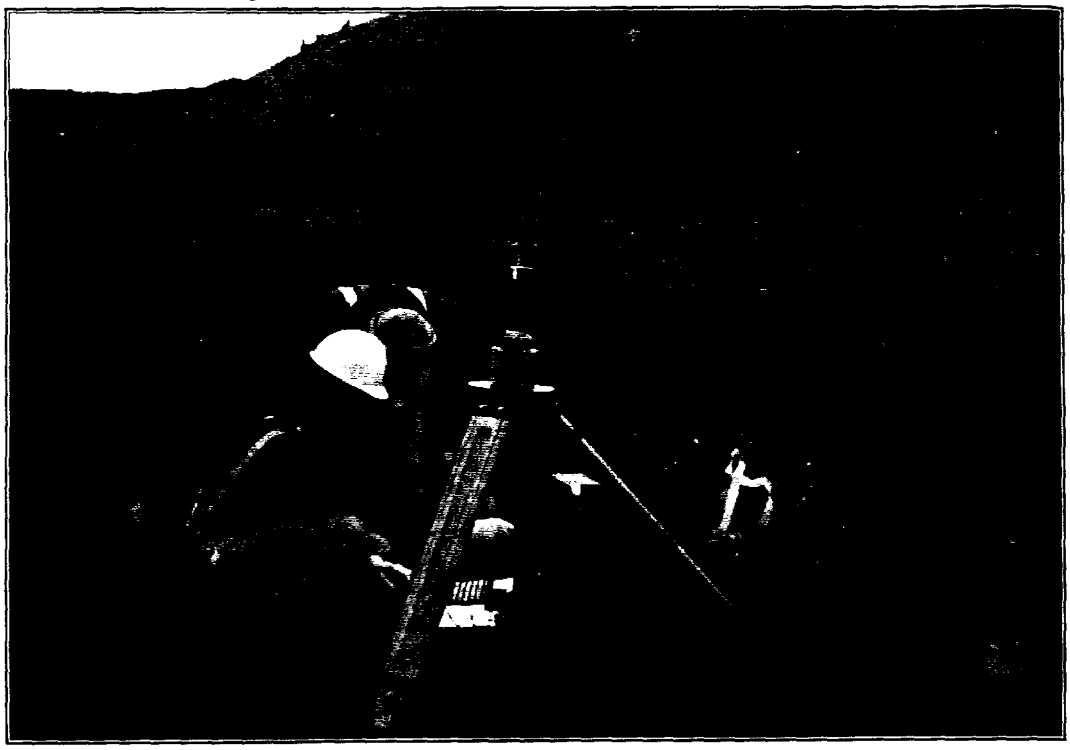
Multichannel Analyzers

The Canberra MCAs were used with a 3-in. by 3-in. NaI scintillation detector to identify radioisotopes present in the soil. The MCAs measured gamma-ray activity in units of counts per minute (cpm). The NaI detectors were shielded by 2 cm (0.8 in.) of lead and mounted on a tripod at a height of 1 m (3 ft) above ground surface (Figure 5-3). The field of view at the ground surface was approximately 2 m (7 ft) in diameter. Energy calibration of the unit was performed using a Cs-137 source for the lower-energy gamma radiation and a cobalt-60 source for the higher-energy gamma radiation. Each in situ, or in place, position was counted for 10 minutes. The in situ system was used to identify radioisotopes both natural and man-made in origin. The system could also measure the average concentration of radioisotopes in its field of view, if uniform.

Eberline ESP-2 Ratemeters

The Eberline ESP-2 ratemeters with NaI detectors measured gamma-ray activity in units of cpm. The NaI detectors were shielded with 2 cm (0.8 in.) of lead to restrict the field of view. The "region of interest" was set to measure the pulse height corresponding to the gamma-ray energy of Cs-137 (662 kiloelectron volts [keV]). Eberline ESP-2 ratemeters with NaI 3-in. by 3-in. detectors were used for walkover surveys of the disposal mound and also in the survey to locate the 1962 experimental test plots.

Figure 5-3
Multichannel Analyzer Mounted on Tripod



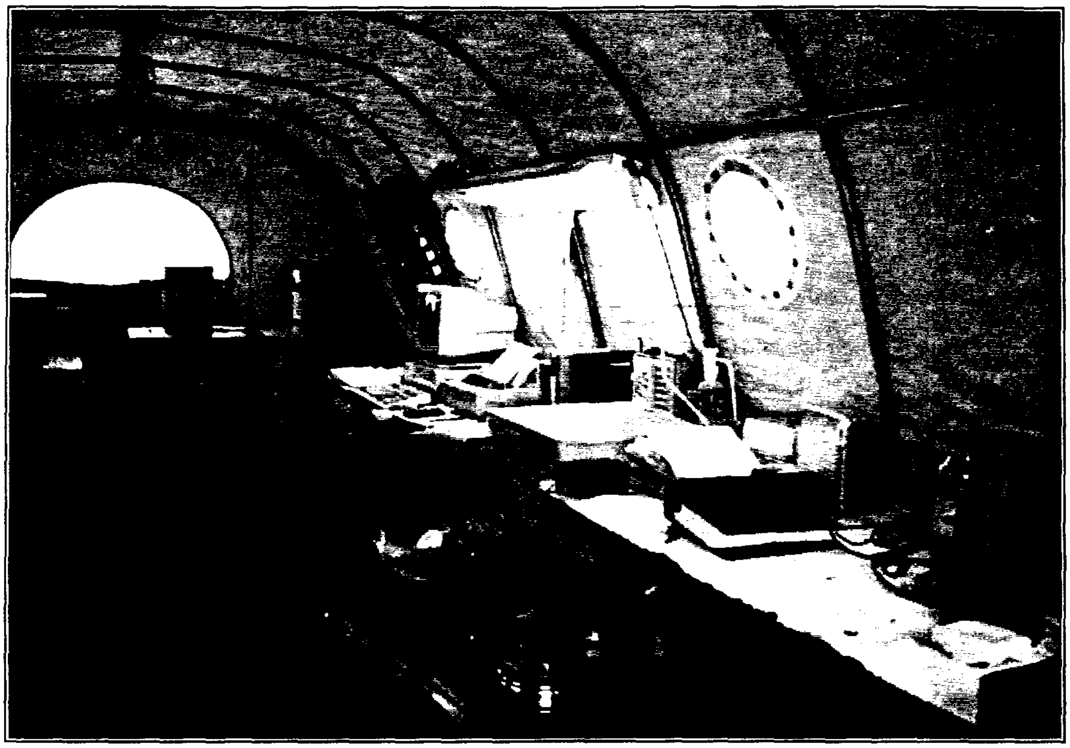
5.4 On-Site Laboratory

The on-site laboratory at the Project Chariot Site contained three Canberra cryostat-cooled high-purity germanium detectors, a drying oven, and an electronic balance (Figure 5-4). The detectors were surrounded by a 10.16-cm (4-in.) lead shield to minimize background radiation interference. Two of the detectors were operated by DOE personnel, while a third was operated by ADEC and Foster Wheeler personnel for independent analysis purposes.

The Canberra gamma-spectroscopy systems that were used in the on-site laboratory are state-of-the-art equipment and are used at virtually all national laboratories in the United States. To ensure accuracy when analyzing samples, a guide must be established to standardize the equipment measurements. This guide is referred to as a standard.

Two radioactive standards were used at the on-site laboratory. One standard contained 0.8 Bq/g (22 pCi/g) of Cs-137, about twice the clean-up level activity. The other standard was a mixed gamma source containing eight different isotopes, one of which was Cs-137 at a concentration of 36.8 Bq/g (994 pCi/g). The other seven isotopes were cadmium-109, cobalt-57 and 60, cerium-139, mercury-203, tin-113, and yttrium-99. These isotopes represent gamma energies from the low-end to the high-end of the spectrum. These standards were National Institute of Standards and Technology (NIST) traceable and were sealed in a 2-in. petri dish. Each standard was analyzed at the off-site laboratory to ensure the certified activity was correct.

Figure 5-4
On-Site Laboratory



The high-purity germanium detectors were calibrated using the mixed gamma standard. Although the primary radioisotope of concern was Cs-137, the calibration allowed for the detection of gamma-emitting isotopes within the energy range of 88 to 1836 keV. The mixed gamma standard was counted for 1 hour and then counted again for 30 minutes on each detector. The 1-hour counts were used to calibrate the detectors. The 30-minute counts were used to verify that the calibrations were correct. The results of the 1-hour counts and the 30-minute counts had to be within 10 percent of the certified activity of the standard for the equipment to be considered accurately calibrated.

Calibration checks were performed each day before analyzing samples by counting the mixed gamma standard for 10 minutes and an empty shield count for 10 minutes. The 10-minute count of the mixed gamma standard was used to verify the efficiency of each detector, whereas the 10-minute empty-shield count was used to verify that the detectors and lead shields were not contaminated.

For each batch of 20 samples, the mixed gamma standard and Cs-137 standard were counted to verify operation of the detectors. A blank sample containing clean, dry sand was also analyzed. For each batch, the blank sample was treated as a normal soil sample and went through each step of the preparation procedure to ensure that none of the samples became contaminated during sample preparation.

Each day that samples were prepared, the operation of the electronic balance was verified. This verification consisted of weighing NIST-traceable weights, one weight above 50 grams (g) (1.8 ounces [oz]) and one weight below 50 g.

Once received at the on-site laboratory, soil samples were dried in an oven for 4 to 12 hours and then ground to a powder with a mortar and pestle. Approximately 50 g (1.8 oz) of soil were placed in a 2 3/4-in. petri dish and sealed with tape. Samples were then counted for 30 minutes using the germanium detectors. The 30-minute count time was necessary to obtain a detection limit of 0.04 to 0.08 Bq/g (1 to 2 pCi/g) of Cs-137.

As expected, some soil samples contained Cs-137. Other naturally occurring isotopes were detected, such as potassium-40, bismuth-214, and lead-212. No Americium-241 (Am-241) was detected above the gamma-spectroscopy detection limit in soil samples. Americium-241, a gamma emitter, is also present if Pu-239 is present. Therefore, no Pu-239 was evident in any of the samples. At the completion of the cleanup, all clean closure samples collected contained less than 0.4 Bq/g (10 pCi/g) of Cs-137.

An ADEC chemist selected various samples to be independently analyzed at the on-site laboratory and counted these samples using the third germanium detector. This detector was calibrated and used by ADEC to oversee the operation of the on-site laboratory. Foster-Wheeler Representatives also used this detector to analyze samples that they and the representatives of the North Slope Borough had taken.

5.5 Verification of On-Site Laboratory Results

Ten percent of all soil samples collected were split and sent to an off-site laboratory, the IT St. Louis Laboratory, for verification of the on-site laboratory's results. The off-site laboratory analyzed the samples for gamma and gross alpha and beta radiation.

The off-site laboratory has four high-purity germanium detectors cooled with liquid nitrogen and operated in a temperature-controlled room. These detectors have 10-cm (4-in.) lead shields to further reduce background radiation. The off-site laboratory also has a low-background gas-flow proportional counter that was used to analyze alpha and beta radiation in the soil samples.

The off-site laboratory used approximately 650 g (23 oz) of soil in the gamma spectroscopy analysis. This larger sample size gave a more reliable representation of the radioactivity in the soil. At the completion of the cleanup, the radioactivity detected in samples at the on-site laboratory was comparatively equal to the value detected for each split sample by the off-site laboratory within instrument error limits. The results support the reliability of the on-site equipment. Table 5-3 presents a comparison of the results for on-site and off-site analyses.

ADEC and Foster Wheeler Representatives selected various duplicate and split samples, which were sent to their respective off-site laboratories for analysis.

Table 5-3
Project Chariot Off-Site Laboratory Verification of On-Site Laboratory Results (Results in Picocuries per Gram)

Sample Number [a]	Cesium 137	±2s [b]	Potassium 40	±2s	Lead 210	±2s	Lead 212	±2s	Bismuth 212	±2s	Bismuth 214	±2s	Thallium 208	±2s	Radium 226	±2s	Radium 228	±2s	Thorium 234	±2s	Thorium 228	±2s
SS-007	<MDA [c]		13.63	2.71	<MDA		<MDA		<MDA		<MDA		<MDA		<MDA		<MDA		<MDA		<MDA	
SS-007 - offsite	<MDA		12.2	1.40	<MDA		0.98	0.08	<MDA		<MDA		<MDA		0.60	0.09	<MDA		0.99	0.65	<MDA	
SS-010	<MDA		7.73	2.71	<MDA		<MDA		<MDA		0.43	0.22	<MDA		<MDA		<MDA		<MDA		<MDA	
SS-010 - offsite	<MDA		5.6	1.20	<MDA		<MDA		<MDA		<MDA		<MDA		<MDA		<MDA		<MDA		<MDA	
SS-014	<MDA		14.5	3.31	<MDA		1.01	0.34	<MDA		<MDA		<MDA		<MDA		<MDA		<MDA		<MDA	
SS-014 - offsite	<MDA		14.44	4.26	<MDA		1.08	0.16	<MDA		<MDA		0.34	0.17	0.72	0.23	<MDA		<MDA		<MDA	
SS-014 DUP - offsite	<MDA		9.10	4.67	<MDA		0.95	0.29	<MDA		<MDA		<MDA		0.72	0.29	<MDA		<MDA		<MDA	
SS-016	<MDA		15.65	3.44	<MDA		<MDA		<MDA		<MDA		<MDA		<MDA		<MDA		<MDA		<MDA	
SS-016 - offsite	<MDA		10.8	1.3	<MDA		0.98	0.08	<MDA		<MDA		<MDA		0.61	0.08	<MDA		1.1	0.5	<MDA	
SS-024	<MDA		6.72	2.09	<MDA		<MDA		<MDA		<MDA		<MDA		<MDA		<MDA		<MDA		<MDA	
SS-024 - offsite	<MDA		<MDA		<MDA		<MDA		<MDA		<MDA		<MDA		<MDA		<MDA		<MDA		<MDA	
SS-036	<MDA		9.63	1.99	<MDA		<MDA		<MDA		<MDA		<MDA		<MDA		<MDA		<MDA		<MDA	
SS-036 - offsite	<MDA		<MDA		<MDA		0.86	0.26	<MDA		<MDA		<MDA		<MDA		<MDA		<MDA		<MDA	
SS-038	<MDA		<MDA		<MDA		0.83	0.21	<MDA		<MDA		<MDA		<MDA		<MDA		<MDA		<MDA	
SS-038 - offsite	<MDA		<MDA		<MDA		0.81	0.17	<MDA		<MDA		<MDA		<MDA		<MDA		<MDA		<MDA	
SS-040	<MDA		<MDA		<MDA		0.76	0.16	<MDA		<MDA		<MDA		<MDA		<MDA		<MDA		<MDA	
SS-040 - offsite	<MDA		9.92	3.89	<MDA		0.99	0.14	<MDA		<MDA		0.33	0.16	0.93	0.21	<MDA		<MDA		<MDA	
SS-051	<MDA		<MDA		<MDA		<MDA		<MDA		<MDA		<MDA		<MDA		<MDA		<MDA		<MDA	
SS-051 - offsite	<MDA		8.89	1.51	<MDA		0.56	0.08	<MDA		<MDA		0.24	0.05	0.55	0.06	0.45	0.12	<MDA		<MDA	
SS-062	<MDA		<MDA		<MDA		<MDA		<MDA		<MDA		0.51	0.16	<MDA		<MDA		<MDA		<MDA	
SS-062 - offsite	0.1	0.03	10.13	1.74	<MDA		0.66	0.05	<MDA		<MDA		0.24	0.04	0.55	0.06	0.69	0.11	0.84	0.19	<MDA	
SS-064	<MDA		<MDA		<MDA		0.61	0.23	<MDA		<MDA		0.42		<MDA		<MDA		<MDA		<MDA	
SS-064 - offsite	<MDA		10.28	1.73	0.9	0.41	0.82	0.06	0.69	0.24	<MDA		0.25	0.05	0.71	0.06	0.76	0.1	0.98	0.34	<MDA	
SS-088	<MDA		14.12	3.81	<MDA		0.9	0.2	<MDA		<MDA		<MDA		<MDA		<MDA		<MDA		<MDA	
SS-088 - offsite	<MDA		14.8	2.10	<MDA		1.2	0.10	<MDA		<MDA		0.34	0.04	0.54	0.04	0.93	0.10	<MDA		2.8	1.2
SS-091	<MDA		<MDA		<MDA		1.1	0.28	<MDA		<MDA		<MDA		<MDA		<MDA		<MDA		<MDA	
SS-091 - offsite	<MDA		18.4	1.40	<MDA		1.2	0.08	<MDA		<MDA		0.36	0.03	0.56	0.04	1	0.10	1.2	0.20	<MDA	
SS-091 DUP - offsite	<MDA		16	2.40	<MDA		1.1	0.10	0.74	0.18	<MDA		0.34	0.04	0.65	0.05	1	0.10	0.95	0.19	<MDA	

[a] Matrix = Soil

[b] Standard deviation

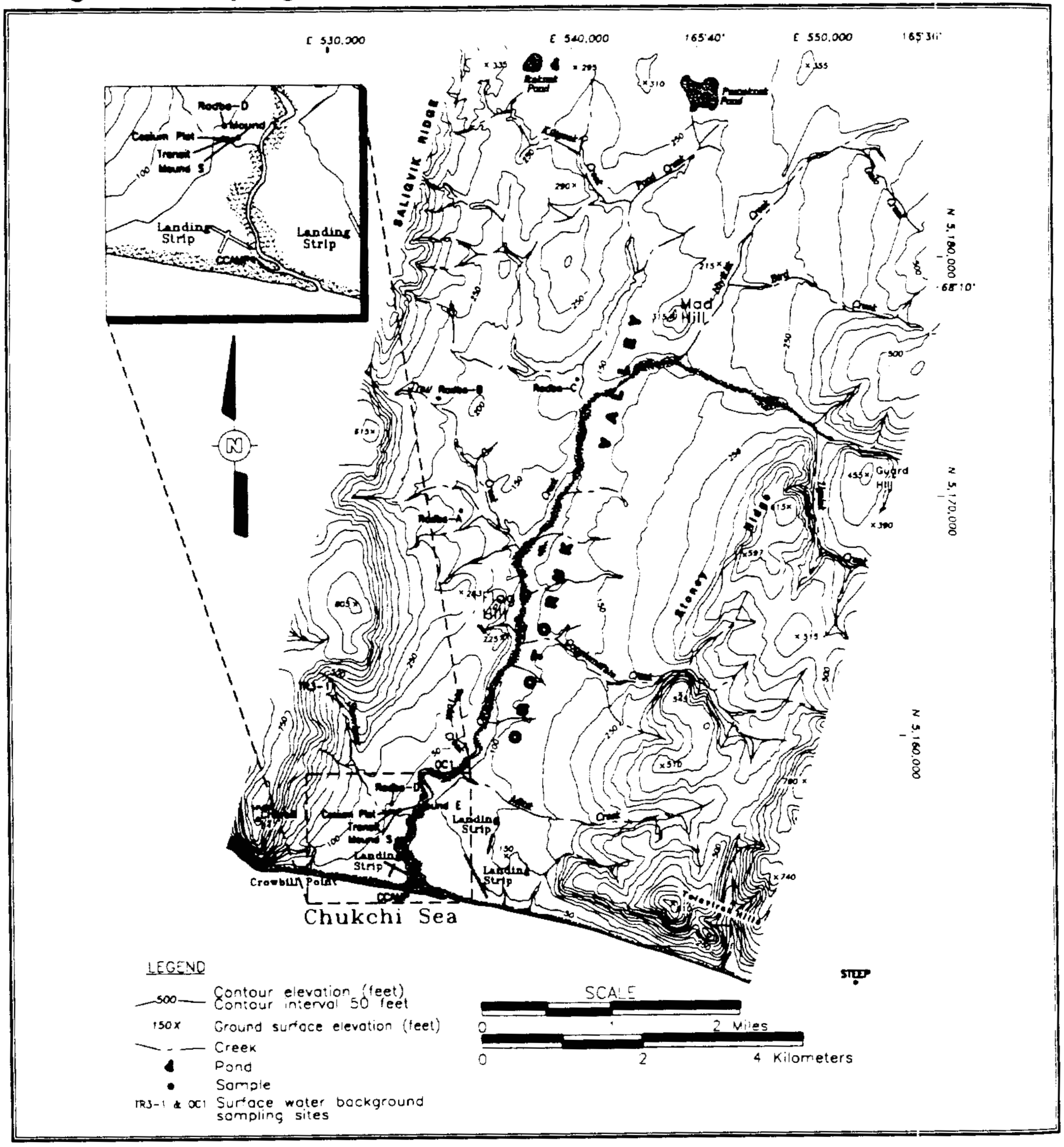
[c] Minimum detectable activity

5.6 Background Sampling

Background (control) samples were required to compare site conditions to the unaffected surrounding environment. This enables comparison between natural conditions and conditions influenced by man-made radioisotopes.

Representative background samples of surface water and sediment were collected at two locations upstream from the disposal mound. The sample locations were within Ogotoruk Creek and at the upper reach of Snowbank Creek. All selected background sampling locations were judged to be outside the influence of past activities conducted by AEC. These locations were selected based on a review of the historical data and field reconnaissance. Background stations are plotted on Figure 5-5.

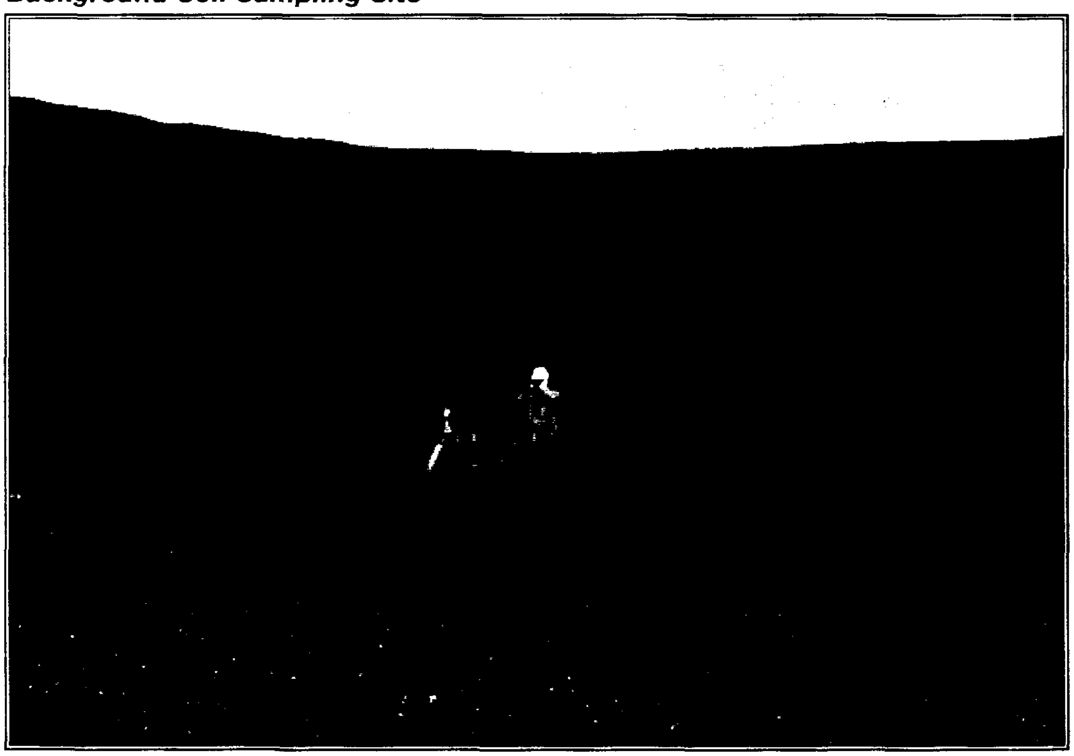
Figure 5-5
Background Sampling Locations



All background soil samples were collected in 5-cm (2-in.) depth increments (Figure 5-6). Background soil sampling was performed in the top 5 cm (2 in.) to determine the naturally occurring background levels of radioactivity. Selection of the criteria for defining an acceptable accuracy for background determination was based on the natural variations (of background levels) occurring in the environment.

Four background soil-sampling stations, A, B, C, and D, were chosen from undisturbed locations in the Ogotoruk Valley (Figure 5-5). One sampling location was located near the former disposal mound, and the other three were located several miles north into the Ogotoruk Valley. The original location selected for the surface-background soil sample near the disposal mound was east of Ogotoruk Creek, upstream from the confluence of Snowbank Creek and Ogotoruk Creek. This sampling location was subsequently changed due to the shale formations present in that area, which, although naturally occurring, contributed to higher radiation levels. The sampling station was relocated to 60 m (200 ft) west of the northwest corner of the EZ. This background location near the former disposal-mound site was chosen to establish a benchmark for comparison of contaminated areas to local background values. The other three locations were used to show the diversity of the background levels of radiation throughout the Ogotoruk Valley.

Figure 5-6
Background Soil Sampling Site



The soil sample results from these locations are found on Figures 5-7 through 5-10 (A, B, C, and D). At each background location, a 30-m by 30-m (100-ft by 100-ft) grid was constructed. Seven out of nine points within the grid were randomly identified for measurements.

The following radiation measurements were taken at each of the seven points:

- a 10-minute gamma-ray spectrum using the MCA for an in situ measurement with the shielded detector placed 1 m (3 ft) above the ground
- 1-minute and 10-minute counts using the ESP-2/NaI system with the shielded detector placed 1 m (3 ft) above the ground
- a 10-minute count using the PIC with the sensor placed 1 m (3 ft) above the ground.

An example of the MCA spectrum measured at Background Site D (Figure 5-11) indicated naturally occurring potassium-40 as the most dominant gamma radioisotope in the soil.

The aerial radiological surveys conducted by EG&G/EM indicated that there were background areas that exhibited radiation levels higher than the background average due to the associated outcroppings of black shale. The MCA was used to investigate and compare contaminated areas and background locations to confirm that the radiation from the outcropping of black shale was naturally occurring. Figure 5-12 illustrates the MCA spectrum measured at one of these shale outcrops. This spectrum indicated that the gamma radiation emitted from the shale was from naturally occurring potassium-40 and thallium-208.

Surface soil samples were analyzed on-site by gamma spectroscopy. Naturally occurring potassium-40 was detected in almost all samples taken with approximately 1.2 Bq/g (32 pCi/g) being the highest activity. The background soil sample analyses for Cs-137 resulted in activities below the detection limit of the gamma-spectroscopy instrumentation in all samples. A sample of moss collected at one of the background soil sampling locations indicated levels of Cs-137 above the detection limit. Moss and lichen both accumulate fallout by direct deposition. The Cs-137 activity of the moss sample was 0.073 Bq/g (1.97 pCi/g), which is consistent with radioactivity concentrations in this area as a result of world-wide fallout. This sample was taken at Background Site B, located several miles north of the Base Camp in the Ogotoruk Valley. For comparison purposes, Cs-137 activity up to 27 Bq/g (728 pCi/g) for the test-plot area and 219.3 Bq/g (5,927 pCi/g) for the mound was detected. The highest Cs-137 activity detected in soil samples used to confirm clean closure of the mound was 3.16 pCi/g, which is far below the established clean-up level of 10 pCi/g.

Figures 5-7 through 5-10
Background Soil Sample Results at Locations A through D
(Grid Size 100' x 100' Readings Are in Picocuries per Gram for Cs-137)

Figure 5-7 Location A

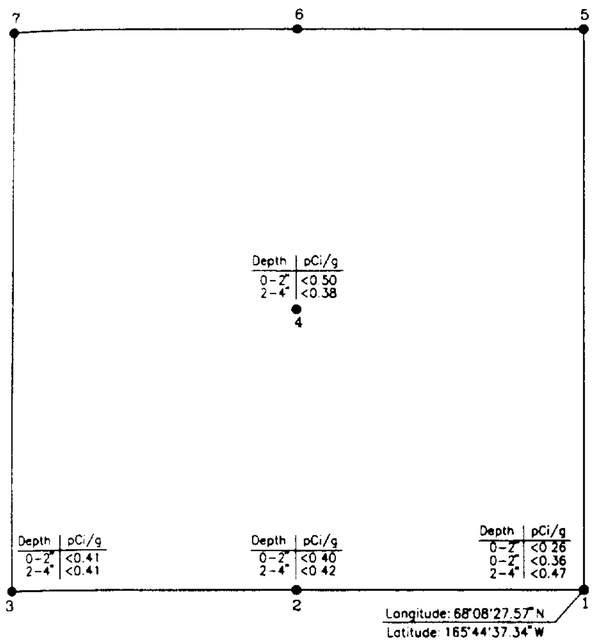


Figure 5-8 Location B

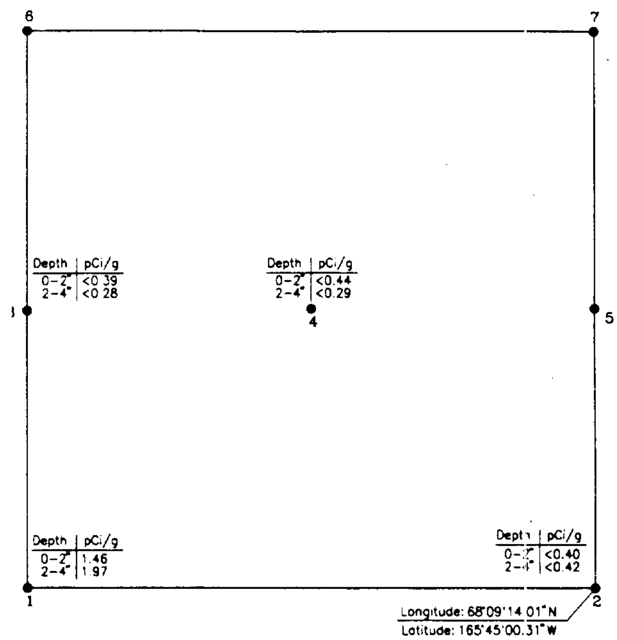


Figure 5-9 Location C

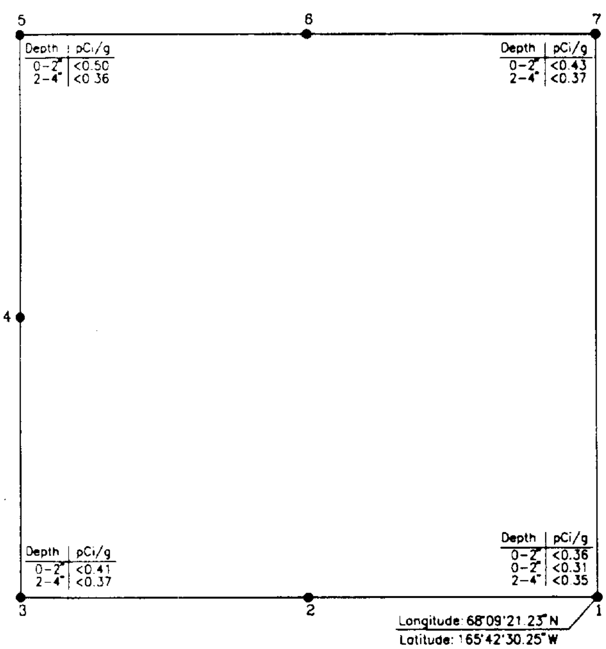
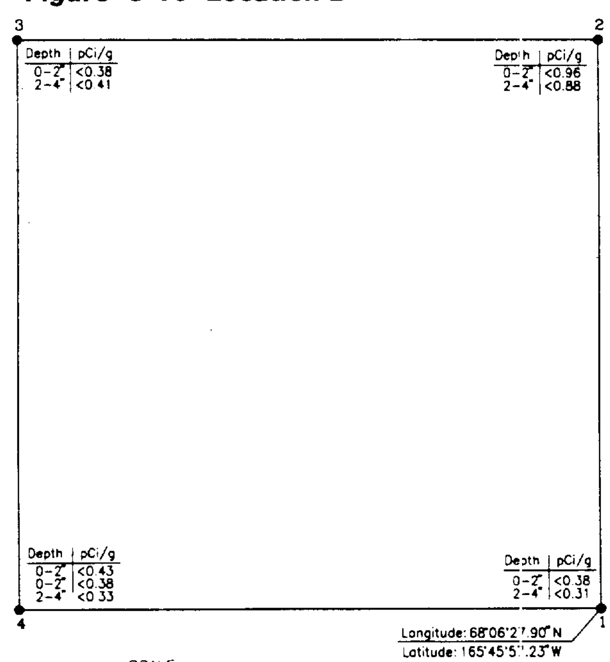


Figure 5-10 Location D



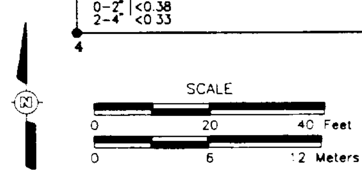
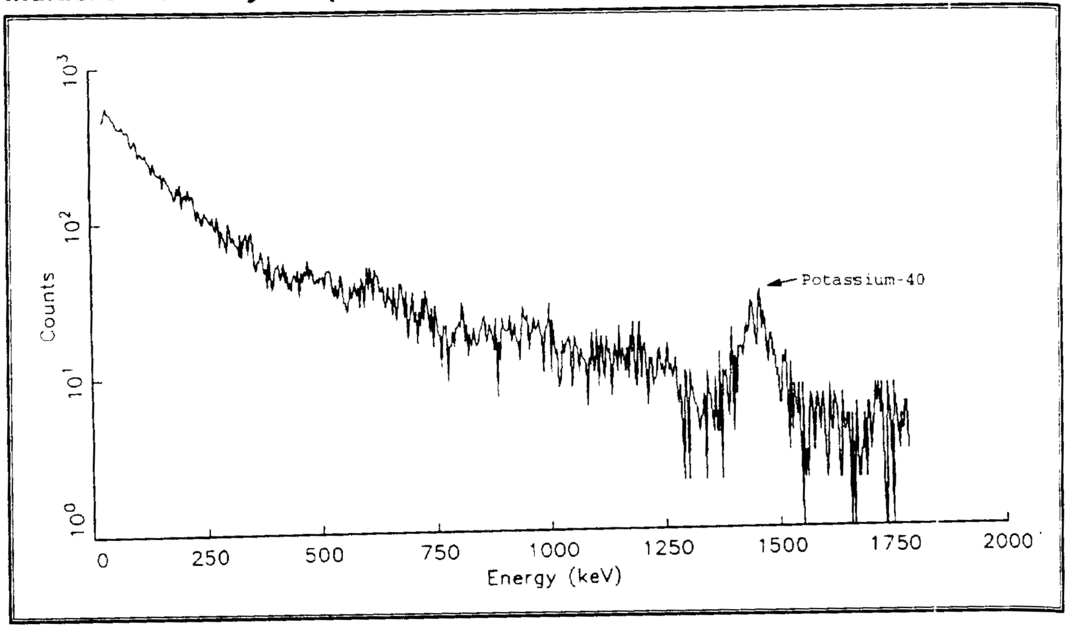


Figure 5-11
Multichannel Analyzer Spectrum for Background Area D (near Mound)



The gross alpha/beta analysis results for the mound and test-plot clean-closure composite samples were also compared to results for soil samples from the background location soil samples (as shown on Table 5-4). The comparison of these sample results indicated that the average gross-alpha and gross-beta activity in the clean-closure samples was less than those activity levels found in the background location samples.

Figure 5-12
Multichannel Analyzer Spectrum for Shale Outcrop along Snowbank Creek

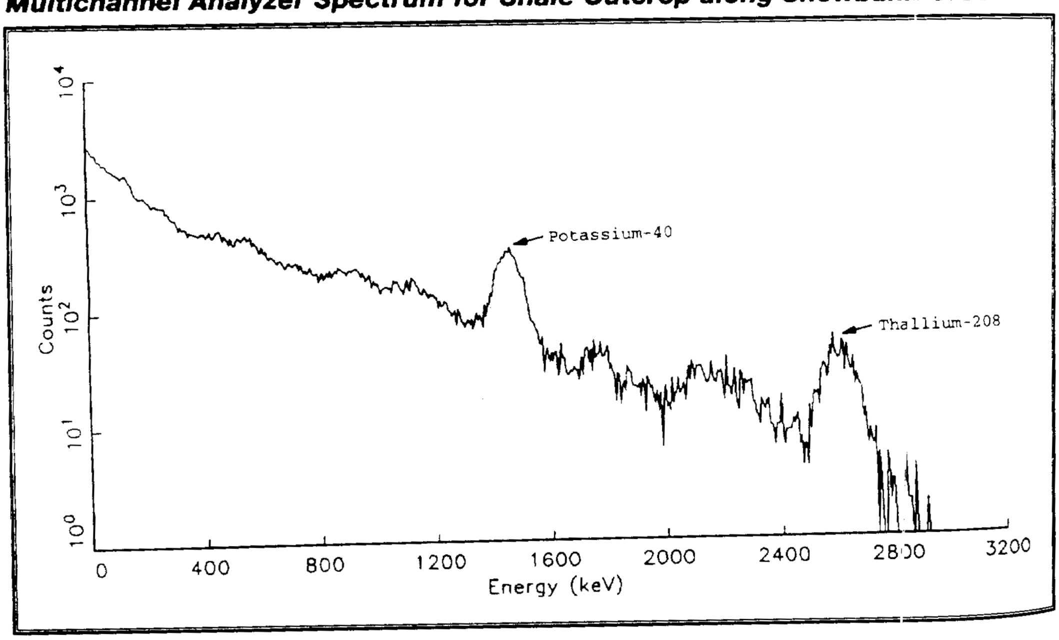


Table 5-4
Soil Samples Analyzed at the Off-Site Laboratory for Gross Alpha/Beta

Background Location Soil Sample Results (Gross Alpha/Beta Analysis)		
Sample Number	Gross Alpha (pCi/g)[a]	Gross Beta (pCi/g)
SS-007	14.1	20.9
SS-010	8.1	21.9
SS-014	10.0	24.6
SS-016	9.9	28.7
SS-088	10.4	29.3
SS-091	12.0	32.6
SS-024	8.4	21.0
AVERAGE	**10.4**	**25.6**

Mound Clean-Closure Soil Sample Results (Gross Alpha/Beta Analysis)		
Sample Number	Gross Alpha (pCi/g)	Gross Beta (pCi/g)
CHR-CC-N	5.7	17.8
CHR-CC-S	4.3	17.0
CHR-CC-E	7.6	21.3
CHR-CC-W	10.3	24.5
AVERAGE	**7.0**	**20.2**

Test-Plot Clean-Closure Soil Sample Results (Gross Alpha/Beta Analysis)		
Sample Number	Gross Alpha (pCi/g)	Gross Beta (pCi/g)
CHR-CC-P-N	9.8	24.6
CHR-CC-P-S	6.2	20.7
CHR-CC-P-E	5.2	23.1
CHR-CC-P-W	11.1	22.9
AVERAGE	**8.1**	**22.8**

[a] Picocuries per gram.

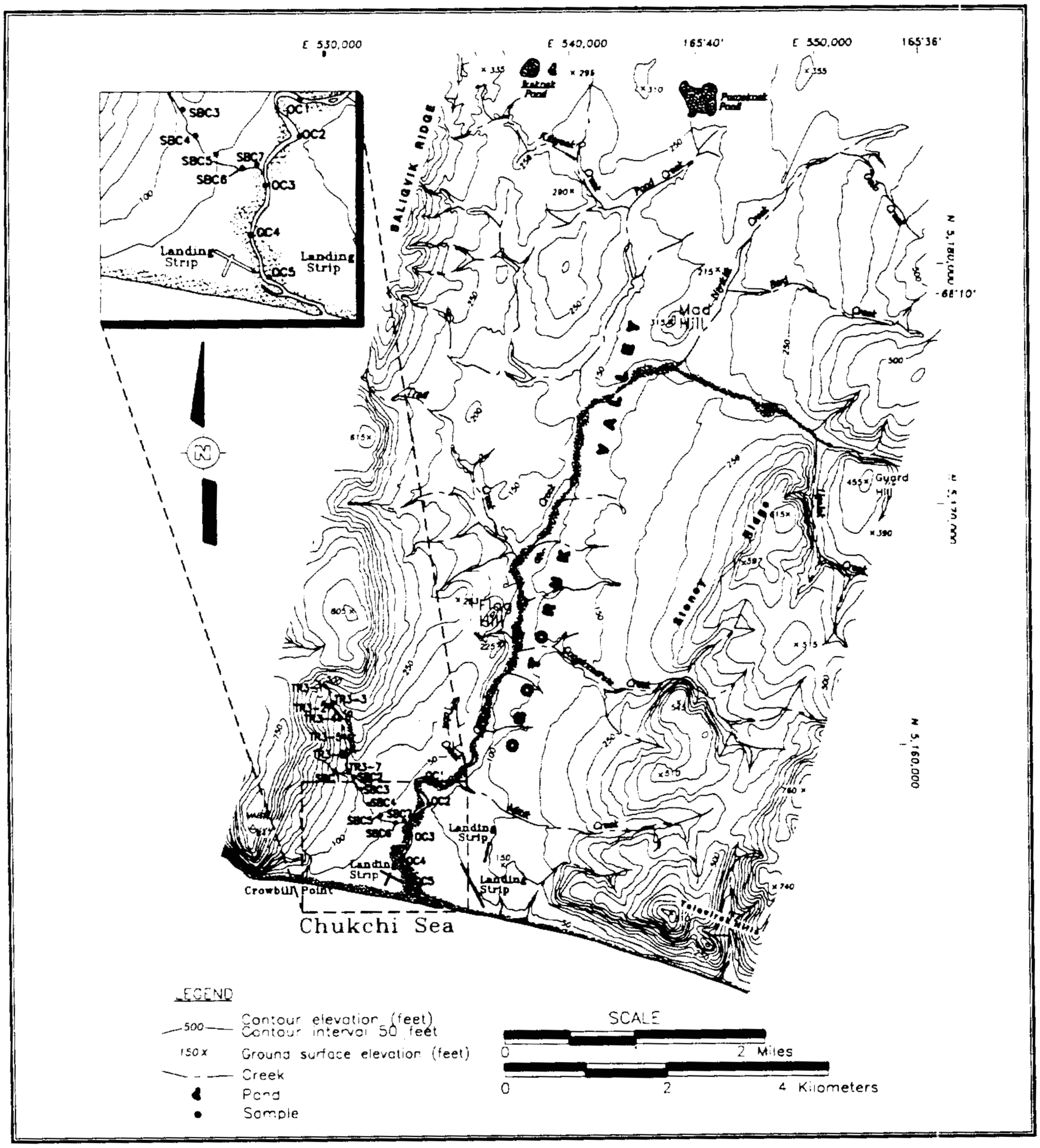
5.7 Surface Water and Sediment Sampling

The principal freshwater component of the Ogotoruk Valley is Ogotoruk Creek. The Ogotoruk Creek drainage is composed of numerous tributaries (Snowbank, Mitik, Tobit, Conglomerate, Trail, Kiliguak, and Niyklik Creeks) and two ponds (Ikaknak and Pumaknak) near its headwaters. Four bodies of water are within the area of concern: Ogotoruk Creek, the upper and lower reaches of Snowbank Creek, and an ephemeral pond near the disposal mound.

5.7.1 Description of Work Performed

On June 22, 1993, a site reconnaissance was conducted, and preliminary observations were made as to potential sampling locations and methods of collection. These observations were drafted into Appendix A, Part 1, Field Sampling Plan of the Sampling and Analysis Plan for Project Chariot: 1962 Tracer Study Remedial Action Plan.[2] In accordance with the Field Sampling Plan (FSP), representative surface water and sediment samples were to be collected to determine if residual tracer-study isotopes remained. The FSP called for 20 samples to be collected (14 from Snowbank Creek, 5 from Ogotoruk Creek, and 1 from the ephemeral pond at the mound site). Sample-identification numbers were then derived, and grab samples were collectec and submitted for radiological analysis. Figure 5-13 shows the actual locations of the sample stations.

Figure 5-13
Surface Water and Sediment Sampling Locations



During the USGS studies, the tributaries of Snowbank Creek were identified by consecutive number as they traveled away from Ogotoruk Creek. Tributary 1 was the first branch off Snowbank Creek. An interview with one of the USGS researchers indicated that Tributary 2 was a very small branch of Snowbank being only several inches wide and several feet long.[12] During recent site reconnaissance and during the surface water and sediment sampling, however, it was noted that what was once considered Tributary 2 was no longer identifiable. To prevent confusion concerning the naming of the upper tributaries of Snowbank Creek, it was decided that locations of the creek would be identified as being either the upper or lower reaches. The section of Snowbank Creek between Ogotoruk Creek and the first tributary was referred to as the "lower reach of Snowbank Creek." The section of Snowbank Creek from the first tributary traveling away from Ogotoruk Creek was referred to as the "upper reach of Snowbank Creek."

Sampling Procedure

The surface water and sediment sample-collection procedure is outlined below; complete Standard Operating Procedures (SOPs) used for collection of surface water, sediment, and supporting sampling documentation can be found in Appendix A, Part 3 of the Remedial Action Plan.[2] The general procedure used by field personnel was as follows:

- Bodies of water were measured along their length and flagged at 30-m (100-ft) increments, using a tape measure and pin flags.
- Specific sampling station locations were then selected based on these increments within Ogotoruk Creek and the upper and lower reaches of Snowbank Creek; these locations were then double flagged.
- Surface water grab samples were collected at midchannel at each station by directly dipping the sample container into the water upstream of the sampler and allowing the container to fill. The sample team collected split samples by using a disposable beaker and bucket and then transferring the water into appropriate sample containers (beakers were prerinsed with water from the sampling station site). In locations where it was impossible to collect at midchannel because of insufficient water, the sampling team found a location within the general vicinity where flow was obstructed and a pool was created. If this was not possible, sediment was removed with a decontaminated trowel to make a pooled area where the liquid could be collected after allowing for settling of the disturbed sediment.
- Sediment grab samples were also collected at midchannel at each station using a decontaminated trowel. Sample volumes for split samples were collected into a stainless-steel mixing bowl, mixed, and then placed into appropriate containers. For locations where it was impossible to collect at midchannel because of insufficient sediment, the sampling team found a

location within the general vicinity where sediments were available. If true sediments could not be located, a sample of bottom gravel was collected.

- Temperature, pH, conductivity, salinity, and dissolved oxygen readings of the surface water were taken and documented during sampling activities at each of the stations.
- Two sets of sediment and surface water samples were collected at each station. These included a sample for on-site analysis and off-site confirmatory analysis.
- The sampling team used prelabelled sample containers. Sample containers for water samples were received from the laboratory with preservative already in the bottles. The sampling team wiped the sample containers clean, placed them into a cooler, and brought them back to the Base Camp.
- Applicable information regarding the sample (type, location, date and time of collection, sampler's name, and analysis requested) was recorded in the field on sample labels, Field Activity Daily Logs, and Sample Collection Logs before leaving the station.
- Chain-of-custody was maintained in the field by either keeping the samples in actual possession, within view, locked or sealed to prevent tampering, or placed in a secure area.
- Once back at camp, sample pH was checked and adjusted as needed. Sample containers were sealed with custody tape, placed into a Ziploc™ bag, sealed again with custody tape, and placed into a larger plastic bag inside a cooler prepared for off-site shipment.
- Chain-of-Custody/Request for Analysis Forms were completed and placed in the shipment coolers.

Both written and photographic documentation of all segments of the field activities were recorded using field, photo, and sample collection logs.

Grab samples are discrete aliquots that are representative of one specific sample site at a specific point in time. Grab samples were appropriate since the sources or conditions were expected to be consistent over both the period of field activities and the geographical area. Additionally, the entire sample was collected at one particular point and all at one time.

5.7.2 Analytical Results

Surface water and sediment samples collected at the Project Chariot Site were initially analyzed in the on-site laboratory (gamma spectra) and then sent to the off-site laboratory for more detailed analyses. The analyses included gross alpha; gross beta; Cs-134 and 137; potassium 40; lead 210 and 212; bismuth 212 and 214; thallium 208; radium 223, 224, 226, and 228; thorium 234 and

228; uranium 235; and protactinium 231 and 234. The surface water and sediment samples collected at the site were not analyzed for Strontium-90 (Sr-90) by DOE because Sr-90 did not make up a principal portion of any of the radioactive tracer material used by the USGS.

Activities of the radioisotopes were expressed in terms of either picocuries per liter (pCi/l) in the case of surface water or picocuries per gram (pCi/g) for sediments, to two significant digits. The error of measurement (mean ± two standard deviations) and minimum detectable activity (MDA) were expressed to the same number of decimal places.

Surface Water

Thirty-three surface water samples were analyzed: 22 unique sample locations (stations), 2 labelled duplicate samples, and 9 blind duplicate samples.

None of the samples analyzed was found to contain the following 16 isotopes: Cs-134; potassium 40; lead 210 and 212; bismuth 212 and 214; thallium 208; radium 223, 224, 226, and 228; thorium 234 and 228; uranium 235; and protactinium 231 or 234. Levels of Cs-137 and gross alpha and beta for each of the four bodies of water of concern are discussed below and are presented in Table 5-5.

Cesium-137 levels in surface water ranged from 5.30 pCi/l to 9.86 pCi/l. The average value detected was 7.36 ± 2.79 pCi/l. All of the surface water samples collected at the Project Chariot Site analyzed for Cs-137 were less than the background level (activity) of 9.86 pCi/l established for the Ogotoruk Creek.

Surface water activities for gross alpha and beta ranged from nondetect to 30.47 pCi/l for alpha and nondetect to 28.19 pCi/l for beta. The average value detected was 3.18 ± 14.39 pCi/l for alpha and 3.32 ± 11.41 pCi/l for beta. Of these samples, one (Ephemeral Pond Station 02, 30.47 pCi/l) was above the state of Alaska Drinking Water Regulations Maximum Contaminant Level of 15 pCi/l for alpha activity (18 AAC 80 1991). None of the samples analyzed was found to be above the Gross Beta Criterion of 50 pCi/l.

Ogotoruk Creek

Ogotoruk Creek surface water sample results for Cs-137 ranged from a low of 5.76 pCi/l to a high of 9.86 pCi/l. The mean result was 8.13 ± 3.66 pCi/l. The sample with the highest detected concentration occurred at Station 01, which was the background (control) station for surface bodies of water within the Ogotoruk Valley. Station 01 was located furthest upstream from the mound and test plots and was, therefore, thought to be free of any Project Chariot-related radiological contamination. The sample with the lowest-detected concentration of Cs-137 in Ogotoruk Creek occurred at Station 02 immediately downstream of the background location.

Table 5-5
Analytical Results for Surface Water and Sediment Samples
(Results in Picocuries per Liter and Picocuries per Gram)

Ephemeral Pond			Upper Reach of Snowbank Creek		
Surface Water	**Sediment**		**Surface Water**	**Sediment**	
ND to 30.47	2.54 to 15.85	Gross Alpha	0.93 to 1.66	0.59 to 15.21	Gross Alpha
0.36 to 28.19	5.87 to 23.23	Gross Beta	0.16 to 6.29	4.93 to 31.76	Gross Beta
5.82 to 8.10	0.02 to 0.32	Cesium 137	5.30 to 8.55	0.03 to 0.09	Cesium 137
ND	9.14 to 11.13	Potassium 40	ND	ND to 16.78	Potassium 40
ND	0.81 to 1.86	Lead 210	ND	ND to 2.00	Lead 210
ND	0.03 to 0.88	Lead 212	ND	ND to 1.03	Lead 212
ND	0.36 to 0.44	Bismuth 212	ND	ND to 0.67	Bismuth 212
ND	0.21 to 0.24	Thallium 208	ND	ND to 0,28	Thallium 208
ND	ND* to 0.17	Radium 223	ND	ND to 0.27	Radium 223
ND	0.05 to 0.79	Radium 226	ND	ND to 1.34	Radium 226
ND	0.62 to 0.83	Radium 228	ND	ND to 0.97	Radium 228
ND	0.24 to 0.89	Thorium 234	ND	ND to 1.16	Thorium 234
			ND	ND to 1.82	Thorium 228

Lower Reach of Snowbank Creek			Ogotoruk Creek		
Surface Water	**Sediment**		**Surface Water**	**Sediment**	
0.08 to 2.26	1.03 to 28.58	Gross Alpha	0.29 to 0.67	2.56 to 11.35	Gross Alpha
0.20 to 2.88	5.35 to 35.57	Gross Beta	0.76 to 4.58	4.63 to 28.98	Gross Beta
6.02 to 9.86	0.02 to 1.80	Cesium 137	5.76 to 9.86	0.02 to 0.08	Cesium 137
ND	ND to 41.75	Potassium 40	ND	ND to 19.58	Potassium 40
ND	ND to 10.16	Lead 210	ND	ND to 1.69	Lead 210
ND	ND to 1.26	Lead 212	ND	0.66 to 0.98	Lead 212
ND	ND to 0.84	Bismuth 212	ND	ND to 0.61	Bismuth 212
ND	ND to 0.06	Bismuth 214	ND	ND to 0.32	Thallium 208
ND	ND to 0.32	Thallium 208	ND	ND to 0.29	Radium 223
ND	ND to 0.33	Radium 223	ND	ND to 0.46	Radium 224
ND	ND to 1.41	Radium 226	ND	ND to 0.70	Radium 226
ND	ND to 0.97	Radium 228	ND	ND to 0.93	Radium 228
ND	ND to 1.52	Thorium 234	ND	ND to 0.96	Thorium 234
ND	ND to 3.82	Thorium 228	ND	ND to 1.97	Thorium 228
ND	ND to 3.62	Protactinium 234			

*ND - Not Detected

Ogotoruk Creek surface water sample results for gross alpha ranged from 0.29 to 0.67 pCi/l. The mean result was 0.34 ± 0.55 pCi/l. The sample with the highest detected concentration occurred at Station 03. Station 03 was located at the confluence of Snowbank and Ogotoruk Creeks downstream of the mound. The sample with the lowest detected concentration occurred at Station 04 downstream of the mound location. None of the samples analyzed from Ogotoruk Creek was found to be above the state of Alaska drinking water criteria for gross alpha activity.

Ogotoruk Creek surface water sample results for gross beta ranged from a low of 0.76 pCi/l to a high of 4.58 pCi/l. The mean result was 1.75 ± 2.35 pCi/l. The sample with the highest detected concentration occurred at Station 05 (blind-duplicate sample run). Station 05 was located at the confluence of Ogotoruk Creek and the Chukchi Sea 914.6 m (3,000 ft) downstream of the mound. The sample with the lowest detected concentration occurred at Station 02 immediately upstream of the confluence of Snowbank and Ogotoruk Creeks. None of the samples analyzed from Ogotoruk Creek was above the state of Alaska drinking water criteria for gross beta activity.

Lower Snowbank Creek

Lower Snowbank Creek surface water sample results for Cs-137 ranged from a low of 6.02 pCi/l at Station 03 to 9.86 pCi/l for Station 07. The mean result for all stations was 8.17 ± 2.84 pCi/l. At Station 07, three separate analyses were run. The results for these samples ranged from 7.22 to 9.86 pCi/l. The average of the three samples was 8.86 pCi/l. Additional stations, which were run for duplicate analysis, include Station 03 (average 6.37 pCi/l) and Station 05 (average 9.28 pCi/l). Based on the average for each of the Lower Snowbank Creek samples, all stations were determined to be below the Ogotoruk Creek background activity of 9.86 pCi/l for Cs-137.

Lower Snowbank Creek surface water sample results for gross alpha ranged from 0.08 pCi/l at Station 03 (blind-duplicate sample run) to 2.26 pCi/l for Station 06. The mean result for all stations collected was 1.06 ± 1.50 pCi/l. All stations sampled on Lower Snowbank Creek for gross alpha activity were determined to be below the state of Alaska drinking water criteria by at least an order of magnitude.

Lower Snowbank Creek surface water sample results for gross beta ranged from a low of 0.20 pCi/l at Station 02 to 2.88 pCi/l for Station 03. The mean result for all stations collected was 1.40 ± 1.77 pCi/l. All stations sampled on Lower Snowbank Creek for gross beta activity were determined to be below the state of Alaska drinking water criteria.

Upper Snowbank Creek

Upper Snowbank Creek surface water sample results for Cs-137 ranged from a low of 5.30 pCi/l for Station 07 (blind-duplicate sample run) to a high of

8.55 pCi/l for Station 05. The mean result for all stations collected was 7.01 ± 2.25 pCi/l. All locations sampled on Upper Snowbank Creek were below the Ogotoruk Creek background activity for Cs-137.

Upper Snowbank Creek surface water sample results for gross alpha ranged from a low of 0.93 pCi/l for Station 03 to a high of 1.66 pCi/l for Station 02. All locations sampled on Upper Snowbank Creek were determined to be below the state of Alaska drinking water criteria for gross alpha contamination.

Upper Snowbank Creek surface water sample results for gross beta ranged from a low of 0.16 pCi/l for Station 03 and 07 (blind-duplicate sample runs) to a high of 6.29 pCi/l for Station 02. The mean result for all stations collected was 1.61 ± 3.71 pCi/l. All locations sampled on the Upper Snowbank Creek were determined to be below the state of Alaska drinking water criteria for gross beta contamination.

Ephemeral Pond

Three locations from the ephemeral pond near the disposal mound were also sampled. The locations selected were downgradient of the mound. The lowest concentration of Cs-137 detected was 5.82 pCi/l; the highest was 8.10 pCi/l. The average for the pond samples was 7.19 ± 1.82 pCi/l. All samples were lower than the background activity for the Ogotoruk Creek.

The gross alpha activity ranged from nondetect (Station 03 and 01 blind duplicate) to 30.47 pCi/l (Station 02). The mean result for all stations collected was 14.01 ± 25.05 pCi/l. Station 02 (30.47 pCi/l) was found to be above the state of Alaska drinking water criteria.

Ephemeral-pond samples were also run for gross beta activity. The lowest concentration detected was 0.36 pCi/l at Station 01 (blind-duplicate sample) to a high of 28.19 pCi/l at Station 02. The mean result for all stations collected was 11.26 ± 20.59 pCi/l. None of the samples analyzed was found to be above the state of Alaska drinking water criteria for gross beta activity.

Sediment

Thirty-two sediment samples were analyzed. Of these samples, none contained cesium-134, barium 140, uranium 235, or protactinium 231. Levels of the other fourteen isotopic analyses and gross alpha and beta scans (in pCi/g) for each of the four bodies of water of concern were within the ranges presented in Table 5-5.

Ogotoruk Creek samples ranged from 0.02 to 0.08 pCi/g for Cs-137. The lowest detected concentration occurred at Station 05 (blind-duplicate run), which was located at the confluence of Ogotoruk Creek and the Chukchi Sea, and the highest occurred at Station 01, which represented the background location. In all, seven samples were analyzed from five different locations on Ogotoruk Creek. The average for all samples on Ogotoruk Creek was 0.06 ± 0.05 pCi/g.

Ogotoruk Creek samples analyzed for gross-alpha activity ranged from 2.56 to 11.35 pCi/g, while the results for gross-beta activity went from 4.63 to 28.98 pCi/g. The lowest detected alpha activity occurred at Station 05 (blind-duplicate run), which was located at the confluence of Ogotoruk Creek and the Chukchi Sea. The highest activity occurred at Station 02, which was located between the disposal mound and the background station. The lowest detected beta activity occurred at Station 05 (blind-duplicate run); the highest occurred at Station 04, which was located between the disposal mound and the Chukchi Sea. A duplicate, a blind duplicate, and the original sample were run at Station 05. The average activity of the Station 05 samples was 5.79 pCi/g for alpha and 19.38 pCi/g for beta. In all, seven samples were analyzed from five different locations on Ogotoruk Creek. The average alpha activity for all samples on Ogotoruk Creek was 7.62 ± 5.24 pCi/g. The average beta activity for all samples on Ogotoruk Creek was 23.66 ± 17.17 pCi/g.

Lower Snowbank Creek samples ranged from 0.02 to 1.80 pCi/g for Cs-137. In all, 11 samples were analyzed from 7 different locations on lower Snowbank Creek. The average for all samples on lower Snowbank Creek was 0.43 ± 1.38 pCi/g.

Lower Snowbank Creek samples analyzed for gross alpha activity ranged from 1.03 to 28.58 pCi/g. The results for gross beta activity ranged from 5.35 to 35.57 pCi/g. The lowest detected beta activity occurred at Station 05 (blind-duplicate run), which was located adjacent to the disposal mound; the highest also occurred at Station 05. The average alpha activity for all samples on lower Snowbank Creek was 9.11 ± 18.28 pCi/g. The average beta activity was 20.40 ± 21.98 pCi/g.

Upper Snowbank Creek samples ranged from 0.03 to 0.09 pCi/g for Cs-137. The lowest detected concentration occurred at Station 07 (blind-duplicate sample run), which was located at the first confluence of upper Snowbank Creek, and the highest at Station 01 from the northernmost fork of the tributary. In all, ten samples were analyzed from seven different locations on the upper portion of Snowbank Creek. The average for all samples from the upper portion of Snowbank Creek was 0.06 ± 0.04 pCi/g.

Upper Snowbank Creek samples analyzed for gross alpha activity ranged from 0.59 to 15.21 pCi/g. The results for gross beta activity ranged from 4.93 to 31.76 pCi/g. The lowest detected beta activity occurred at Station 03 (blind-duplicate run), which was located upstream of the northern fork of upper Snowbank Creek; the highest occurred at Station 07. The average alpha activity for all samples was 5.98 ± 10.89 pCi/g. The average beta activity for all samples was 18.36 ± 22.98 pCi/g.

The ephemeral-pond samples ranged from 0.02 to 0.32 pCi/g for Cs-137. These results were from Location 02 at the pond (blind-duplicate runs with an average of 0.13 pCi/g). In all, four samples were analyzed from two different locations at the ephemeral pond. The average for all samples at the pond was 0.13 ± 0.27 pCi/g.

The ephemeral pond samples analyzed for gross alpha activity ranged from 2.54 to 15.85 pCi/g. The results for gross beta activity went from 5.87 to 23.23 pCi/g. In all, four samples were analyzed from two different locations at the ephemeral pond. The average for all samples at the pond was 9.49 ± 10.90 pCi/g for alpha activity and 18.02 ± 16.33 pCi/g for beta activity.

5.8 Radiological Surveys

Radiological surveys were performed to:

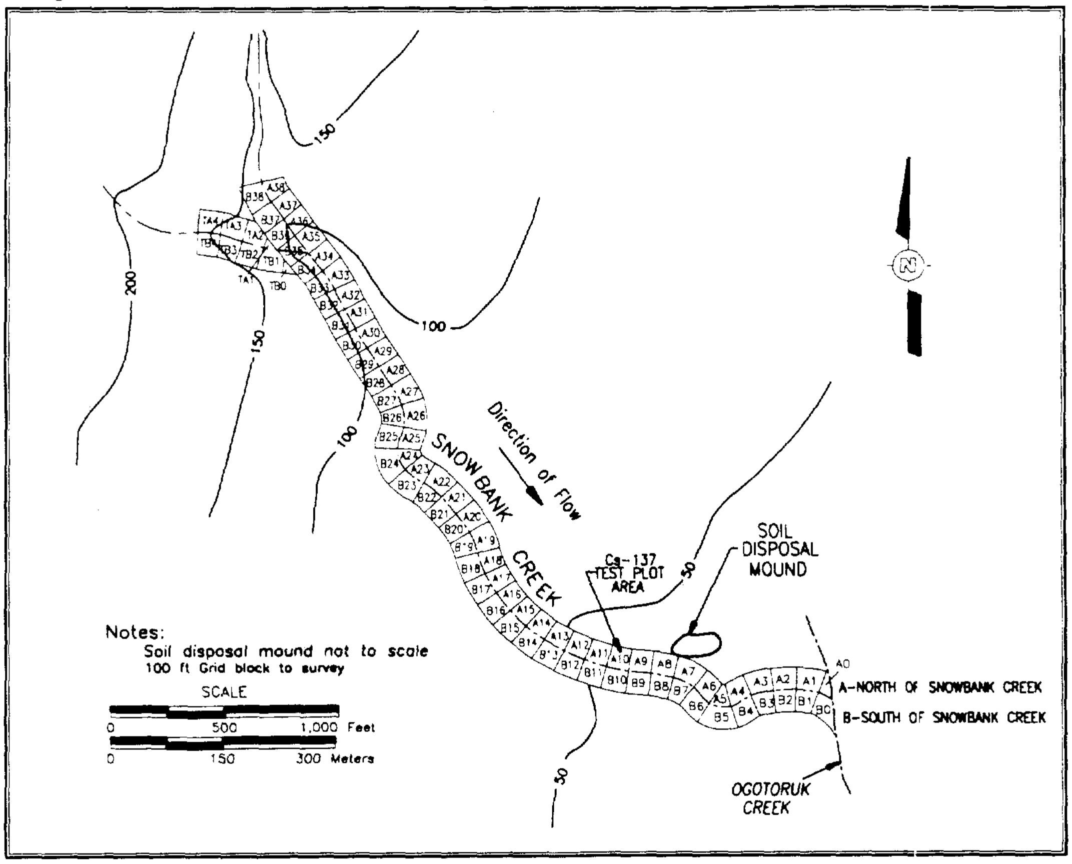
- locate the original tracer-study test plots
- determine whether residual radioisotopes remained upon excavation of the disposal mound and Cs-137 test plots
- characterize the surface radiation levels along Snowbank Creek, its tributaries, and Ogotoruk Creek
- identify any areas of radiological contamination between each lift of soil from the mound.

The radiation survey and screening process at the mound continued until noncontaminated soil was reached at the bottom of the excavation, as discussed in Section 6.1.

A visual examination of the tundra was conducted on each side of Snowbank Creek in an attempt to locate the experimental test plots. The visual inspection began at the junction of Ogotoruk and Snowbank Creeks and ended where the Snowbank tributaries began. No disturbed areas were identified that may have constituted a former test plot.

Before performing the radiation survey, a grid was established along Snowbank Creek. Historical information showed that all the test plots were west of the mound. The test-plot survey grid began at the junction of Snowbank and Ogotoruk Creeks, approximately 200 m (660 ft) east of the mound. The western boundary of the grid was at the confluence of Tributary No. 1 and Snowbank Creek. The grid continued along each stream to 150 m (500 ft) beyond the confluence of Tributary No. 1 and Snowbank Creek as shown in Figure 5-14. A benchmark was established as a reference point for the grid. This reference point was then surveyed by the GPS team. This grid system extended 30 m (100 ft) beyond the banks of Snowbank Creek to the north and south as shown in Figure 5-14. The limiting distance from the creek was set at 30 m (100 ft) based on an interview with a former USGS researcher in which he indicated that all test plots were within 20 m (60 ft) of the creek.[12] The reason for limiting the

Figure 5-14
Diagram of Radiation Survey Grid System



test plots to within 20 m (60 ft) of the creek was that the USGS investigators had only 15 m (50 ft) of garden hose attached to the gasoline-powered pump used to supply the water to the plots. The grid consisted of mutually perpendicular lines spaced at equal intervals, dividing the survey area into equal 30-m by 30-m (100-ft by 100-ft) sections. The meandering of the creek resulted in trapezoid-shaped grid sections in some areas. West of the disposal mound, Snowbank Creek was confined to a narrow ravine so that when the creek broke into two or more channels, its total width was less than 9 m (30 ft). Beginning approximately at the disposal mound, the side channels meander much wider than 20 m (60 ft) and form marshes on the north side of the creek. One such channel and marsh is located close to the disposal mound.

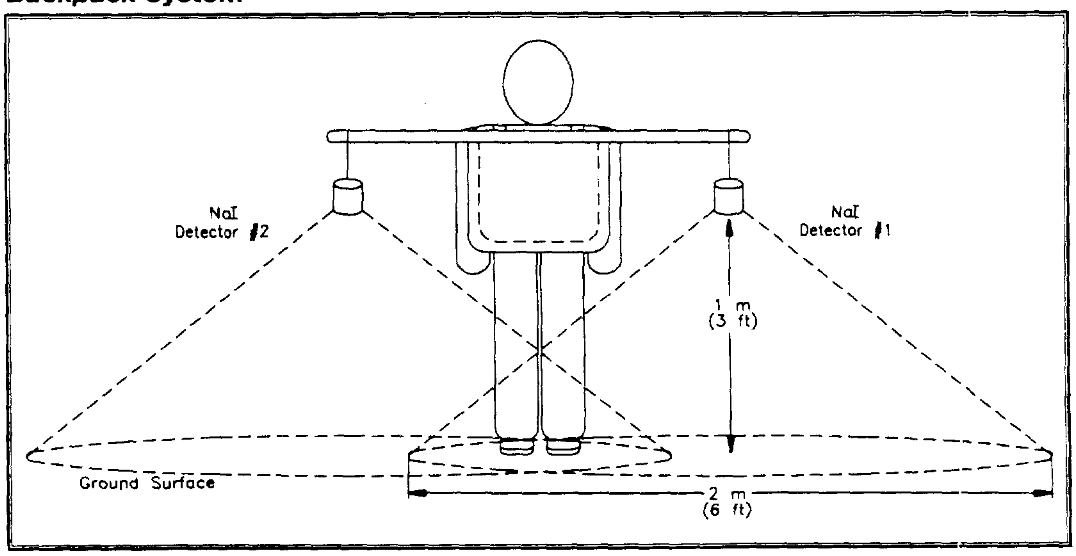
The grid system, as initially laid out, did not include Test Plots 112 and 117, the disposal mound, or a portion of the small marsh (Figure 1-4). Test Plot 117 was the sediment-transport test. It was located on the upper reach of Snowbank Creek. This plot was investigated by taking sediment samples along the upper and lower reaches of Snowbank Creek. The surrounding area was also surveyed with radiation detection equipment to ensure that no contamination remained from the 1962 study. Test Plot 112 was identified visually on a tributary of Snowbank Creek. The test-plot area was identified using a photograph of the test plot taken during the original experiments and by ground disturbance resulting from those experiments. The original sign was found. Test Plot 112 originally contained Sr-85, which, with a 64-day half-life, had since decayed away. This area was surveyed with the MCA and NaI detector to verify that it was not radioactively contaminated. No radioactivity was found other than that due to natural background.

The disposal mound was located 6 m (20 ft) north of the initial grid. The grid was, therefore, extended to include the entire EZ in order to cover the mound and the region that could have been supplied by the marsh. The area in the EZ around the disposal mound was surveyed as a separate unit from the grid system, and the small channel south of the mound was completely surveyed.

Of the 10 test plots (2 located beneath the mound) included in the survey, only 3 were expected to contain any contamination. These were Test Plots 105, 106, and 107, the plots that received Cs-137. The remaining test plots, including Test Plots 112 and 117, were tests with radioisotopes that would have since decayed to background levels. Therefore, elevated levels of radioactivity were not expected at these locations.

The areas within the grid were radiologically surveyed on foot with a backpack detection system. This system was comprised of a backpack frame with a mounted bar from which two NaI detectors were suspended (Figure 5-15). The detection system consisted of two Eberline ESP-2 ratemeters coupled with two 3-by 3-in. NaI detectors. The detectors were shielded with approximately 2 cm (3/4 in.) of lead to collimate the detectors' field of view to approximately

Figure 5-15
Backpack System



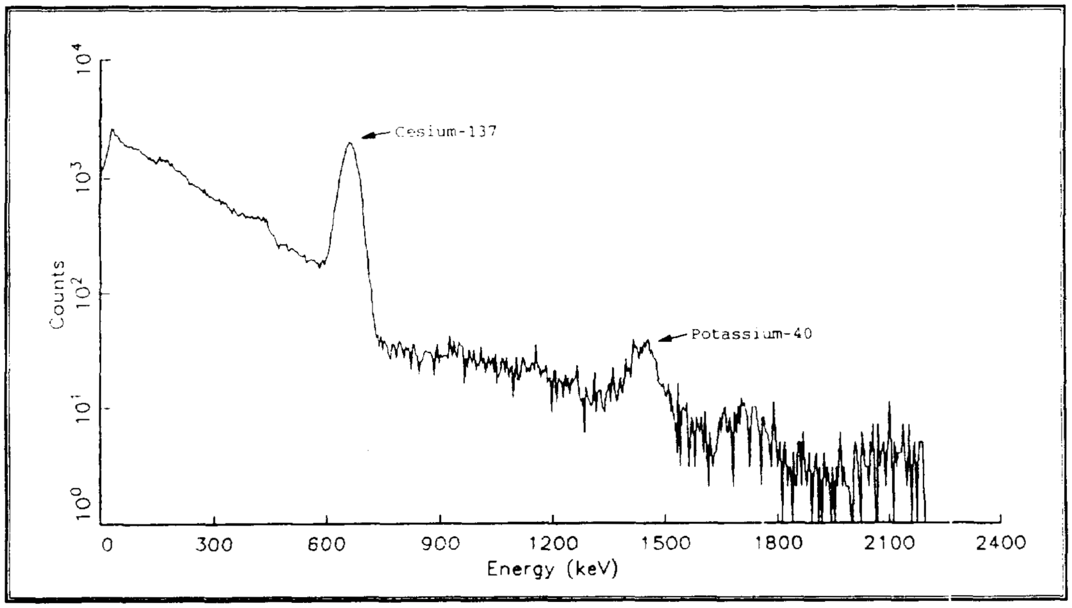
2 m (7 ft) when held 1 m (3 ft) above the ground surface. The ESP-2 ratemeter was set to measure the gamma energy for Cs-137. The alarm on the ESP-2 was set to respond if the cpm measured greater than the 95-percent lower limit of detection (LLD). This is the level at which there is a 95-percent confidence that the measurement is higher than background levels.

This system allowed the technician to cover nearly twice as much area since each detector was shielded to observe a 2-m (7-ft) diameter area. The technician walked at a slow rate (approximately 1 meter per second [3 feet per second]). Areas having increased levels of Cs-137 (greater than 95-percent LLD) tripped the alarm and were flagged. There were five areas in which the alarm sounded, including Grid B3 (two alarm points in this grid), Grid B4, Grid B5, and Grid A10 (Figure 5-14). Grid A10 contained the Cs-137 test-plot area. The areas were mapped and further monitored with the in situ MCA detection system to determine if Cs-137 was present. The MCA survey of alarm points in Grid B3, Grid B4, and Grid B5 indicated that no Cs-137 was present. Several other alarms that were noted during the walkover survey were attributed to an increase in background radiation as a result of potassium-40 in shale. The ESP-2 was calibrated in an area of low background radiation and set to respond to the Cs-137 energy region. The increased background potassium-40 in some of the areas surveyed resulted in an increase in background in the Cs-137 region causing the ESP-2 to alarm. In most areas where alarms were noted, shale was readily visible; therefore the alarm was easily interpreted. In Grid B3, Grid B4, and Grid B5, there was no shale visible on the surface of the ground because these areas were covered by vegetation. There was an increase in the amount of shale near the surface, resulting in an increase in potassium-40, thus causing the ESP-2 to alarm. The MCA survey of these areas indicated only natural background radiation.

A location of elevated radioactivity was found on the north side and within 4.6 m (15 ft) of Snowbank Creek and 70 m (225 ft) west of the disposal mound. The dimensions of the area and its close location to willows, as compared to the photographs of the test plots during the original tracer study, indicated that it was Test Plot 107. The MCA/NaI system was used to identify the contamination as Cs-137. Figure 5-16 illustrates the Cs-137 peak. The peak for naturally occurring potassium-40 can also be found in the spectrum. A soil sample was taken, and subsequent analyses indicated Cs-137 at approximately 26.9 Bq/g (727 pCi/g) for the highest concentration. This identification increased the likelihood that the location was Test Plot 107.

The areal extent of the contamination of the test-plot area was determined by scanning with the hand-held Eberline ESP-2/NaI detector approximately 8 cm (3 in.) above the surface. The survey extended from the most contaminated region until background was reached and the contaminated area was flagged. The contaminated area was found to be a broad crescent shape much larger than any single test plot. Examination of photographic records showed that

Figure 5-16
Multichannel Analyzer Spectrum of Test-Plot Area



Test Plots 105, 106, and 107 were located within a few feet of one another and near willows configured as those in and around the crescent-shaped area. The total area delineated was greater than that of all three Cs-137 test plots. Therefore, the area probably encompassed all three test plots and the deliberate overflows from activities at plots 105 and 107, as shown in Figure 5-17.

The contaminated area was marked off for removal in a rectangular area approximately 6 m by 5 m (19.5 ft by 16 ft). Composite soil sampling was then performed to characterize the radioactivity in the soil (Figure 5-18). It was this area from which soil was removed as part of the remedial action. For purposes of documenting this action, the area of soil removal was designated as the former Test Plot 107.

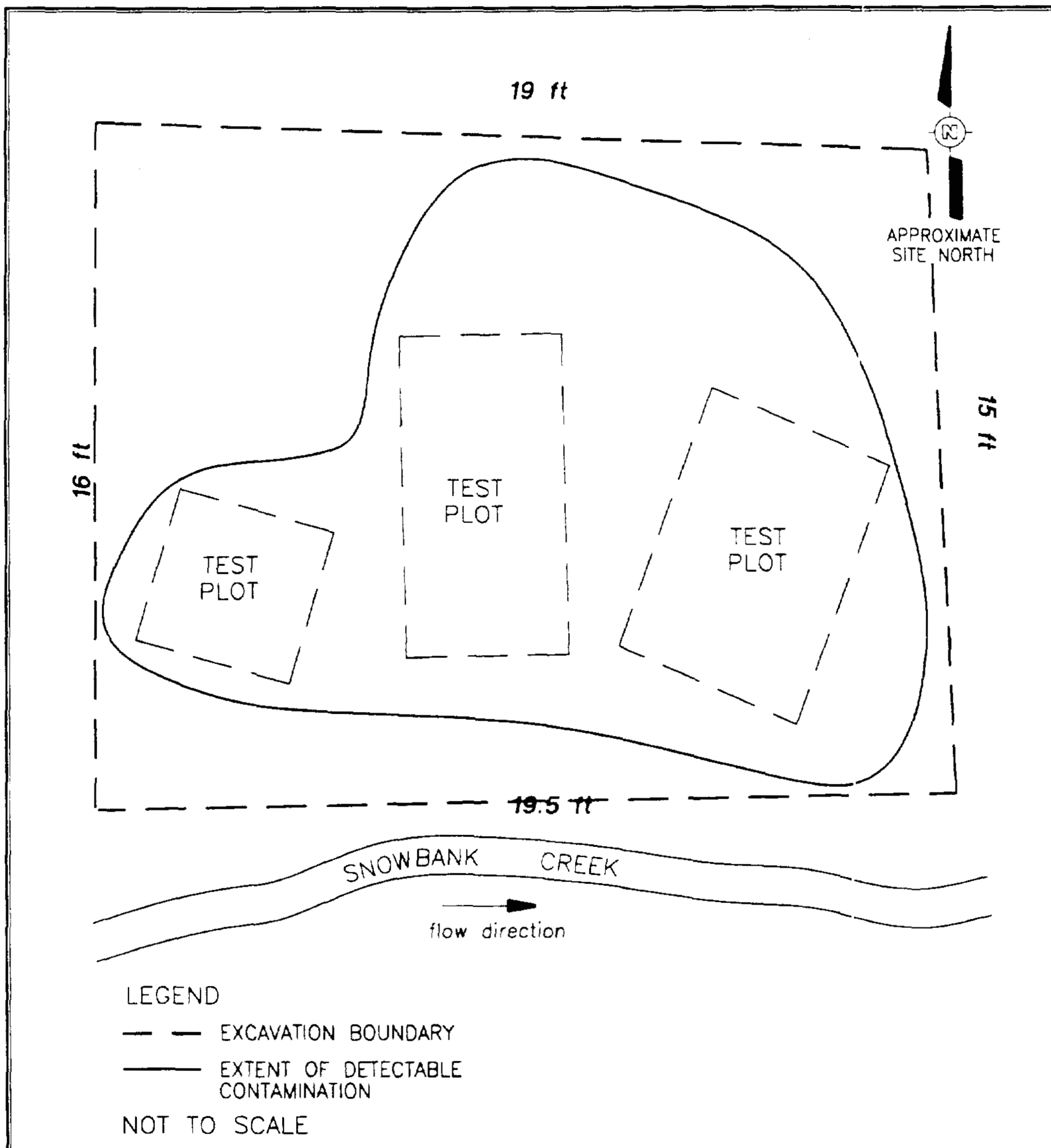
5.9 Biological Sampling

Biological sampling was performed to evaluate radioisotope concentrations in selected biota in the vicinity of the Project Chariot Site.

The objectives of the biological sampling program were to:

- obtain samples of selected biological tissues in the Project Chariot area
- measure radioisotope concentrations (especially Sr-90 and Cs-137) in the samples
- compare current results to past measurements
- make an evaluation of the radioecological significance of the results.

Figure 5-17
Simulated Location of Former Cs-137 Test Plots 105, 106, and 107

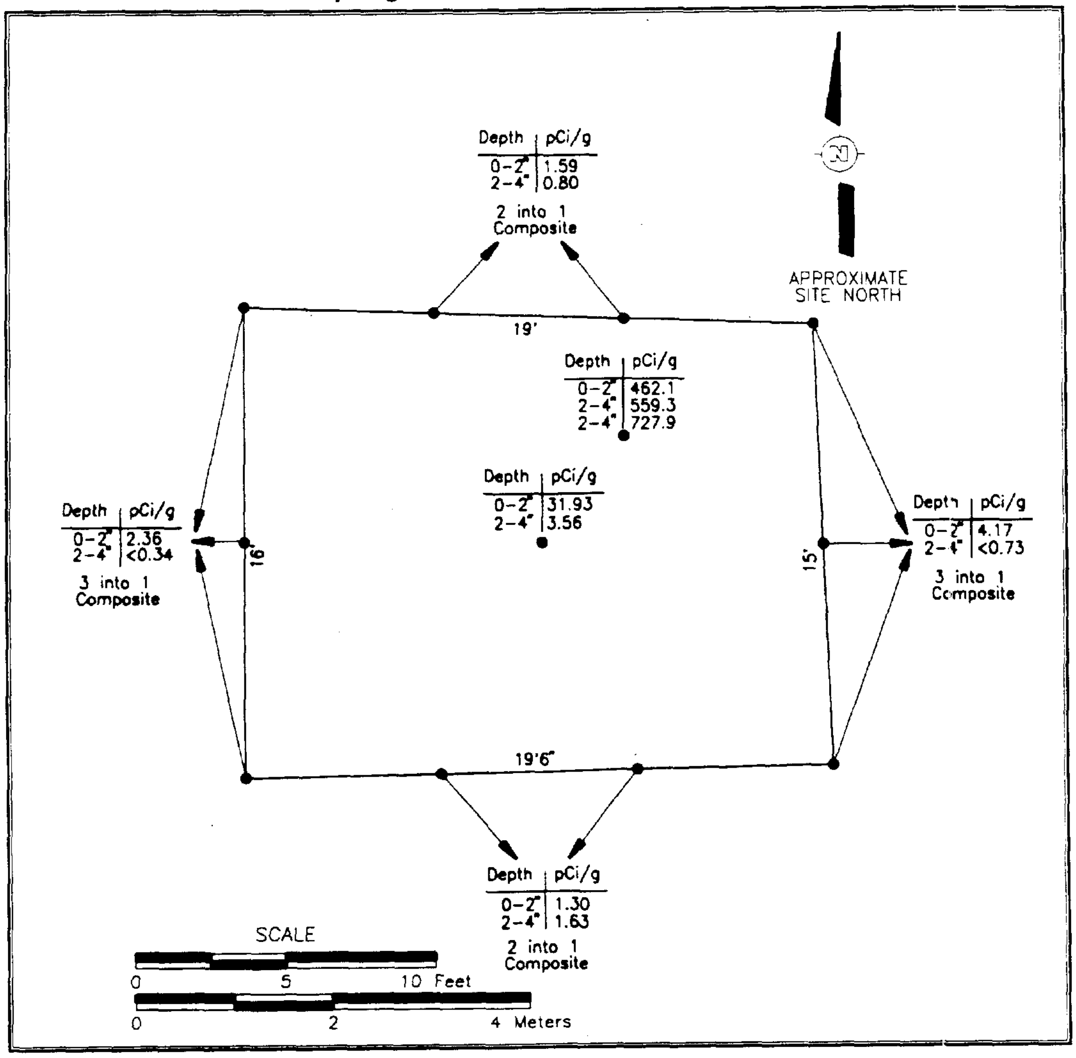


Biota sampling began on July 30, 1993, at the disposal mound. Vegetation samples were collected, and small mammal trapping began. The trapping continued until August 6, 1993, at which time remediation activities began and biota sampling activities ceased at the disposal mound. Biota sampling continued in other areas until August 23, 1993.

5.9.1 Vegetation

Vegetation samples were collected at 17 locations. With the exception of locations in Kisimilok Valley, the sampling locations were in the same general areas studied by AEC during 1959 through 1971 (Figure 5-19). Figure 5-20

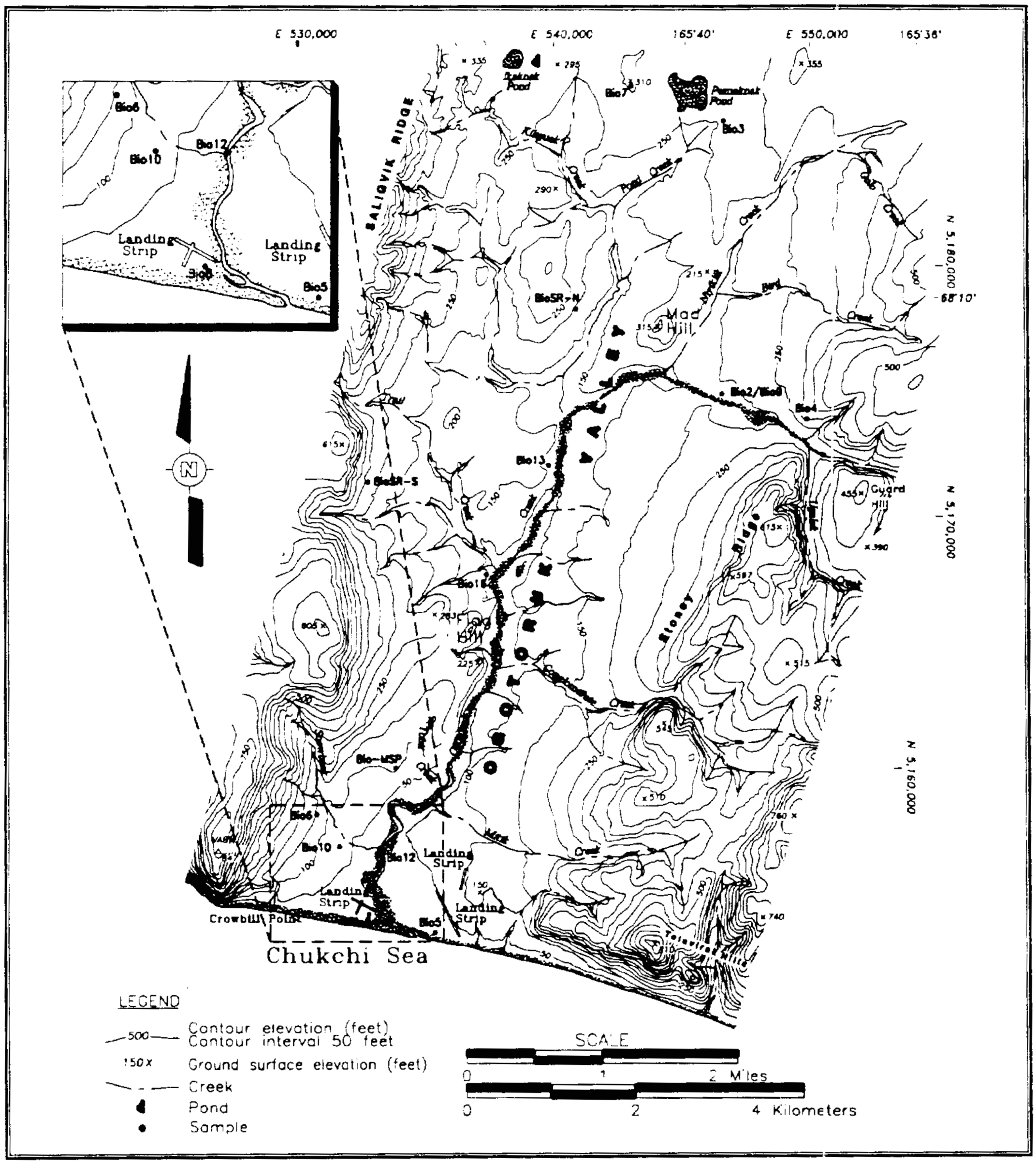
Figure 5-18
Former Cesium-137 Test-Plot Area
Pre-Excavation Soil Sampling Results in Picocuries per Gram



shows the sampling sites used from 1959-1961 and was the basis of designating the 1993 sampling locations. The 1971 sites were near Sites 4, 6, and 7 on Figure 5-20. Fourteen locations are in the Ogotoruk Valley, and three reference locations are in Kisimilok Valley. Samples of the following plant species were obtained:

- Fungi -various species, composited by location
- Lichens -*Cladina-Cetraria spp.; Cetraria delisei; C. cucullata; C. cucullata/C. islandica; Cornicularia spp.; Stereocaulon paschale*
- Grass -*Arctophila fulva*
- Sedges -*Carex aquatilis, C. bigelowii; Eriophorum vaginatum; E. angustifolium*

Figure 5-19
Biota Sampling Locations in Ogotoruk Valley 1993

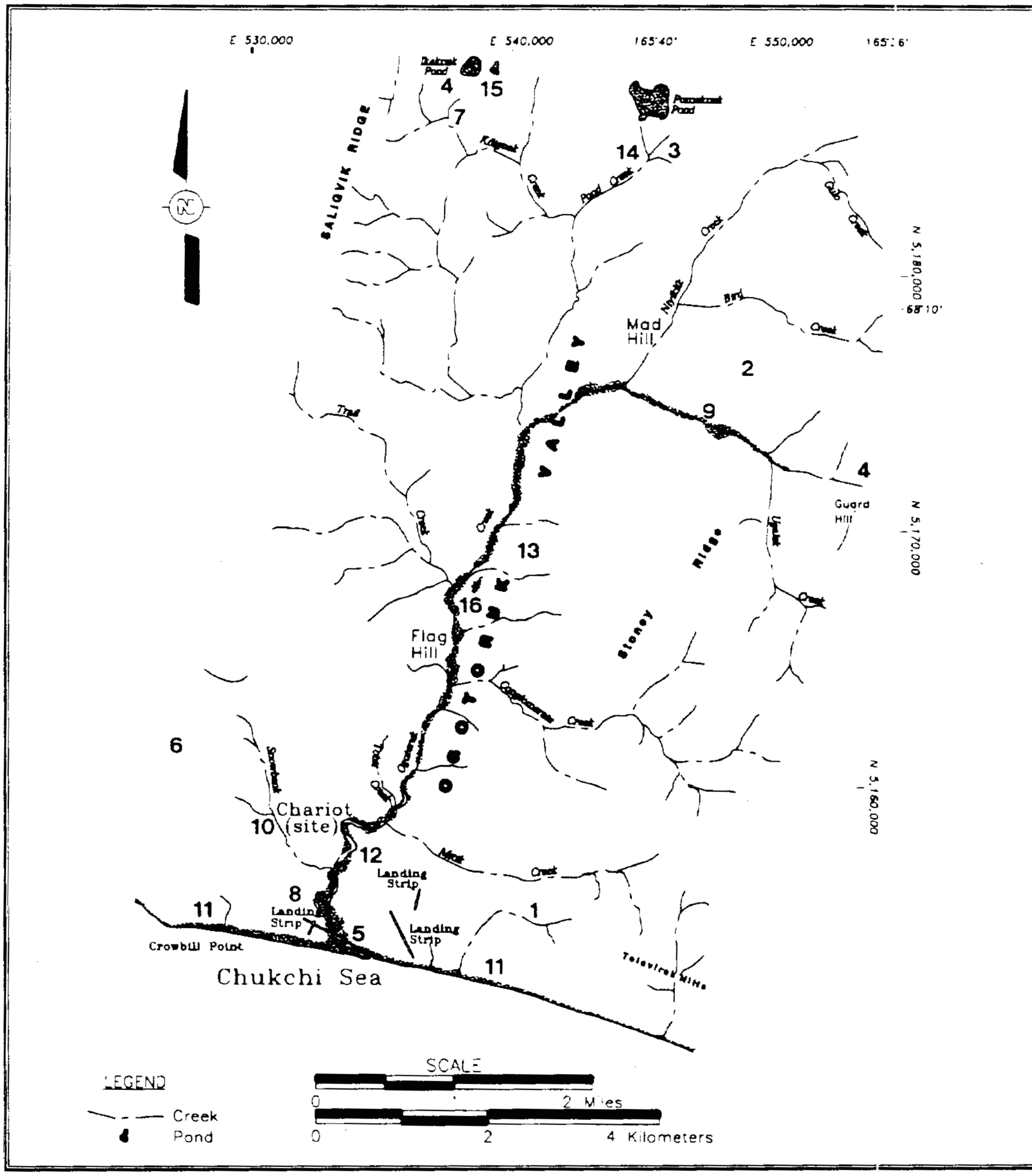


- Shrubs -Dryas octopetala, D. integrifolia (heath plants); Cassiope tetragona (heath plant); Salix alaxensis, S. lanata, S. planifolia var. pulchra (willows); Betula nana (birch); Ledum decumbens (labrador tea); Vaccinium uliginosum (blueberry).

A total of 151 vegetation samples was obtained. The various sample types are shown by location in Table 5-6 and summarized in Table 5-7.

A portable square-meter sampling frame was set within representative stands of the vegetation type to be sampled (Figure 5-21). All aboveground portions of plants within the frame were clipped or hand-picked, placed in Ziploc™ plastic

Figure 5-20
Biological Sampling Sites in Ogotoruk Valley during 1959 - 1971



bags, labeled, and closed with custody tape to preserve the integrity of the samples. Wherever possible, three vegetation samples were collected per square meter to provide average distribution and variation estimates of biomass and radioisotope inventories. Most lichen samples were collected from populations scattered over several square meters. Only *Cetraria delisei* (snowpatch lichen) occurred in continuous stands suitable for quadrate sampling. Snowpatch lichen was therefore substituted for *Masonhalea richardsonii* in the initially proposed sampling schedule.

Table 5-6
Types and Number of Biota Samples Collected at Project Chariot Locations

	Location																Kisimilok Valley			
	●	●	●	■	■	●	■	■	■	■	■		▲	▲	Cs-137	▲				
Sample Type	2	3	4	5	6	7	8	10	12	13	16	Mound	SR-N	SR-S	Plot	MSP	KV-1	KV-2	KV-3	Total
Lichens																				
Cladina-Cetraria					1	1		1				1	1	1			1			7
Cornlcularia		1				1														2
C. delisei	6	3	3			3		3												18
Other	1																			1
Fungi																				
Fungi	1	1		1	1	1						1	1	1						8
Sedges and Grass																				
Carex		3	3		3	3		3				6			4		3	3	3	34
Eriophorum						3		3				3								9
Erioph-Carex					3	3														6
Grass												3								3
Shrubs																				
Dryas					3								3	3						9
Willow								3	6	3	3	3			1		3	3	3	28
Labrador tea												2								2
Blueberries	3							1						3			2			9
Heather					3			3												6
Birch												6					3			9
Mammals																				
Voles/Lemmings	1				1			2			1	1					2			8
Ground Squirrels	3			3	2		5				1	5		2	2	3	4	2		32
Caribou																				24
Musk Oxen																				2
Grizzly Bear																				1
Birds																				
W. ptarmigan					3						4									7
Totals	15	8	6	4	20	15	5	19	6	3	9	31	5	10	7	3	18	8	6	225

● Upper Valley
■ Lower Valley
▲ Middle Valley

Table 5-7
Number of Samples Collected for Each Vegetation Type at Project Chariot during July-August 1993

Vegetation Type	Number
Lichens	28
Fungi	8
Grass	3
Sedges	49
Shrubs	63
TOTAL	**151**

Sampling of vegetation followed the proposed original Biota Sampling Task as nearly as possible. However, variations were required to adjust for (1) discontinuous distributions of plant species (especially lichen) since not all proposed sample types were available at desired locations; (2) the addition of sample types and locations to meet Point Hope and Kivalina villagers' requests; and (3) a more thorough description of radioisotope distribution, particularly in the vicinity of the disposal mound. Differences from the proposed number of vegetation samples in SOP-CHR-24 of the Site Assessment and Remedial Action Plan are shown in Table 5-8.

Figure 5-21
Collection of Vegetation Samples

Table 5-8
Variance from Proposed Vegetation Samples

Sample Type	No. Samples Proposed	No. Samples Obtained
Lichens	36	28
Fungi	0	8
Sedges/Grass	27	52
Shrubs	27	63

All vegetation samples collected from the disposal mound and test-plot area were screened for contamination with a Geiger-Muller counter prior to being removed from their plastic bags. At Base Camp, most vegetation samples were weighed, transferred to cheesecloth bags, and hung from the laboratory tent frame to dry. Samples were later transferred to a constant-temperature (100°C [212°F]) oven for 24 to 48 hours, then reweighed and returned to their original Ziploc™ bags to await milling. The oven, Ziploc™ bags, and other storage facilities were routinely sealed with custody tape to ensure sample integrity. The laboratory tent was either continuously occupied or locked to preserve sample integrity.

Once all vegetation samples had been collected and dried, they were individually processed in a Wiley mill, which ground the samples to pass through a 2-millimeter screen. Samples were milled in the following order: (1) from Kisimilok Valley (control location); (2) from upper Ogotoruk Valley (1959-1971 control locations); (3) from lower Ogotoruk Valley locations other than those from the disposal mound; and (4) from the mound area. The vegetation from the disposal-mound area was again screened for radioactive contamination prior to milling. Although no above-background readings were ever observed, this procedure reduced the potential for cross contamination of samples.

The list of biota samples was provided to ADEC and to a representative of Foster-Wheeler for their selection of desired sample splits for interlaboratory comparisons of radioisotope analyses. This provided a basis for decisions about combining dried samples to provide sufficient biomass for analyses.

Combining dried samples was especially critical in the case of lichens because of their very low biomass but relatively high specific radioactivity. Milled samples were placed directly in counting containers specified for each laboratory and sealed with custody tape. Four types of counting containers were used for radioisotope analyses: a 500-milliliter (ml) Marinelli beaker, a 250-ml gamma can, and 45- and 90-ml petri dishes, depending upon the amount of sample available. Analyses were conducted at the off-site laboratory, which is DOE- and Environmental Protection Agency (EPA)-certified. Eleven vegetation split samples were provided to Foster Wheeler and 24 to ADEC, with 4 of the samples split among ADEC, DOE, and Foster-Wheeler. All vegetation samples were properly documented with Chain-of-Custody/Request for Analysis Forms according to QA/QC procedures.

Percent moisture measurements were performed on two samples each of lichens, sedges, and shrubs to confirm wet/standard dry weight ratios, as well as to provide a constant basis for determining radioisotope concentration and for comparing former studies. Ratios of field wet weight to standard dry weight were measured in several hundred samples of various types from Cape Thompson during 1959-1971 and reduced the need for repetitious measurements.

Samples were grouped into plants and animals as two distinct matrices and then batched into groups of 20 samples maximum. Groups were termed sample delivery groups, which were then analyzed, reviewed, and reported individually.

5.9.2 Mammals/Birds

Small mammals (voles and lemmings) were collected by Museum Special snap-traps baited with peanut butter and rolled oats. The traps were then set in large vegetative communities or were densely concentrated at the disposal mound and the nearby test-plot area. Initially, 42 traps were set at the mound and in nearby locations until it was clear that small mammal populations were at a low in their population cycle. At that time, 300 additional traps were used to increase trapping success. Snap-trapping conducted at 7 locations for 4,378 trap-nights yielded 33 small mammals (Table 5-9).

Thirty-two arctic ground squirrels were collected by live-trapping and by using a shotgun at 11 selected locations. All small mammals and ground squirrels were

Table 5-9
Small Mammals Collected by Snap-Trapping Effort

Location	Number of Trap Nights	Catch
Mound	378	3 Tundra vole
2	100	2 Tundra vole
6	300	1 Varying lemming
10	2,400	11 Tundra vole 4 Red-backed vole 4 Varying lemming
KV-1	400	3 Tundra vole 1 Varying lemming
KV-2	400	1 Tundra vole
KV-3	400	1 Tundra vole 1 Varying lemming
Cs-137 Plot	360	1 Tundra vole
TOTAL		**33**

placed in custody-taped Ziploc™ plastic bags upon collection and returned to the laboratory tent.

They were then refrigerated until pelts and internal organs were removed. Ground squirrels were of sufficient size to provide separate samples of muscle, bone, and carcass from each individual animal. Small mammals (voles and lemmings) were processed as carcass only. Several animals were combined to form samples of sufficient size. Bone samples were dried for several days in the constant-temperature (100°C [212°F]) oven and then processed; individual animals provided 6 to 12 g (0.2 to 0.4 oz) of dried bone for radioisotope analyses.

Ptarmigan were collected using a shotgun whenever the opportunity presented itself at selected locations. Seven ptarmigan were collected in the Ogotoruk Valley during the first two weeks of sampling. The Scientific Collecting Permit from ADFG allowed 10 ptarmigan to be taken. Three birds were reserved for Kisimilok Valley. However, no birds were encountered at that location, and no more birds were seen at Ogotoruk Valley near the end of the collection activities. Feathers, skin, and internal organs were removed and muscle and bone separated. The bone samples were dried, and the muscle and carcass samples were processed.

Muscle and bone samples of 24 caribou taken by subsistence hunters were purchased from residents of Kivalina and Point Hope. These were processed similarly to the other mammals. Caribou sampling during Project Chariot was designed to provide insight into the diet of the Kivalina and Point Hope natives at that time and to provide a basis for estimation of radiation dose. A grizzly bear that had been found dead on the beach about 8 km (5 mi) east of the Project Chariot camp provided bone and muscle samples of a top carnivore of the area. Bone samples of two musk oxen killed northwest of Kivalina in September 1992 were obtained through the cooperation of ADFG personnel in Kotzebue.

Variation from mammal sampling proposed in SOP-CHR-20 of the Site Assessment and Remedial Action Plan was minor but necessary to adapt the field sampling to existing conditions.[2] Results are reported in Table 5-10.

Musk oxen, fish, and marine mammal samples were requested from villagers, but none was obtained. Fish nets and traps were placed in lower Ogotoruk Creek, but no fish were seen or taken.

Carcasses of small mammals, ground squirrels, and ptarmigan and muscle samples of ground squirrels, ptarmigan, grizzly bear, and caribou were processed; 350 to 500 ml of distilled water were added to each sample. Split samples were provided to ADEC and Foster-Wheeler according to their selection from available samples. ADEC received samples of seven ground squirrels, six caribou, and one ptarmigan. Foster-Wheeler received one sample each of ground squirrel and small mammal and four caribou samples. Split

Table 5-10
Variance from Proposed Animal Samples

Sample Type	Number Proposed	Number of Samples
Voles/lemmings	15	8*
Ground Squirrel	24 - 30	32
Caribou	20	24
Musk Oxen	0	2
Grizzly Bear	0	1
Ptarmigan	10	7
Fish	2	0

*33 animals composited into 8 samples

samples were placed directly in the various counting containers furnished by each agency, sealed with custody tape, and relinquished to ADEC or Foster-Wheeler. All samples were documented with Chain-of-Custody/Request for Analysis Forms according to QA/QC procedures. Animal tissue samples that were not provided as sample splits were frozen and kept in a secure freezer until shipment to the off-site laboratory. Percent moisture determinations were performed on muscle and carcass samples.

5.9.3 Analytical Results

Samples were counted for 1 hour during gamma scans and 100 minutes for Sr-90. A greater number of positive values was obtained for Sr-90 because interfering radioisotopes were removed during the chemical separation procedure. Gamma scans contained a wide variety of radioisotopes originating from natural sources, such as uranium-238 and thorium-232 decay schemes, as well as from worldwide fallout. Concentrations of radioisotopes were expressed to two significant figures, with the error of measurement (mean ± the standard deviation) and the minimum detectable activity (MDA) expressed to the same number of decimal places as the activity.

All vegetation samples were dried from 95 to 98 percent of standard dry weight prior to milling and placing in containers for analysis. Animal samples were corrected for percent solids by percent moisture determinations at the laboratory; muscle and carcass samples contained appreciable (70 to 97 percent) moisture due to natural body water and the 350- to 500-ml water added during processing to enable sample splitting. As a result, the MDA for such samples was significantly increased and resulted in "less than" values for Cs-137 in most animal samples.

5.9.3.1 Vegetation

Radioisotope concentrations (pCi/g dry weight) in vegetation samples from Ogotoruk Valley and Kisimilok Valley (control) are presented in Table 5-11. Very low levels, usually in the range of 0.2 to 1.0 pCi/g Sr-90 and < 0.10 pCi/g Cs-137, were uniformly observed in most samples collected over the region.

As a result, several collection locations were combined to summarize the data, as follows:

Disposal Mound :	Retained as single study location
Test-Plot Area :	Retained as single study location
Lower Valley :	Locations 5, 6, 8, and 10
Middle Valley :	Locations 12, 13, 16, SR-S, SR-N, and MSP
Upper Valley :	Locations 2, 3, 4, and 7
Kisimilok Valley :	KV-1, KV-2, and KV-3 combined.

Therefore, the number of samples collected as shown in Table 5-6 is not equal to the number analyzed after samples were composited.

5.9.3.2 Animals

Radioisotope concentrations in mammal samples are presented in Table 5-12, and ptarmigan samples are summarized in Table 5-13. Only Sr-90 occurred in consistently measurable concentrations in muscle, bone, and carcass samples. Occasional varying concentrations occurred in Sr-90 values, such as the high concentrations reported in ground squirrel carcasses at the test-plot area and at Middle Valley locations. Cesium-137 and transuranic elements were usually below their MDAs.

5.9.4 Evaluation of Results

Concentrations of Sr-90 and Cs-137 in biota samples were essentially uniform over the area. The concentrations indicated that most radioisotopes detected had their origin in natural sources or from worldwide fallout. This fallout was primarily deposited during and following the 1961-1963 period of nuclear weapons testing in the atmosphere. The exception was the slightly higher concentration of Cs-137 in sedge growing on the test-plot area.

All vegetation samples from the disposal mound contained uniformly low concentrations of all radioisotopes, including the transuranic elements Pu-238, 239, and 240 and Am-241. These elements were of interest because they were contained in the Sedan fallout applied to the test-plot area. These transuranic elements were identified when Reynolds Electrical & Engineering Co., Inc., sampled and analyzed the soil from around the Sedan Crater at the NTS on September 12, 1992.

Table 5-11
Radioisotopes Measured in Project Chariot Vegetation Samples
August - September 1993 *(Page 1 of 2)*

Fungi						
Picocuries per gram dry weight (mean ± standard deviation [SD])						
Location	N[a]	Sr-90	Cs-137	Pu-238	Pu-239 & 240	Am-241
USGS Mound	(1)	0.10 ± 0.20	2.9 ± 0.2	0 ± 0.04	-0.01 ± 0.02	
Upper Valley	(3)		5.5 ± 1.9			
Middle Valley	(2)		4.5 ± 5.4			
Lower Valley	(1)		<0.43			
Lichens						
Picocuries per gram dry weight (mean ± SD)						
Location	N[a]	Sr-90	Cs-137	Pu-238	Pu-239 & 240	Am-241
Cetraria delisei						
Upper Valley	(16)	0.63 ± 0.14	1.8 ± 1.1			
Lower Valley	(2)	0.51 ± 0.01	1.4 ± 0.2	-0.3 ± 0.02	0.01 ± 0.02	
Cetraria cucullata						
USGS Mound	(1)	0.42 ± 0.19	0.57 ± 0.09			
Upper Valley	(2)		0.36 ± 0.04			
Lower Valley	(3)	0.28 ± 0.19	0.46 ± 0.04			
Kisimilok	(1)		0.25 ± 0.06			
Cornicularia divergens						
Upper Valley	(2)		1.6 ± 0.07			
Stereocaulon paschale						
Upper Valley	(2)		<0.50			
Sedges						
Picocuries per gram dry weight (mean ± SD)						
Location	N[a]	Sr-90	Cs-137	Pu-238	Pu-239 & 240	Am-241
Carex spp.						
USGS Mound	(4)	0.47 ± 0.25	<0.10	0.03 ± 0.06	-0.04 ± 0.05	0.01 ± 0.03
Cs-137 Plot	(1)	0.48 ± 0.11	1.5 ± 0.20			
adjacent	(2)		<0.19			
Lower Valley	(8)	0.37 ± 0.11	<0.12			
Upper Valley	(4)	0.52 ± 0.14	<0.12			
Kisimilok	(10)	0.56 ± 0.49	<0.13			
Eriophorum spp.						
USGS Mound	(3)	0.32 ± 0.02	<0.12	-0.11 ± 0.06	-0.01 ± 0.06	0.04 ± 0.05
Lower Valley	(6)	1.2 ± 1.2	<0.14			
Upper Valley	(4)	0.38 ± 0.15	<0.12			

Table 5-11
Radioisotopes Measured in Project Chariot Vegetation Samples
August - September 1993 *(Page 2 of 2)*

Shrubs Picocuries per gram dry weight (mean ± SD)						
Location	N[a]	Sr-90	Cs-137	Pu-238	Pu-239 & 240	Am-241
Willows (*Salix* spp.)						
USGS Mound	(3)	1.4 ± 0.6	<0.10	-0.06 ± 0.04	0 ± 0.02	0.06 ± 0.05
Cs-137 Plot	(3)	NA	<0.15			
Middle Valley	(10)	NA	<0.09			
Kisimilok	(9)	1.0 ± 0.8	<0.07			
Dwarf Birch (*Betula nana*)						
USGS Mound	(4)	0.8 ± 0.2	<0.11	-0.02 ± 0.03	0.04 ± 0.03	0.02 ± 0.07
Kisimilok	(2)	2.9 ± 1.7	<0.11			
Heath Plants (*Ledum decumbens, Cassiope tetragona, Dryas* spp.)						
USGS Mound	(2)	0.6 ± 0.0	<0.09			
Lower Valley	(6)	2.6 ± 3.0	0.11 ± 0.02			
Middle Valley	(4)	1.4 ± 0.3	0.18 ± 0.06			
Blueberry (*Vaccinium uliginosum*)						
Middle Valley	(3)	0.15 ± 0.15	<0.06			
Upper Valley	(3)	0.33 ± 0.20	<0.09			
Kisimilok	(1)	0.30 ± 0.19	<0.12			

[a] Number of samples

Highest values for Sr-90 occurred in lichens, particularly in the snowpatch lichen *Cetraria delisei*. The lichens' ability to concentrate fallout radioisotopes has long been known and studied because of the importance of lichens as a carrier of radioactivity in the lichen-caribou-human food chain.[13, 14]

Highest Cs-137 concentrations were in fungi, although the > 10-fold range of values overlapped those of lichen species. Sedge (*Carex aquatilis*) growing on the test-plot area contained the highest Cs-137 concentration (1.5 ± 0.2 pCi/g) of all vascular plants and was comparable to concentrations in lichens. Samples of the same species harvested from adjacent areas and willows surrounding the test-plot area had Cs-137 concentrations consistently below the MDAs for all samples.

The uniformity of values is further reflected in the comparison of analyses performed by laboratories under contract to ADEC, Foster-Wheeler, and DOE (Table 5-14). Caution should be exercised in interpreting differences in values given, due to the very low current levels of radioisotopes compared with concentrations observed during 1961 as shown in Table 5-15.[13, 14, 15, 16, 17]

Table 5-12
Radioisotopes Measured in Project Chariot Mammal Samples
August - September 1993 *(Page 1 of 2)*

Voles and Lemmings *(Microtus oeconomus and Dicrostonyx torquatus)* (Several animals composited into each sample) Picocuries per gram dry weight (mean ± SD)						
Location	N[a]	Sr-90	Cs-137	Pu-238	Pu-239 & 240	Am-241
USGS Mound Carcass	(1)	1.7 ± 0.07	<0.36	-0.01 ± 0.01	-0.01 ± 0.01	-0.09 ± 0.30
Cs-137 Plot Carcass	(1)	1.2 ± 0.06	<1.69			
Lower Valley Carcass	(2)	2.4 ± 0.09	<1.25	0.03 ± 0.03	-0 ± 0.01	0.06 ± 0.06
Upper Valley Carcass	(2)	2.2 ± 0.07	<1.7			
Kisimilok Valley Carcass	(3)	2.4 ± 1.1	<0.62			
Caribou *(Rangifer tarandus)* - Samples purchased from village residents Picocuries per gram dry weight (mean ± SD)						
Location	N[a]	Sr-90	Cs-137	Pu-238	Pu-239 & 240	Am-241
Kivalina (mostly taken 6/7/93 and 8/20/93, Cape Seppings - Cape Thompson area)						
Muscle	(12)		0.54 ± 0.20			
Bone	(10)	6.9 ± 1.8				
Point Hope (mostly taken 7/1/93 - 8/15/93, Singoalik River area)						
Muscle	(10)		1.3 ± 0.65			
Muscle	(2*)		1.6 ± 1.2	-0.14 ± 0.41	-0.23 ±0.46	0.32 ± 0.36
Bone	(10)	6.1 ± 1.7				
Bone	(2*)	8.0 ± 0.35		-0.05 ± 0.02	0.01 ± 0.02	0.09 ± 0.05
*Reported "sick" by hunter; special collection and analysis						
Musk Oxen *(Ovibos moschatus)* - Samples from Alaska Dept. Fish and Game; animals died near Kivalina about 9/1/92 Picocuries per gram dry weight (mean ± SD)						
Location	N[a]	Sr-90	Cs-137	Pu-238	Pu-239 & 240	Am-241
Kavrorak Bone	(2)	2.4 ± 0.17	<0.17			
Grizzly Bear *(Ursus arctos)* Picocuries per gram dry weight (mean ± SD)						
Location	N[a]	Sr-90	Cs-137	Pu-239	Pu-239 & 240	Am-241
5 miles east of Chariot						
Muscle	(1)	0.70 ± 1.97	<0.44			
Bone	(1)	1.6 ± 0.03	<0.15			

Table 5-12
Radioisotopes Measured in Project Chariot Mammal Samples
August - September 1993 *(Page 2 of 2)*

Arctic Ground Squirrel *(Citellus parryi)*
Picocuries per gram dry weight (mean ± standard deviation [SD])

Location	N[a]	Sr-90	Cs-137	Pu-238	Pu-239 & 240	Am-241
USGS Mound - inhabitants (2 animals)						
Muscle	(2)	2.4 ± 0.35	<0.23	-0.52 ± 0.44	0.43 ± 0.35	0.80 ± 0.04
Bone	(2)	1.6 ± 1.2		-0.04 ± 0.04	0 ± 0.03	0.03 ± 0.03
Carcass	(2)	3.1 ± 3.0	<0.51	0.06 ± 0.50	-0.19 ± 0.25	0.18 ± 0.18
USGS Mound - periphery (3 animals)						
Muscle	(2)	3.4 ± 2.0	<0.29	0.06 ± 0.27	-0.04 ± 0.05	-0.50 ± 0.11
Bone	(3)	1.5 ± 0.57		-0.02 ± 0.05	0.01 ± 0.04	-0.09 ± 0.05
Carcass	(5)	5.2 ± 2.2	<0.38	-0.12 ± 0.29	0 ± 0.20	2.6 ± 0.4
Cesium-137 Plot (2 animals)						
Muscle	(2)	2.0 ± 1.8	<0.40			
Bone	(2)	1.4 ± 0				
Carcass	(2)	16 ± 18	<1.0	0 ± 1.2	0 ± 0.81	-1.2 ± 0.8
Lower Valley (10 animals)						
Muscle	(2)	2.4 ± 0.78	<0.33			
Bone	(10)	2.3 ± 0.89				
Carcass	(5)	4.3 ± 3.0	<0.51			
Middle Valley (6 animals)						
Muscle	(4)	2.6 ± 0.08	<0.41			
Bone	(7)	2.1 ± 0.65				
Carcass	(3)	18 ± 5	<1.0			
Upper Valley (3 animals)						
Muscle	(1)	2.3 ± 1.4	<0.44			
Bone	(3)	4.0 ± 0.7				
Carcass	(2)		<1.3			
Kisimilok Valley (6 animals)						
Muscle	(6)	2.0 ± 1.6	<0.32			
Bone	(6)	3.5 ± 0.8				
Carcass	(4)	5.2 ± 0.9	<0.61			

[a] Number of samples

Table 5-13
Radioisotopes Measured in Project Chariot Ptarmigan Samples
August - September 1993

Willow Ptarmigan *(Lagopus lagopus)*
Picocuries per gram dry weight (mean ± standard deviation [SD])

Location	N[a]	Sr-90	Cs-137
Lower Valley			
Muscle	(2)	1.10 ± 0.23	<0.22
Bone	(2)	2.38 ± 2.01	
Carcass	(1)	11 ± 5	<0.18
Middle Valley			
Muscle	(5)	<0.35	<0.35
Bone	(6)	6.7 ± 2.2	
Carcass	(4)	12 ± 5	<0.82

[a] Number of samples

All concentrations of the transuranic elements in biota samples were at or below their detection limits of 0.05 to 0.5 pCi/g. These results were consistent with analytical results from other locations in Ogotoruk and Kisimilok Valleys. Also, Sr-90 and Cs-137 concentrations in all principal species of vegetation covering the mound and the concentrations in food items of local importance were well within acceptable limits. As previously described, sedge (*Carex aquatilis*) collected from the surface of the test-plot area was the exception.

Ground squirrels and tundra voles collected from the disposal mound and from the test-plot area contained no higher concentrations of radioisotopes than comparable samples collected at other locations in Ogotoruk and Kisimilok Valleys. Ground squirrels collected 30 m (100 ft) from the test-plot area contained highly variable Sr-90 concentrations in carcasses and were comparable to values in similar samples from the Middle Valley locations.

Caribou samples obtained from Point Hope and Kivalina contained very low amounts of both Sr-90 and Cs-137 and represented no radiological health hazard to consumers. Cesium-137 concentrations in muscle and Sr-90 in bone samples from the caribou did not significantly differ between villages. Also, two caribou that appeared to be "sick" to a Point Hope hunter, and, therefore, of concern to residents, were analyzed and were found to contain no unusual amounts of Sr-90 or Cs-137. Current Cs-137 levels in caribou were compared to a much more limited sample (one animal during each of 1985, 1986, and 1987). Studies suggest permissible concentrations of Cs-137 in human food items of 300 becquerels per kilogram (Bq/kg) (8 pCi/g) in meat to 1,500 Bq/kg (40 pCi/g) in other foods, such as berries, as limits to remain within accepted population radiation-exposure standards.[18, 19]

Table 5-14
Comparison of Split Sample Analytical Results from Three Laboratories
(ADEC - Lockheed; Foster - Wheeler - Rocky Mtn.; IT - St. Louis)
(Page 1 of 2)

Sample Type	Sample Number(s)	Sr-90 pCi/g[a] dry weight			Cs-137 pCi/g dry weight		
		ADEC [b]	F-W [c]	IT [c]	ADEC	F-W	IT
Lichens							
C. delisei	43/44	1.33		0.50	1.8	2.3	1.5
	103/105	0.77		0.78	2.9		2.8
	125/126					1.1	0.9
	135/136	1.25			2.1		1.8
C. cucullata	80/97	0.58		0.69	0.88		0.95
Sedges							
Carex spp.	13/14					<0.43	<0.10
	16/17					<0.46	<0.11
	60/61/62				<0.07	<1.65	<0.19
	24/25		<0.36	0.58		0.36	<0.13
	144/146				<0.06		<0.10
	114/115/116				0.26		<0.13
	137/138/139				0.04		<0.10
Eriophorum							
	29/31				0.11	<0.54	<0.12
	108/109		<0.59	0.50		0.59	<0.10
	26				0.12		<0.18
Shrubs							
Willows	39				<0.08	<1.1	<0.14
	58				0.18		<0.12
	82/83/84				<0.15	<0.47	<0.07
	70/71				<0.06		<0.08
	85/86				<0.15		<0.12
	KV17/18				<0.05		<0.10
	KV10/11				<0.09		<0.08
Dwarf Birch	30/31				<0.05		<0.11
Heath	77/78/79				0.19		0.18
	94/96				0.13		<0.25
	66				0.03		<0.12
	36/40				<0.08	<0.03	<0.13
	23/32				0.14		<0.09
Blueberry	147				0.03		<0.16
	25/29				0.05		<0.12

Table 5-14
Comparison of Split Sample Analytical Results from Three Laboratories (ADEC - Lockheed; Foster - Wheeler - Rocky Mtn.; IT - St. Louis)
(Page 2 of 2)

Sample Type	Sample Number(s)	Sr-90 pCi/g[a] dry weight ADEC[b]	Sr-90 F-W[c]	Sr-90 IT[d]	Cs-137 pCi/g dry weight ADEC	Cs-137 F-W	Cs-137 IT
Ground Squirrel							
Carcass	57/101	<0.09		6.3	<0.05		<0.54
	57/101(dup)	<0.09		5.5	<0.05		<0.30
	8/9	0.06		<0.038	<0.04		<0.59
	63/64	<0.12		5.2			<0.30
	98/117	0.09		18	0.13		<0.41
	132/133	<0.08		1.6	<0.02		<0.72
	152/153	0.49		4.4	<0.03		<0.39
	KV19/27	0.13		6.0	<0.03		<0.93
Caribou							
Muscle	174.1	<0.09		3.2	0.19	0.33	0.58
	174.1 (dup)			0.9			
	176.1	<0.10		4.9	0.15	<0.08	0.39
	179.1				0.34	0.39	1.2
	180.1				0.06	<0.04	<0.32
	185.1					0.65	2.0
Bone	179.2	3.6		9.7	<0.14		
	180.2	3.1		5.3	<0.14		
Grizzly Bear							
Muscle	165.1	1.4		0.7			<0.44
Bone	165.2	1.4		1.6			
Willow Ptarmigan							
Carcass	48/49	<0.16		11	<0.41		<0.93

[a] Picocuries per gram
[b] ADEC - Lockheed
[c] Foster-Wheeler-Rocky Mtn.
[d] IT-St. Louis

Apparent differences in initial Sr-90 concentrations in ground squirrel and caribou samples indicated by ADEC and the DOE off-site analytical laboratory results were reconciled by reanalyzing 10 split samples with 10 days ingrowth of yttrium-90 (91 percent of secular equilibrium between Sr-90 and Y-90 following chemical separation). Results (Table 5-16) of reanalyses were generally lower and had coefficients of variation one-third those of original analyses. These values reflect the considerable variation associated with current very low levels of worldwide fallout in the Cape Thompson environs, which are in the same range as those measured during 1959-1962 (0.39 to 1.6 pCi/g dry wt) in fewer comparative samples.

Table 5-15
Comparison of Sr-90 and Cs-137 Concentrations in Biota of Project Chariot Environs during 1961, 1971, and 1993)

	Sr-90 pCi/g[a]			Cs-137 pCi/g		
Sample Type	**1961**	**1971**	**1993**	**1961**	**1971**	**1993**
Lichens						
Cladina-Cetraria	2.2	67.0	0.62	30	40	0.41
Cornicularia spp.	5.2	50.0	1.60	20	50	1.6
Sedges						
Carex spp.	3.0		0.44	6.5	5.0	<0.12
Eriophorum spp.	2.5		0.74	7.0	8.1	<0.13
Willows	1.5		1.1	0.5	0.3	<0.11
Heath Plants	4.0		2.1	4.5	8.1	<0.09
Ground Squirrel						
Carcass	1.0		4.1	0.6		<0.75
Bone	4.8		2.1	0		
Tundra Vole						
Carcass	1.2		1.9	0		<1.3
Caribou						
Muscle	0.04		2.0	4.6		0.92
Bone	12		6.5	0.5		
Grizzly Bear						
Muscle	0		0.7	3.1		<0.44
Bone	2.5		1.6	0		<0.15

[a] Picocuries per gram

In summary, compared to other locations in Ogotoruk and Kisimilok Valleys, no unusual amounts of Sr-90; Cs-137; plutonium-238, 239, and 240; and Am-241 were detected in comprehensive sampling of plants and animals from the disposal mound. Cesium-137 concentration in sedge growing on the test-plot area was 10 times the value in sedge at other locations, yet well within acceptable ranges. Cesium-137 was not detected in adjacent willows nor in tundra voles or ground squirrels trapped on or adjacent to the test-plot area, indicating that migration of contaminants had not occurred. Strontium-90 and Cs-137 concentrations in food items of local importance were well within acceptable limits.

Table 5-16

Comparison of 10/21/93 Sr-90 Analyses and 2/14/94 Reanalyses of Ground Squirrel Carcass and Caribou Muscle Samples Split with ADEC (see Table 5-14)

Sample Type	Sample Number	Location	pCi/g dry (X ± 2SD) 1993	1994
Ground Squirrel	9/8	Camp	<0.038	0.52 ± 0.21
Ground Squirrel	152/153	2	NA	0.53 ± 0.24
Ground Squirrel	19/27	KV-1	NA	2.40 ± 0.46
Ground Squirrel	132/133	MSP	NA	4.34 ± 0.57
Ground Squirrel	57/101	Mound	6.3 ± 2.1	2.21 ± 0.30
Ground Squirrel	Duplicate	Mound	5.5 ± 1.9	NA
Ground Squirrel	98/117	SRS/MSP	18 ± 5	0.64 ± 0.22
Ground Squirrel	64/63	6	5.2 ± 2.9	0.19 ± 0.19
Caribou muscle	176	Kivalina	4.9 ± 1.5	0.30 ± 0.18
Caribou muscle	174	Kivalina	3.2 ± 1.0	0.0 ± 0.14
Caribou muscle	Duplicate	Kivalina	0.9 ± 1.0	0.08 ± 0.20

NA - Not Analyzed

Chapter 6.0 Remediation Activities

Remediation activities at the disposal mound and test-plot area included field analysis and soil excavation. After excavation was completed, the disposal mound and test-plot area were backfilled and regraded.

6.1 Preremoval Activities

The trail between the base camp and the disposal mound was established and approved by the FWS Representative on July 30, 1993. It was established on stable tundra along the ridge, upgradient from the disposal mound as shown on Figure 6-1. This trail was managed by limiting traffic to minimize impact on the tundra. Due to heavy rains, the trail became muddy and was closed to motorized vehicle traffic on August 17, 1993. For the remainder of the project, use of the trail was limited to foot traffic, transporting test equipment and supplies, and emergency support activities.

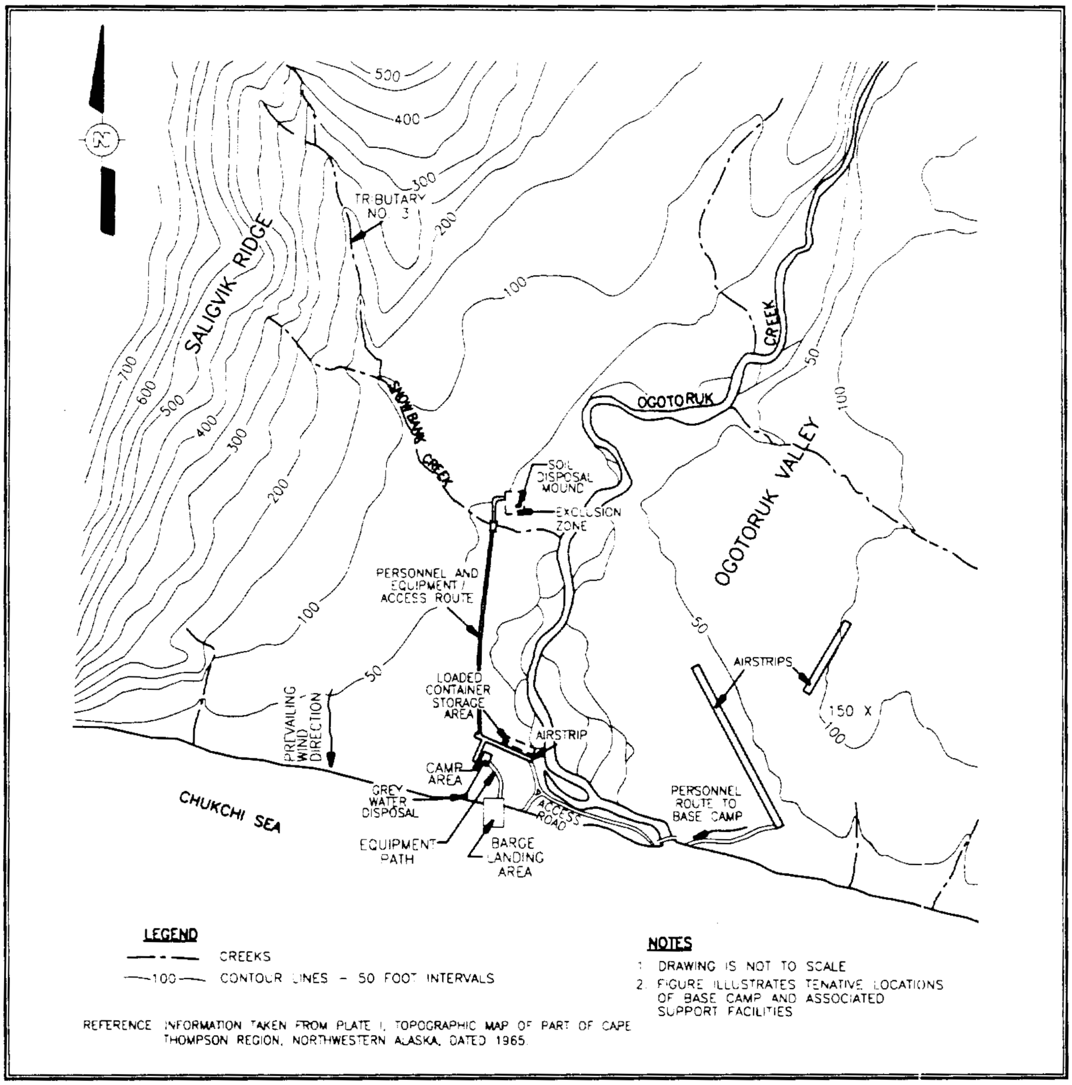
A crossing for the trail was established at Snowbank Creek by installing one 12-in. diameter by 20-ft corrugated plastic pipe, covered to grade with sandbags and bridged with Uni-mats (Figure 6-2). In addition, Uni-mats were laid on each side of the crossing to bridge the muddy low areas next to Snowbank Creek. This area was radiologically surveyed to ensure that the crossing was placed on noncontaminated soil.

The heavy equipment for disposal-mound removal activities (Caterpillar® 966 Front End Loader and Caterpillar® 330L Excavator) was transported from the base camp to the mound site on a double layer of Uni-mats. First, a layer of geotextile fabric was rolled over the tundra. Next, two layers of Uni-mats were placed face up using the loader. The joints between the mats on the bottom layer were straddled by the mats on the top layer. The Uni-mats were then "leap-frogged" from the rear of the procession to the front (Figure 6-3).

The Caterpillar® 330L was used to pick up the mats from the rear and swing them around and over the loader and onto the forks of the loader. The loader would then place the mats at the front of the procession of heavy equipment. This slow-moving procession took approximately three days to traverse the 1.2 km (0.75 mi) from the base camp to the mound site. This method was used to comply with an FWS permit requiring that no greater than 3 pounds per square inch be exerted on the tundra during transport of equipment.

After the trail was established, the EZ and CRZ were laid out at the disposal mound. The trail into the CRZ was established (see Figure 4-2) upgradient (to the west and north) from the mound to avoid activity in the marshy area

Figure 6-1
Transportation Routes for the Project Chariot Site

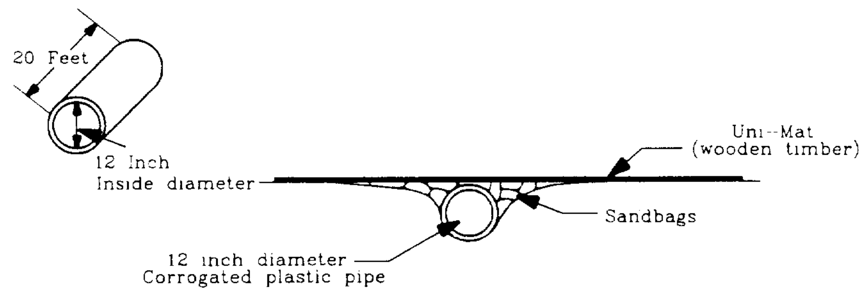


downgradient from the disposal mound and to be upwind from the prevailing winds. The boundary of the EZ and CRZ was marked off with a silt fence and a rope fence with yellow caution tape. A support tent and an incinolet toilet were erected on the north end of the site within the CRZ (Figure 6-4). The personnel entrance from the CRZ into the EZ was established and staffed with two decontamination technicians whenever work was performed within the EZ.

Materials, supplies, and empty B-25 containers were transported from the base camp to the disposal mound along the approved access way on vehicles approved by FWS for tundra use.

Water, vegetation, and animal samples were taken from the ephemeral pond and the disposal-mound site before any excavation of the mound. A sump area

Figure 6-2
Snowbank Creek Temporary Crossing Structure



1. Where feasible, existing access ways were used, with the approval of the U S Fish and Wildlife Service (UFWS) as the route for transportation between the base camp and the soil disposal mound.
2. All vehicles used to traverse the tundra at the site attained the UFWS specified 3 pounds per square inch (psi) ground pressure. The transport of the heavy construction equipment, which occurred once (roundtrip) during the project, achieved the 3-psi ground pressure through the use of a Uni-Mat system to distribute the pressure.
3. At Snowbank Creek, one 12-inch (interior diameter) corrogated plastic pipe (CPP) was positioned in the creek bottom to allow the uninterrupted flow of the water.
4. Sandbags were installed to stabilize the CPP in position and to fill the voids between the CPP and the creek banks.
5. Sandbags were placed over the CPP to furnish a stabilized base
6. A wooden timber Uni-Mat was placed over the layer of sandbags and spanned the creek.
7. At the conclusion of the remedial action, the creek-crossing structure was removed and transported off site.

was then dug in the ephemeral pond. This sump was used to collect the shallow groundwater upgradient from the disposal mound. The water from the sump was pumped into B-25 containers and stored pending analytical results of the water samples.

6.2 Mound Removal

Excavation of the disposal mound began on August 7, 1993. The elevation at the top of the mound grade was determined and used to check the depth of each lift removed from the mound.

The Eberline ESP-2/NaI and MCA radiation detection systems were used during the excavation of the disposal mound to determine whether contamination had been reached or removed. The excavation area was first surveyed with a slow, near-surface scan, using the Eberline ESP-2/NaI setup (Figure 6-5). If an

Figure 6-3
Uni-mat Placement Using "Leap-Frogging" Technique

Figure 6-4
The Exclusion Zone and Contaminant Reduction Zone

Figure 6-5
Surface Survey Performed Using the Eberline ESP-2 NaI System on the Mound

increase in the ESP-2/NaI count rate was noted, the area was then marked, and the MCA was used to determine if Cs-137 was present. If the survey of the excavated area was completed and no Cs-137 was detected, the area was cleared for another lift. The MCA was placed at six locations, two near the center and one in each corner of the mound area. This configuration covered the entire area of the excavation. The outside points were surveyed as a precautionary measure to avoid missing contamination that may have spread outside the area of concern.

As each bucket of soil was removed from the mound, it was spread evenly onto high-density polyethylene (HDPE). The depth of the soil being spread was controlled to be no more than approximately 10 in. (Figure 6-6). This lack of shielding by excess soil allowed detection of any radioactive material present. After each bucket of soil had been spread onto the HDPE, a slow, near-surface survey was performed using the Eberline ESP-2/NaI system (Figure 6-7).

Soil samples were collected from the stockpile of each lift. At least four grab samples were taken from each stockpile. These samples were analyzed at the on-site laboratory by gamma spectroscopy analysis. The Cs-137 activity found in these samples is shown in Figures 6-8 through 6-14. Figure 6-8 shows the Cs-137 soil-sampling results of the excavated soil from Lift 1. Figure 6-9 presents the soil-sampling results of the excavated soil during Lift 2. Figures 6-10 and 6-11 describe the results from Lifts 3A and 3B. Sampling results from

Figure 6-6
Excavated Soil Spread onto High-Density Polyethylene

Figure 6-7
Near-Surface Survey Performed Using the Eberline ESP-2 NaI System

Figure 6-8
Cesium-137 Soil Sampling Results as Picocuries per Gram Excavated Soil during Lift 1 of the Disposal Mound Excavation

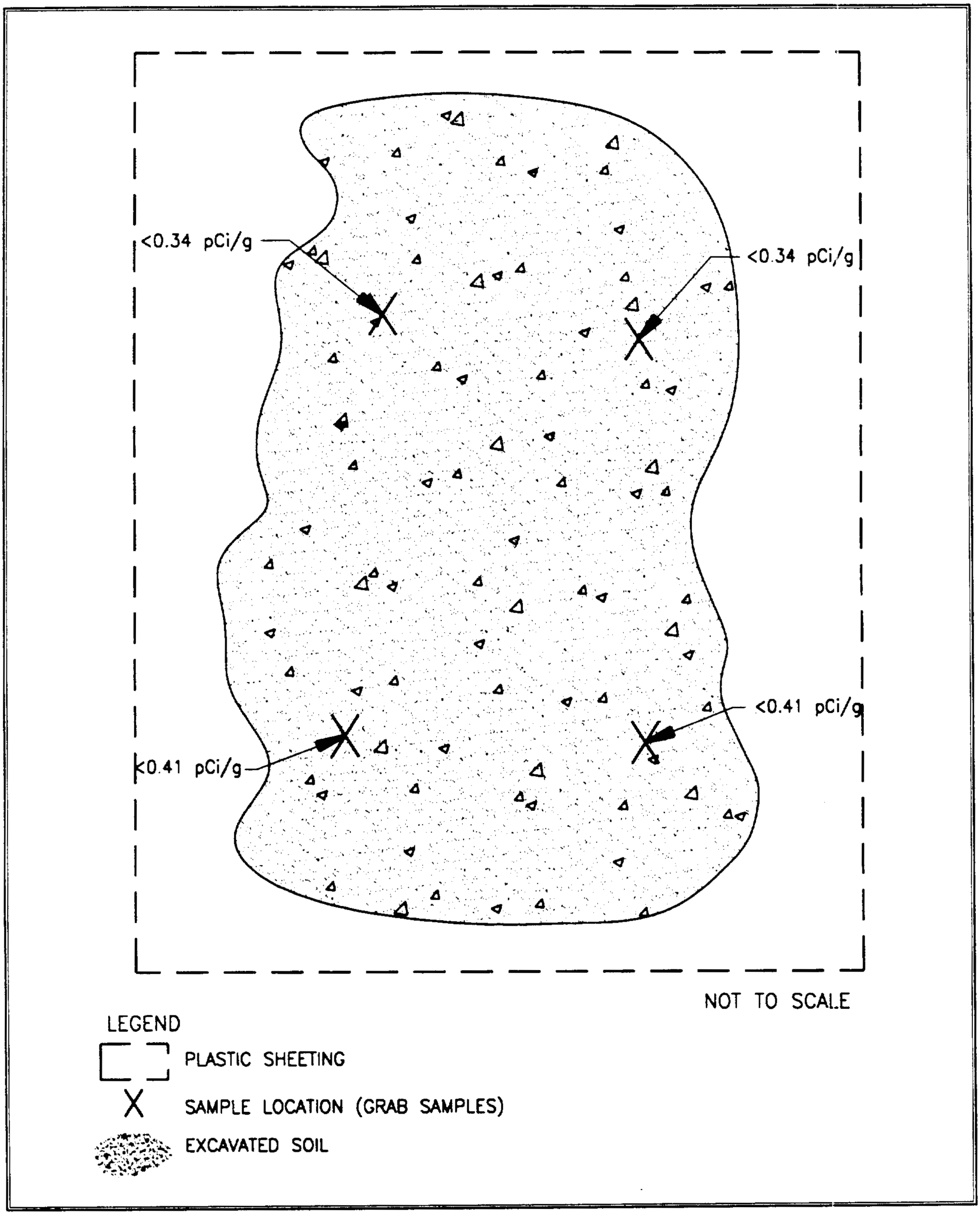


Figure 6-9
Cesium-137 Soil Sampling Results as Picocuries per Gram Excavated Soil during Lift 2 of the Disposal Mound Excavation

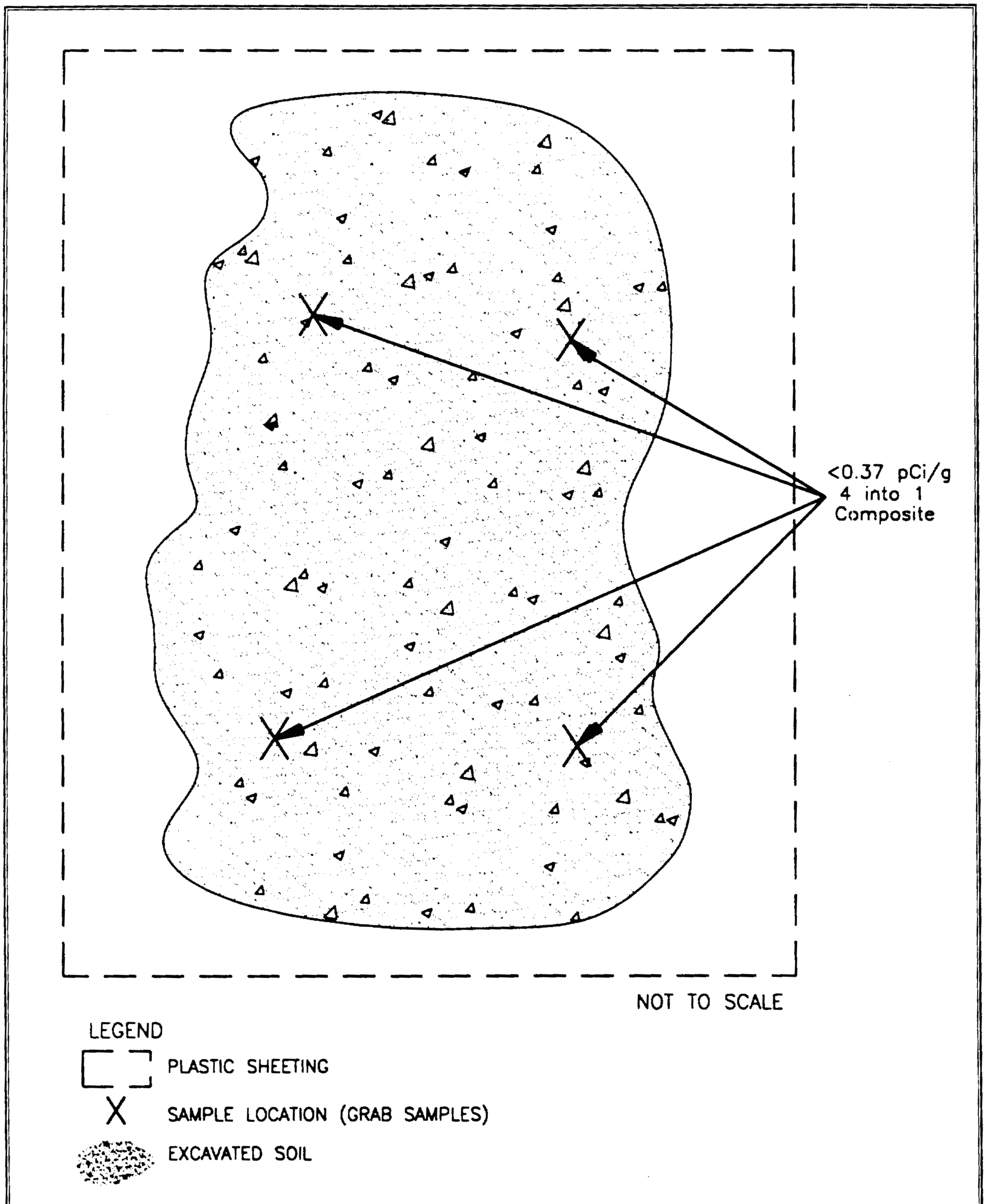


Figure 6-10
Cesium-137 Soil Sampling Results as Picocuries per Gram Excavated Soil during Lift 3A of the Disposal Mound Excavation

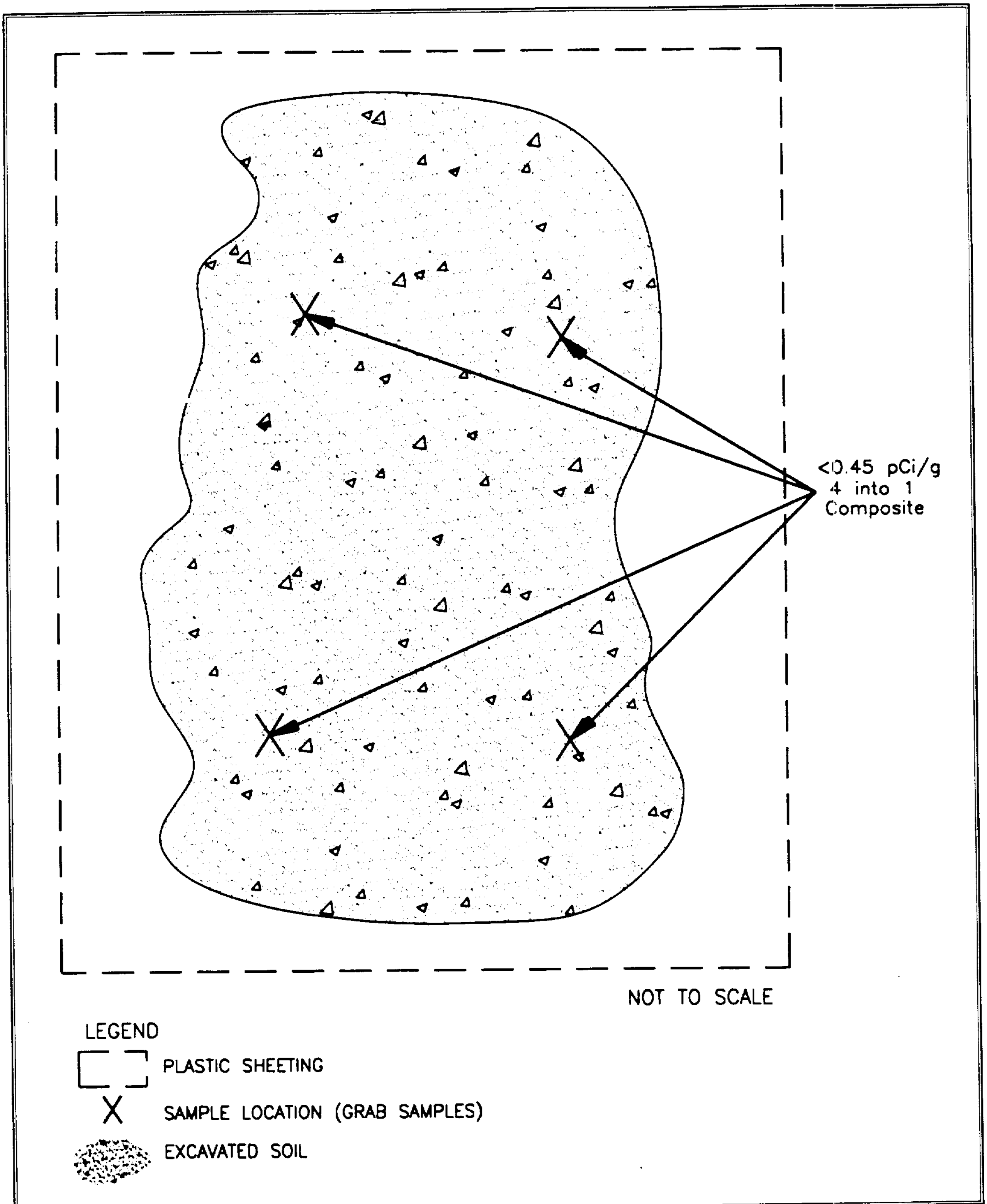


Figure 6-11
Cesium-137 Soil Sampling Results as Picocuries per Gram Excavated Soil during Lift 3B of the Disposal Mound Excavation

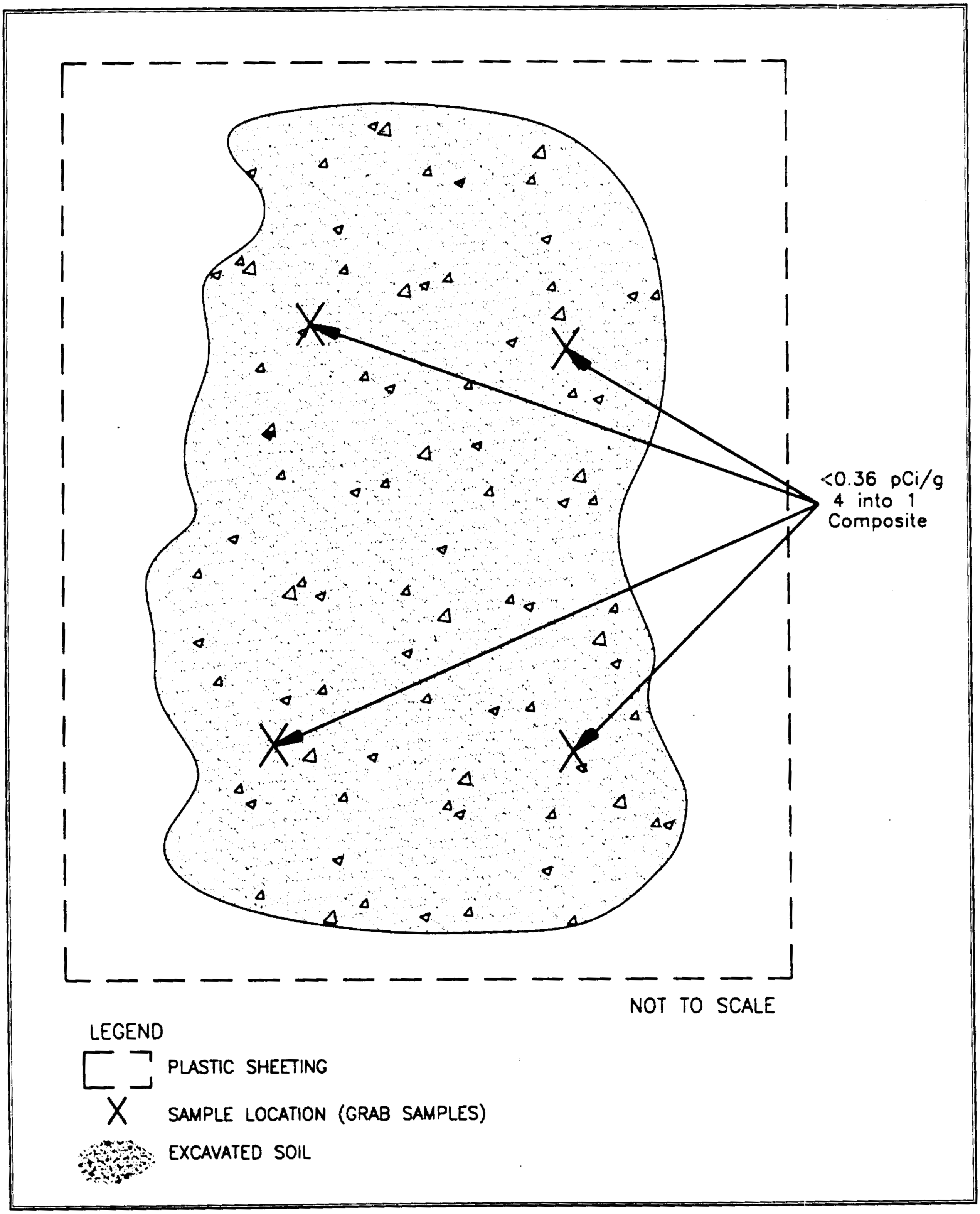


Figure 6-12
Cesium-137 Soil Sampling Results as Picocuries per Gram Excavated Soil during Lift 4 of the Disposal Mound Excavation

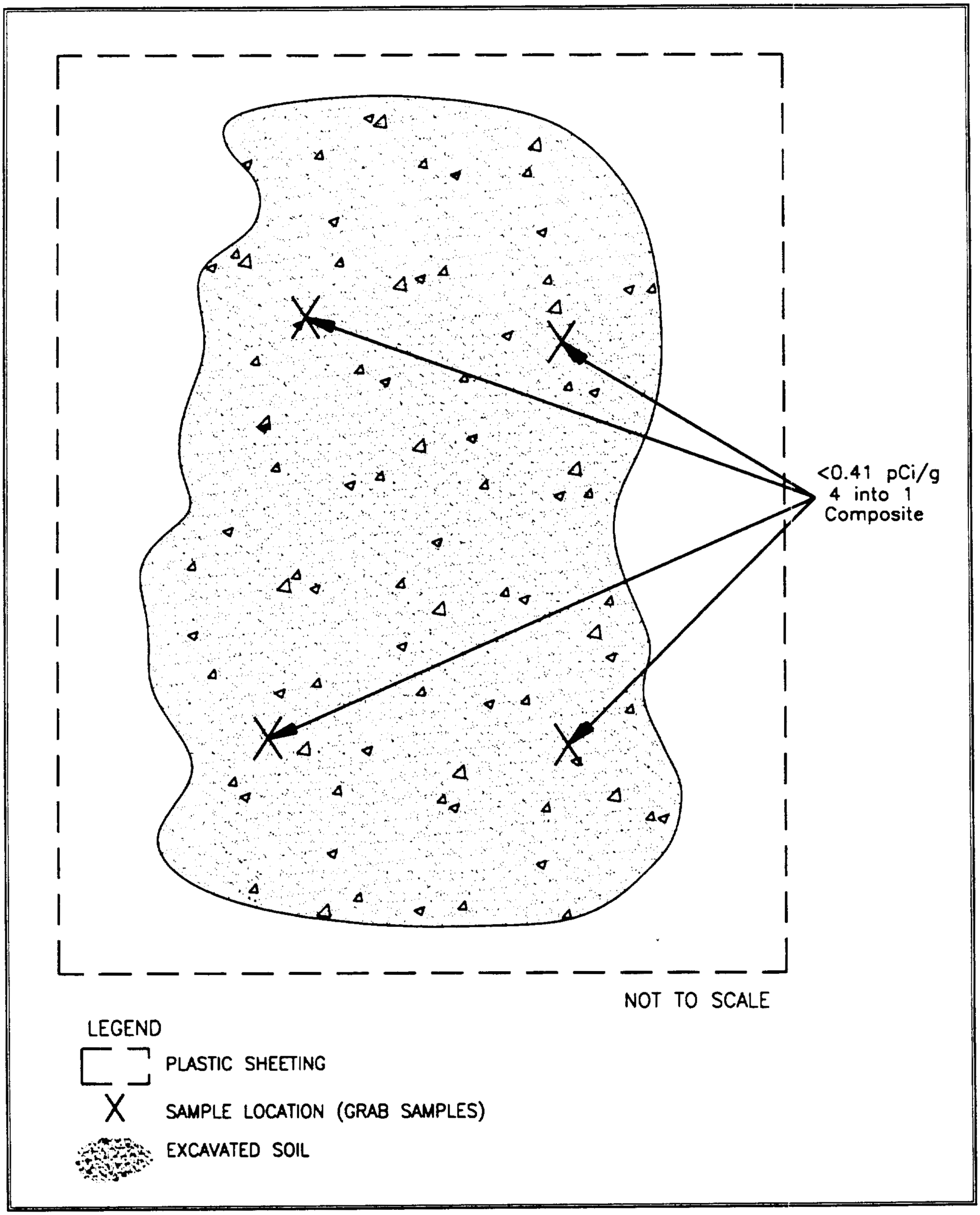


Figure 6-13
Cesium-137 Soil Sampling Results as Picocuries per Gram Excavated Soil That Had Been Accumulated on Plastic Sheeting Halfway through Lift 5

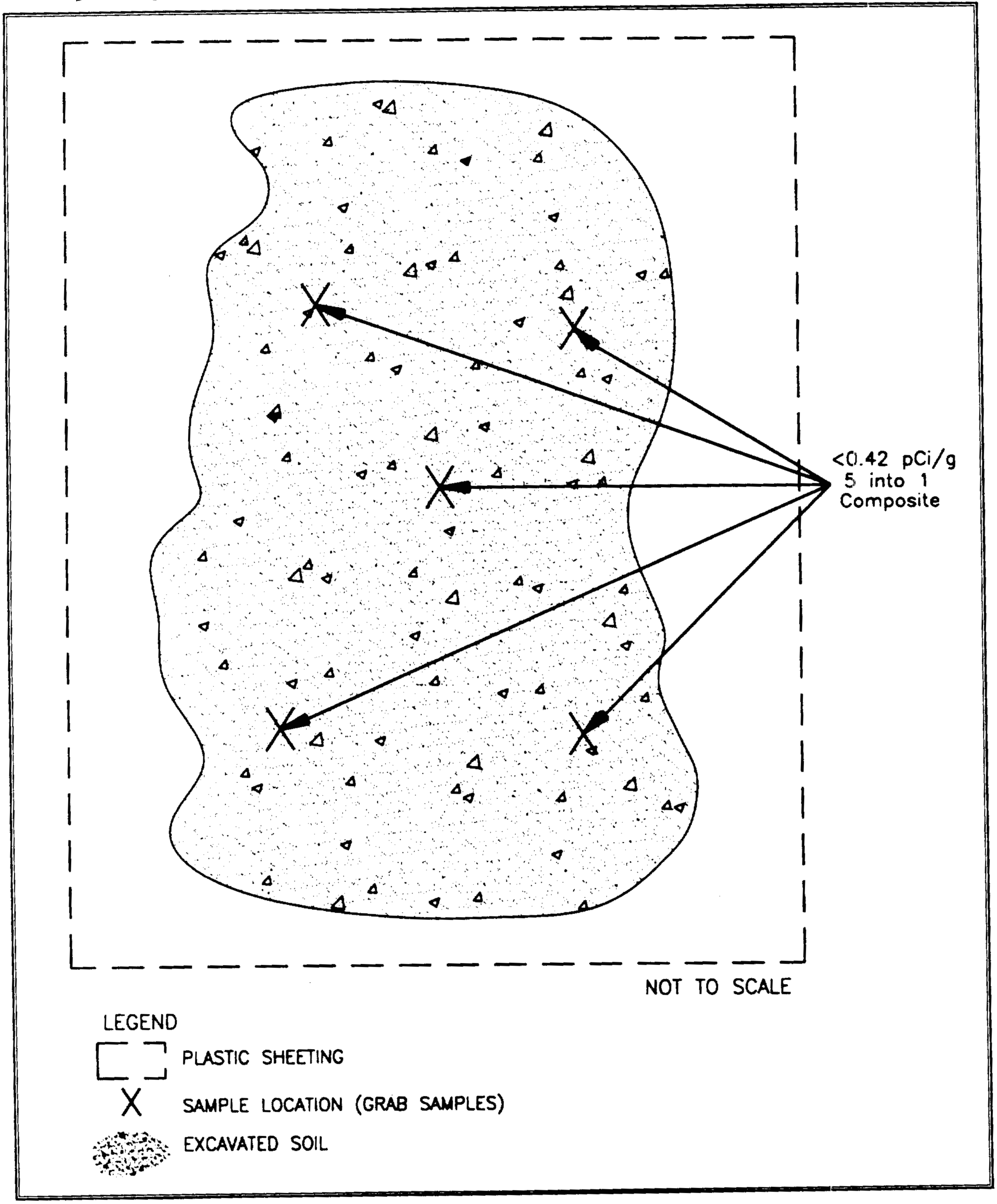
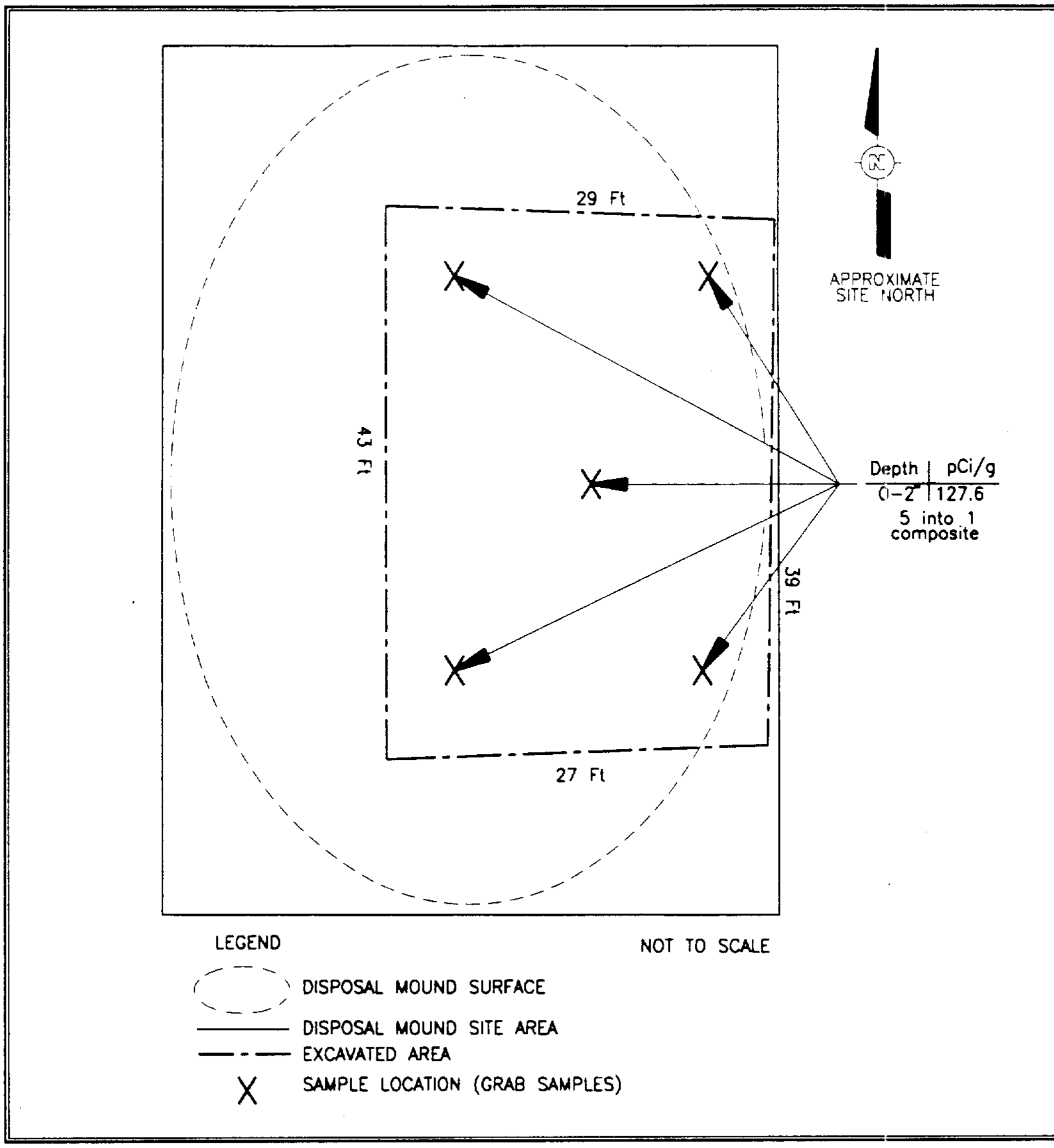


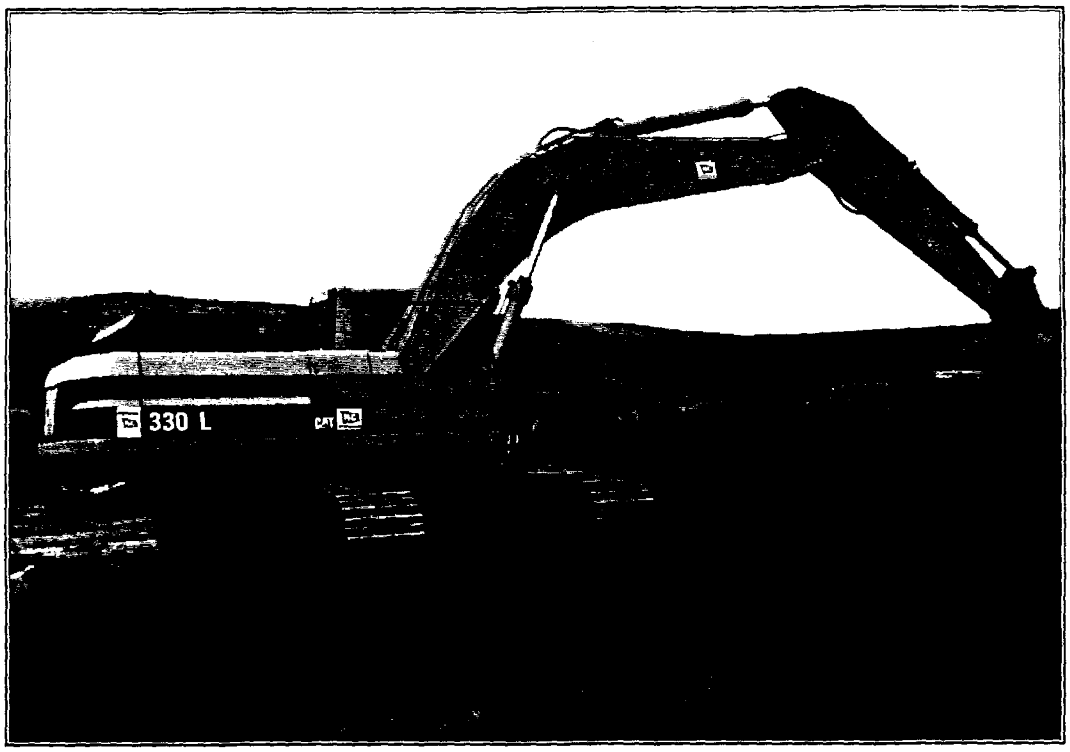
Figure 6-14
Cesium-137 Soil Sampling Results as Picocuries per Gram Composite Soil Sample Taken from Area Excavated during Lift 6



Lifts 4, 5, and 6 are presented in Figures 6-12, 6-13, and 6-14 in pCi/g Cs-137 activity. The analyses from the samples taken from these stockpiles indicated that no Cs-137 was detected; therefore, the soil could be used for clean fill and returned to the excavated area.

The excavation of Lifts 1 through 7 were performed using the Caterpillar® 330L at the perimeter of the mound (Figure 6-15). Lift 3 was broken into two stockpiles: Lifts 3A and 3B. Lift 3A consisted of the top 0.3 m (1 ft) of soil and vegetative matter from the perimeter of the mound. Lift 3B was the next lift of soil from the top of the mound itself. As the excavation proceeded deeper into the mound, radiological surveys of the soil in the stockpile areas were increased

Figure 6-15
Excavation of the Disposal Mound



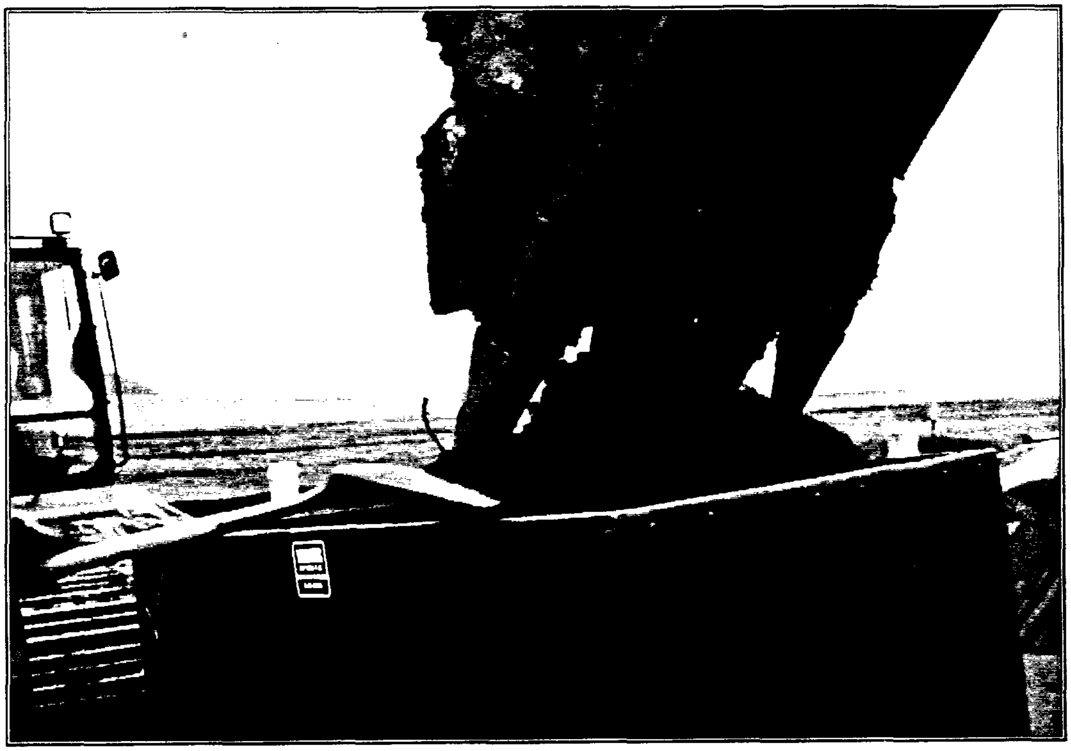
to survey each bucket of excavated soil. During the excavation of Lift 4, permafrost was encountered. Although the permafrost slowed production somewhat, it was not necessary to use the frost bucket.

Prior to the excavation of Lift 5, increased radioactivity was detected, and soil samples were collected. Analysis of these samples indicated that the soil was not radioactively contaminated; rather the radioactivity detected was a result of gamma rays penetrating the clean soil still covering the contamination below. The noncontaminated soil was removed with a shovel.

The excavation of Lift 5 reduced the disposal mound to the level of the surrounding terrain. The soil from the lower portion of Lift 5 was staged on the west side of the mound, surveyed, and sampled. Three samples were taken that confirmed that the radioactive soil had been found. The analysis of samples SS-048, SS-049, and SS-050 from the lower portion of Lift 5 showed that they contained 13.51, 11.63, and 30.29 pCi/g of Cs 137, respectively. The soil from this lower portion was packaged in seven B-25 containers (Figure 6-16).

Initially, the Caterpillar® 330L was operated on Uni-mats on the south, west, and north sides of the mound. However, the loader used to shuttle B-25 containers to the Caterpillar® 330L did not operate well in the mud. To remedy this situation, the Uni-mats on the south and north sides of the mound were relocated to accommodate the loader's pathway. Uni-mats were left on the west side of the mound. The Caterpillar® 330L operated directly on the tundra

Figure 6-16
Loading Soil into B-25 Containers



only within the EZ. This change of operations was approved by the FWS Representative on site.

The first bucket of soil removed from Lift 6 exposed the wood and polyethylene sheeting used in the original tracer studies (Figure 6-17). The contaminated area was defined with the Eberline ESP-2, and noncontaminated soil surrounding the area was excavated. Radiation measurements were performed and soil samples taken to confirm that no contamination existed around the contaminated area (Figure 6-18). The soil, wood, and polyethylene sheeting from Lift 6 were placed into 27 B-25 containers. The radiological survey and sampling at the conclusion of Lift 6 revealed that some contamination remained. Therefore, another 0.3 m (1 ft) of excavation was performed (Lift 7). The soil from Lift 7 was placed into 18 B-25 containers. Another survey indicated that two small spots (approximately 2 ft in diameter) of slightly elevated radioactivity remained at the bottom of Lift 7. Even though the elevated radioactivity was below the 10 pCi/g clean-up level, these two spots were removed manually with shovels and placed into a B-25 container.

Postexcavation confirmatory sampling and analysis were conducted to verify that the established clean-up level had been reached (Section 7.0).

Lift 7 completed the excavation of the disposal mound. Following Lift 7, the Caterpillar® 330L was decontaminated and used to dig a verification trench on

Figure 6-17
Exposed Wood from Lift 6

the west side of the mound area. This trench confirmed that the soil on the west side of the mound was clean (Figure 6-19).

To protect the permafrost, while awaiting analytical testing, an HDPE liner was laid over the excavation following closure sampling of the disposal-mound area. The liner was then covered with approximately 0.6 m (2 ft) of stockpiled soil.

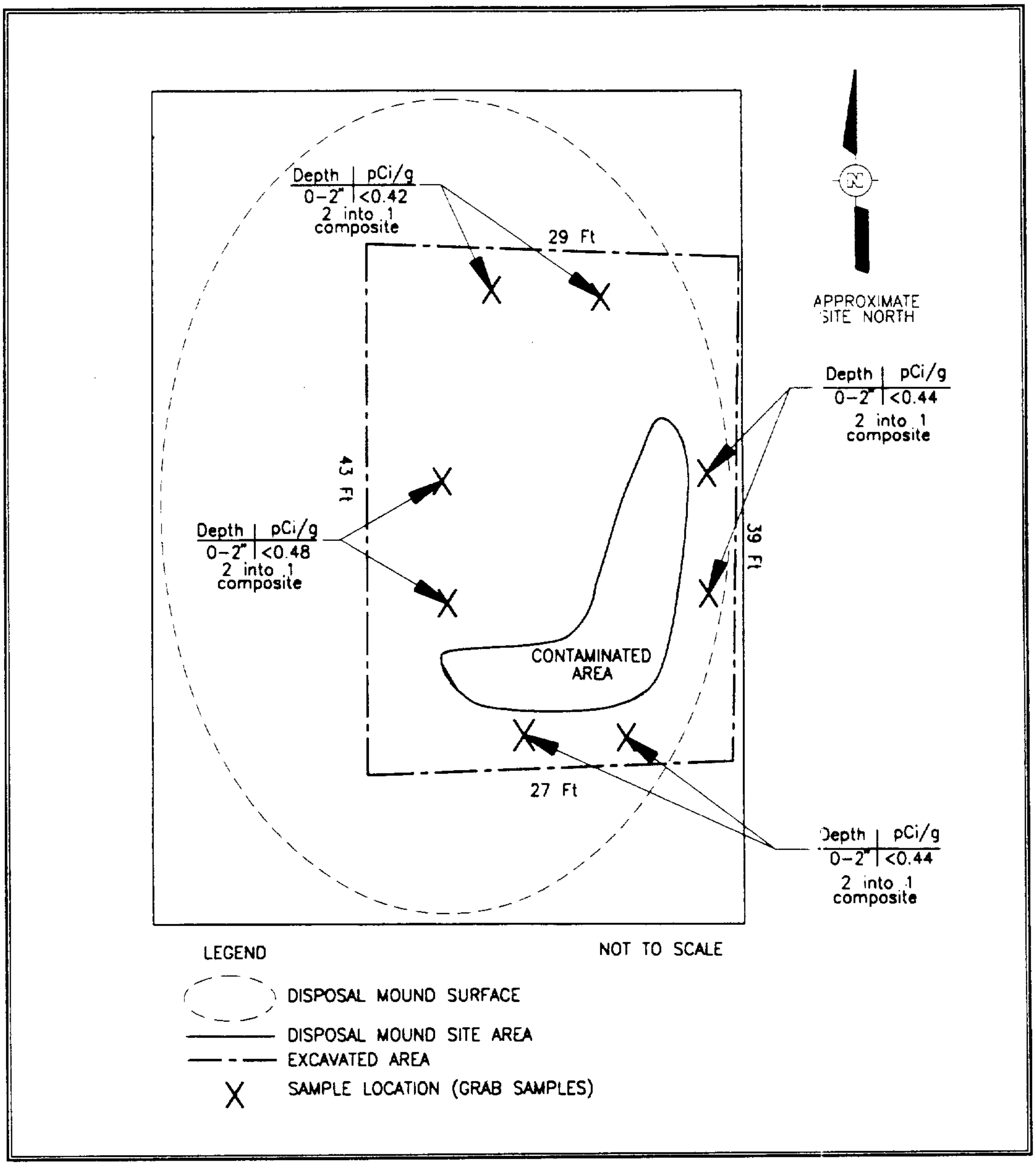
Throughout the packaging of the contaminated soil, empty and loaded B-25 containers were shuttled to and from the base camp with the Nodwell 110 tundra carrier. The empty B-25 containers were placed on an HDPE liner in the loading zone. After filling, the B-25 containers were sealed and transferred to the staging area (Figures 6-20 and 6-21).

6.3 Test-Plot Area Removal

An EZ was created around the boundaries of the test-plot area using HDPE sheeting, and a decontamination area was set up. The MCA was placed at six locations, two in the center and one in each corner of the test-plot area. Central locations were used to identify the contaminated areas. Other points were used to ensure that the areal extent of contamination did not extend beyond the previously measured boundaries of the test-plot area.

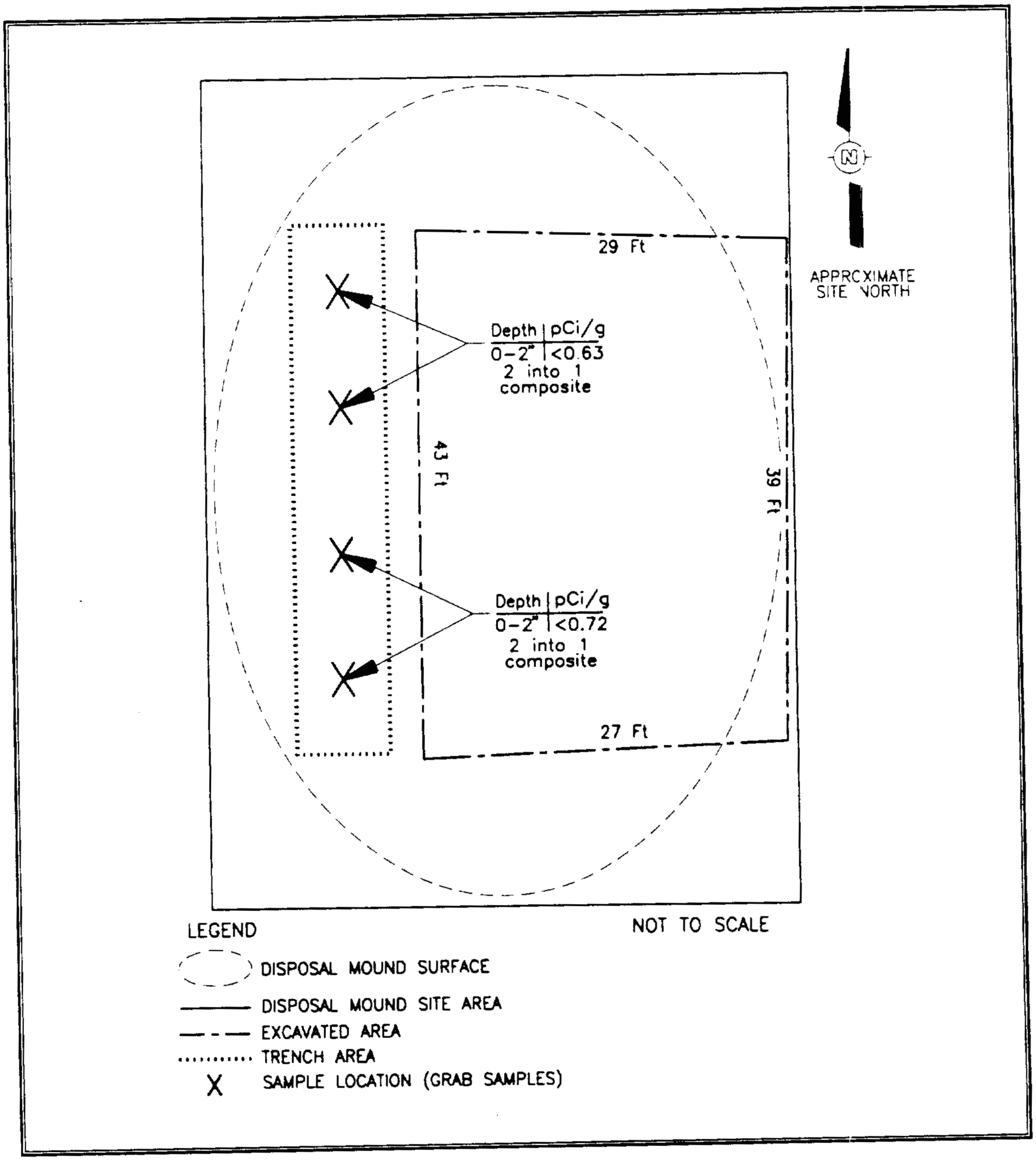
Removal of the test-plot area began on August 17, 1993, and was completed on August 20, 1993. The dimensions of the test-plot area were approximately 6 m

Figure 6-18
Cesium-137 Soil Sampling Results as Picocuries per Gram Investigation to Confirm That Soil around Contaminated Area Was Noncontaminated



by 5 m by 0.3 m (19.5 ft by 16 ft by 1 ft). The contaminated soil was removed manually with shovels and placed in four B-25 containers. Approximately 9 m^3 (12 yd^3) of soil were removed; this amount is based on the dimensions of the excavated area and the approximate depth to which the soil was removed. The area was then resurveyed with the Eberline ESP-2/NaI ratemeter. This survey indicated only background levels of naturally occurring radioisotopes.

Figure 6-19
Cesium-137 Soil Sampling Results as Picocuries per Gram
Sampling of Trench Excavation Area



On August 20, 1993, a hexagonal grid system was laid out across the test-plot area, and final closure sampling was conducted (Figure 6-22). These samples were analyzed at both the on-site and off-site laboratories. Results indicated that the concentrations of Cs-137 were below the clean-up level.

Figure 6-20
B-25 Containers Sealed after Filling

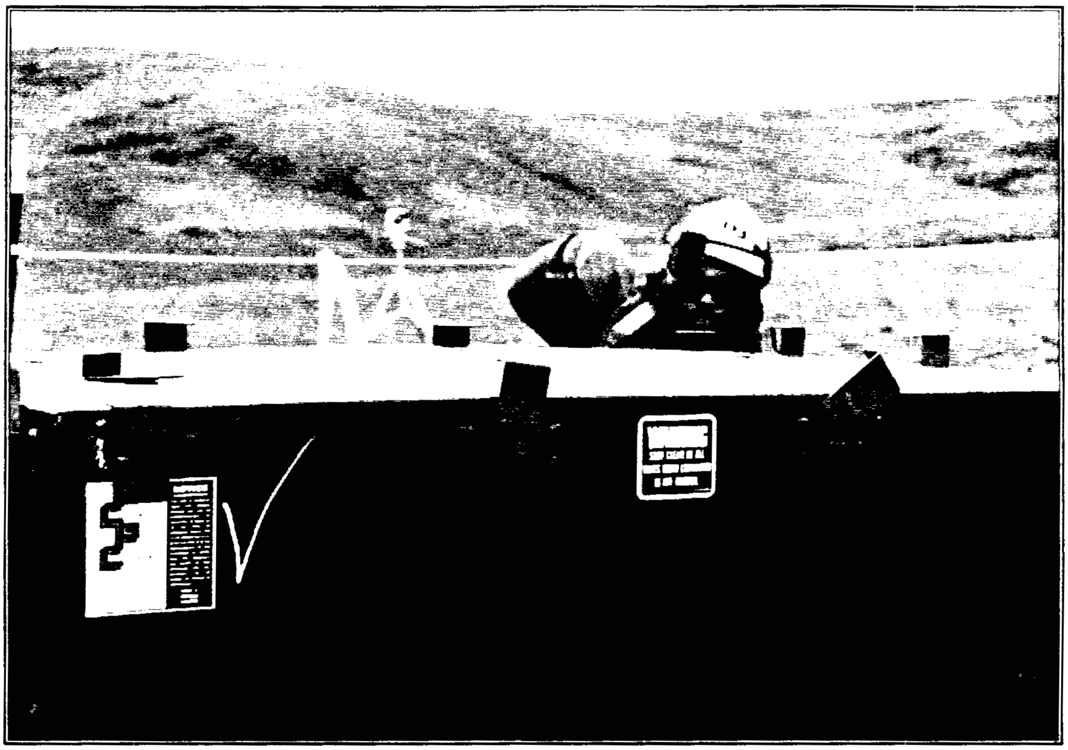


Figure 6-21
B-25 Containers Transferred to Holding Area

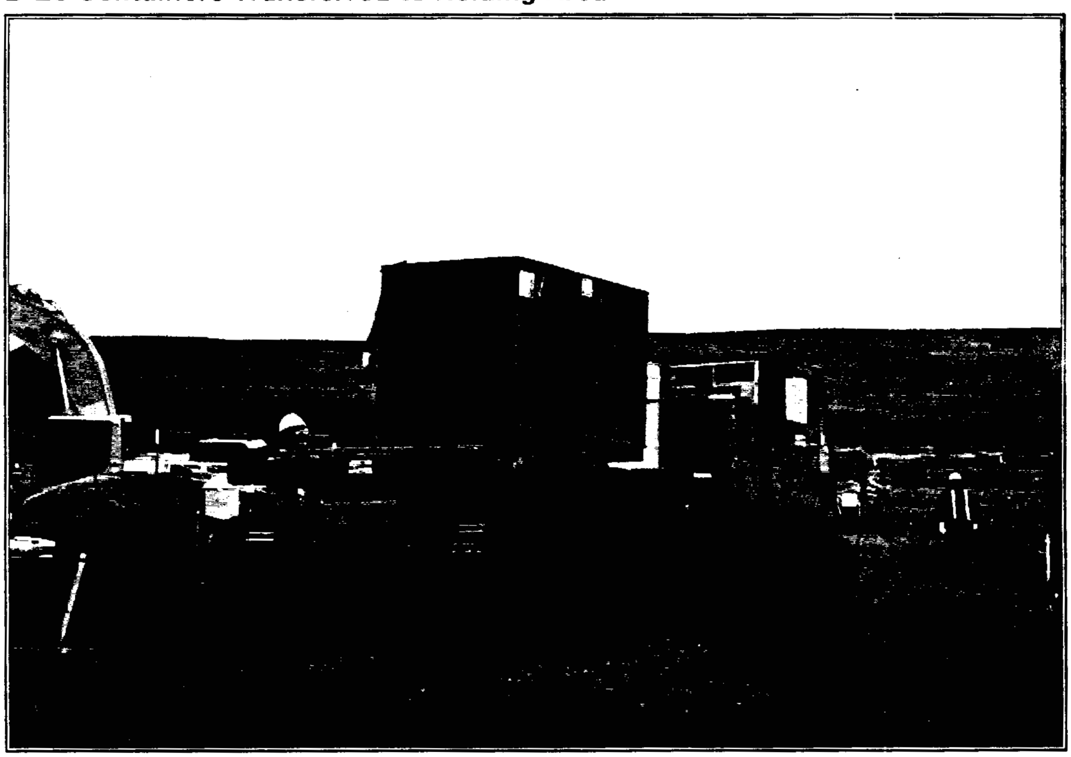


Figure 6-22
Hexagonal Grid System

Chapter 7.0 Post-Excavation Confirmatory Sampling and Analysis Results

The final excavation limits within the mound area were 12 m (39 ft) on the east side, 13 m (43 ft) on the west side, 9 m (29 ft) on the north side, and 8 m (27 ft) on the south side. Approximately 0.46 m (1.5 ft) of contaminated soil above the original ground surface and 0.6 m (2 ft) below the original ground surface were excavated during remediation activities at the mound. The excavation limits at the former test-plot area were approximately a 6-m by 5-m (19-ft by 16.5-ft) area up to 0.3 m (1 ft) in depth.

Following the completion of the excavation and removal activities, a sampling effort was performed to verify that the established clean-up level had been reached for both the disposal mound and former test-plot area. The sampling effort was accomplished by a radiation survey of the mound and former test-plot area, followed by soil sampling and analysis. The radiation survey provided the sampling team with a high degree of confidence that the excavation had been accomplished and that clean levels had been reached. Clean-closure sampling was then performed to confirm that no radiation contamination above clean-up criteria remained.

The clean-closure sampling took place at the mound and test-plot area on August 18 and 20, 1993, respectively. These sampling events were conducted prior to backfilling the disposal mound and test-plot area with clean soils. Criteria and documentation of clean-closure sampling based on the use of the hexagonal grid system are contained in the *Field Manual for Grid Sampling of PCB Spill Sites to Verify Cleanup.*[20]

7.1 Methodology

A predefined hexagonal grid system was used at the disposal mound (Figure 7-1) and test-plot area (Figure 7-2) to determine (1) the locations of grid sampling points at each excavation site, (2) the number of samples to be collected, (3) the on-site field screening locations, and (4) a level of confidence by which the clean-up could be defined.

The following is a summary of the procedure used to determine the dimensions and number of locations sampled when using the hexagonal grid system. A complete copy of the SOP for Establishment of a Hexagonal Grid System for Mound Excavation and supporting sample documentation can be found in Appendix A, Part 3 of the Remedial Action Plan.[2]

As part of the first step in the hexagonal grid system, the excavation sites were measured using a 100-ft steel tape. The excavation was then drawn to scale on

Figure 7-1
Hexagonal Grid System at the Disposal Mound

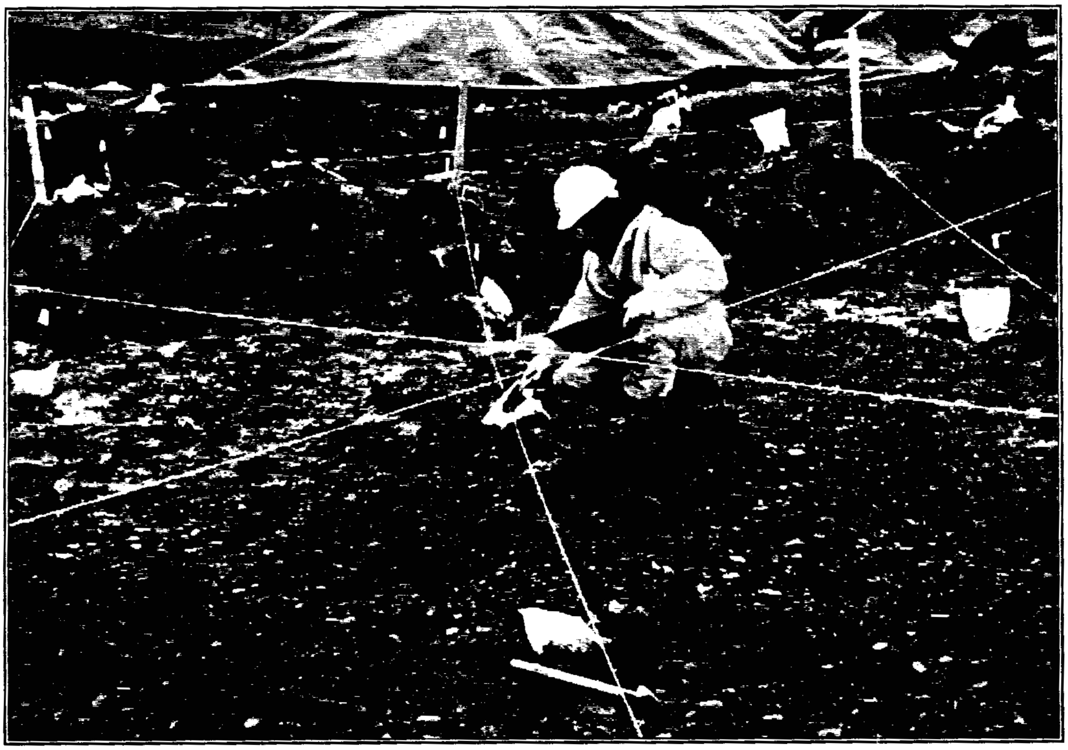


Figure 7-2
Hexagonal Grid System at the Test-Plot Area

graph paper. A circle was drawn around the excavation and the radius determined. For a radius less than 4 ft, 7 samples would be required; for a radius greater than 4 but less than 11 ft, 19 samples would be required; and for a radius greater than 11 ft, 37 samples would be required. Based on the aforementioned sizes of the excavations for the mound and test-plot area, 37 samples were required for each. Sampling at this number of points on the grid resulted in a 98-percent confidence level that the soil of concern had been removed.[20]

Based on the number of samples required and the length of the radius, the spacing between rows and points on the row were determined. The grid was then laid out at the excavation using pin flags starting at the center of the site. Discrete soil samples were collected from each of the sampling points and submitted to the on-site laboratory. The hexagonal grid system was then divided into four equal quadrates. Soil samples were collected from each sample point within each of these quadrates and composited into a single sample for each quadrate. The resulting four composite samples, east, west, north, and south, were then sent to the off-site laboratory for confirmatory analysis.

Soil samples collected from the hexagonal grid system located at the disposal mound and the test-plot area were split with ADEC and Foster Wheeler Representatives. Split samples were analyzed by these groups to confirm the analytical results obtained by DOE at these same locations. The split sample schedule for the grid nodes was as follows:

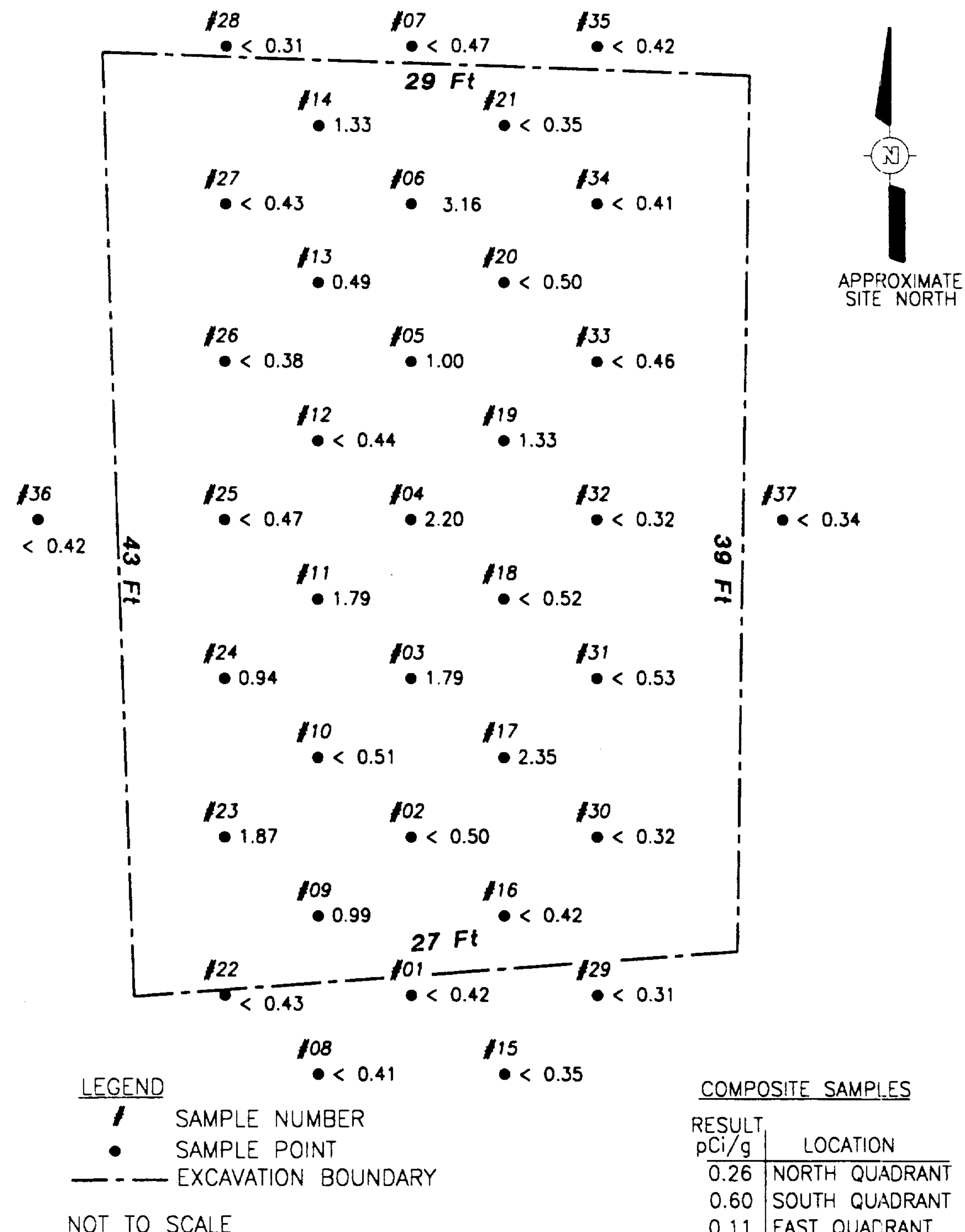
- Clean Closure Sampling Disposal Mound - August 18, 1993
  - ADEC: Thirteen samples were split from locations 2, 9, 11, 13, 14, 17, 18, 23, 26, 28, 35, and 37. In addition, the south composite sample was split.
  - Foster Wheeler: Ten samples were split from node locations 3, 4, 5, 7, 16, 19, 24, 31, 33, and 36. No composite split was requested.
- Clean Closure Sampling Test-Plot Area - August 20, 1993
  - ADEC: Thirteen samples were split from locations 2, 3, 8, 11, 15, 18, 22, 23, 24, 26, 28, and 31. In addition, the west composite sample was split.
  - Foster Wheeler: Five samples were split from node locations 4, 7, 26, 31, and 34. No composite split was requested.

7.2 Results

Cesium-137 activities in soil samples collected and analyzed at the on-site laboratory for clean closure of the disposal mound and test-plot area are reported in Figures 7-3 and 7-4, respectively. All results were determined to be below defined action levels. A comparison of the confirmatory clean closure soil sample results as analyzed by the different laboratories can be found on Tables 7-1 and 7-2. Further, the samples collected for the waste-characterization sampling were determined to contain no listed hazardous materials in quantities that would prohibit disposal of the collected soils at the NTS.

After receiving the analytical results for the confirmatory clean-closure sampling, ADEC authorized the clean closure of the mound and test-plot area on August 23 and 26, 1993, respectively. ADEC approval of closure certification is presented in Attachment B. A representative of the Native Village of Point Hope also surveyed the bottom of the mound-excavation area and concurred with the closure approval.

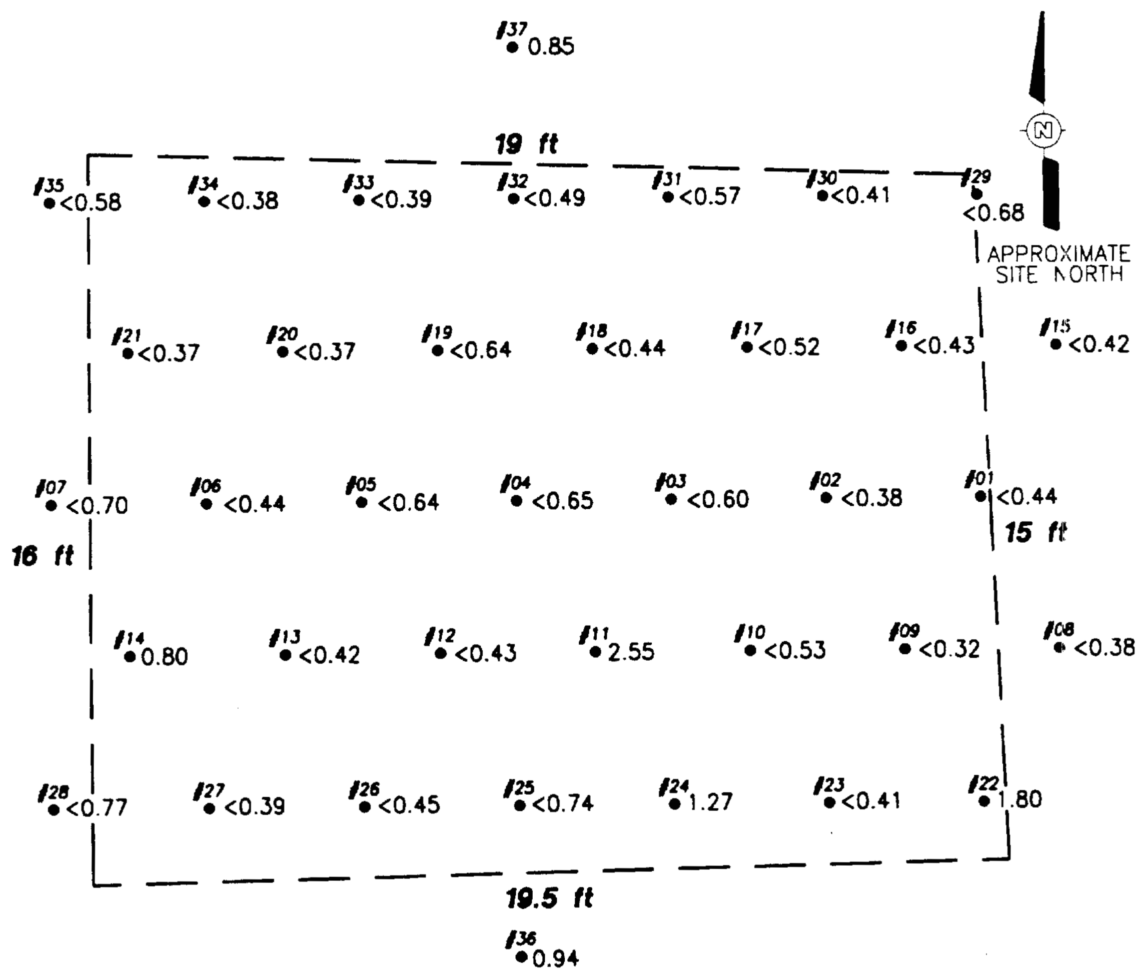
Figure 7-3
Soil Disposal Mound Clean-Closure Soil-Sampling Location and Results Reported as Picocuries per Gram



COMPOSITE SAMPLES

RESULT pCi/g	LOCATION
0.26	NORTH QUADRANT
0.60	SOUTH QUADRANT
0.11	EAST QUADRANT
1.24	WEST QUADRANT

Figure 7-4
Former Cesium-137 Test-Plot Area Clean Closure Soil Sampling Location and Results Reported as Picocuries per Gram Cesium-137 Activity



LEGEND
- ● SAMPLE POINT
- # SAMPLE NUMBER
- — — EXCAVATION BOUNDARY

NOT TO SCALE

COMPOSITE SAMPLES

RESULT pCi/g	LOCATION
0.16	NORTH QUADRANT
0.84	SOUTH QUADRANT
0.10	EAST QUADRANT
0.24	WEST QUADRANT

Table 7-1
Confirmatory Clean Closure Soil Cesium-137 Results for Mound

Quadrate	Sample Number	IT Cs-137 On-Site Analysis Results (pCi/g)	IT Cs-137 Off-Site Analysis Results (pCi/g)	Lockheed Cs-137 Results (pCi/g)
South	CHR-CC-1.01	<0.42	N/A	N/A
South	CHR-CC-1.02	<0.50	N/A	N/A
South	CHR-CC-1.03	1.79	N/A	N/A
*	CHR-CC-1.04	2.20	N/A	N/A
North	CHR-CC-1.05	1.00	N/A	N/A
North	CHR-CC-1.06	3.16	N/A	N/A
North	CHR-CC-1.07	<0.47	N/A	N/A
South	CHR-CC-1.08	<0.41	N/A	N/A
South	CHR-CC-1.09	0.99	N/A	0.896
South	CHR-CC-1.10	<0.51	N/A	N/A
West	CHR-CC-1.11	1.79	N/A	1.169
West	CHR-CC-1.12	<0.44	N/A	N/A
North	CHR-CC-1.13	0.49	N/A	1.194
North	CHR-CC-1.14	<0.45	N/A	0.503
South	CHR-CC-1.15	<0.35	N/A	N/A
South	CHR-CC-1.16	<0.42	N/A	N/A
South	CHR-CC-1.17	2.35	N/A	1.213
East	CHR-CC-1.18	<0.52	N/A	0.046
East	CHR-CC-1.19	1.33	N/A	N/A
South	CHR-CC-1.01 DUP	<0.24	N/A	N/A
North	CHR-CC-1.20	<0.50	N/A	N/A
North	CHR-CC-1.21	<0.35	N/A	N/A
South	CHR-CC-1.22	<0.43	N/A	N/A
South	CHR-CC-1.23	1.87	N/A	0.389
West	CHR-CC-1.24	0.94	N/A	N/A
West	CHR-CC-1.25	<0.47	N/A	N/A
West	CHR-CC-1.26	<0.38	N/A	0.056
North	CHR-CC-1.27	<0.43	N/A	N/A
North	CHR-CC-1.28	<0.31	N/A	0.145
South	CHR-CC-1.29	<0.42	N/A	N/A
South	CHR-CC-1.30	<0.32	N/A	N/A
East	CHR-CC-1.31	<0.53	N/A	N/A
East	CHR-CC-1.32	<0.32	N/A	N/A
East	CHR-CC-1.33	<0.46	N/A	N/A
North	CHR-CC-1.34	<0.41	N/A	N/A
North	CHR-CC-1.35	<0.42	N/A	0.203
West	CHR-CC-1.36	<0.42	N/A	N/A
East	CHR-CC-1.37	<0.34	N/A	0.134
North	CHR-CC-1.34 DUP	<0.37	N/A	N/A
North	CHR-CC-North	N/A	0.26	N/A
South	CHR-CC-South	N/A	0.60	2.304
East	CHR-CC-East	N/A	0.11	N/A
East	CHR-CC-East DUP	N/A	0.09	N/A
West	CHR-CC-West	N/A	1.24	N/A

* This sample was not part of a composite sample because it was located in the center of the grid, and therefore, was not located in a quadrate.
N/A - Not analyzed.

Table 7-2
Confirmatory Clean Closure Soil Cesium-137 Results for Test-Plot Area

Quadrate	Sample Number	IT Cs-137 On-Site Analysis Results (pCi/g)	IT Cs-137 Off-Site Analysis Results (pCi/g)	Lockheed Cs-137 Results (pCi/g)
East	CHR-CC-P-1.01	<0.44	N/A	N/A
East	CHR-CC-P-1.02	<0.38	N/A	N/A
East	CHR-CC-P-1.03	<0.60	N/A	0.423
*	CHR-CC-P-1.04	<0.65	N/A	N/A
West	CHR-CC-P-1.05	<0.64	N/A	N/A
West	CHR-CC-P-1.06	<0.44	N/A	N/A
West	CHR-CC-P-1.07	<0.70	N/A	N/A
East	CHR-CC-P-1.08	<0.38	N/A	N/A
East	CHR-CC-P-1.09	<0.32	N/A	N/A
East	CHR-CC-P-1.10	<0.53	N/A	N/A
South	CHR-CC-P-1.11	2.55	N/A	3.368
South	CHR-CC-P-1.12	<0.43	N/A	N/A
West	CHR-CC-P-1.13	<0.42	N/A	N/A
West	CHR-CC-P-1.14	0.80	N/A	N/A
East	CHR-CC-P-1.15	<0.42	N/A	N/A
East	CHR-CC-P-1.16	<0.43	N/A	N/A
East	CHR-CC-P-1.17	<0.52	N/A	N/A
North	CHR-CC-P-1.18	<0.44	N/A	0.271
North	CHR-CC-P-1.19	<0.64	N/A	N/A
West	CHR-CC-P-1.20	<0.37	N/A	N/A
East	CHR-CC-P-1.01 DUP	<0.43	N/A	N/A
West	CHR-CC-P-1.21	<0.37	N/A	N/A
East	CHR-CC-P-1.22	1.80	N/A	N/A
East	CHR-CC-P-1.23	<0.41	N/A	<0.059
South	CHR-CC-P-1.24	1.27	N/A	N/A
South	CHR-CC-P-1.25	<0.74	N/A	N/A
South	CHR-CC-P-1.26	<0.45	N/A	N/A
West	CHR-CC-P-1.27	<0.39	N/A	N/A
West	CHR-CC-P-1.28	<0.77	N/A	N/A
East	CHR-CC-P-1.29	<0.68	N/A	N/A
East	CHR-CC-P-1.30	<0.41	N/A	N/A
North	CHR-CC-P-1.31	<0.57	N/A	N/A
North	CHR-CC-P-1.32	<0.49	N/A	N/A
North	CHR-CC-P-1.33	<0.39	N/A	N/A
West	CHR-CC-P-1.34	<0.38	N/A	N/A
West	CHR-CC-P-1.35	<0.58	N/A	N/A
South	CHR-CC-P-1.36	0.94	N/A	N/A
North	CHR-CC-P-1.37	0.85	N/A	N/A
South	CHR-CC-P-1.34 DUP	<0.49	N/A	N/A
North	CHR-CC-P-North	N/A	0.16	N/A
South	CHR-CC-P-South	N/A	0.84	N/A
East	CHR-CC-P-East	N/A	0.10	N/A
West	CHR-CC-P-West DUP	N/A	0.12	N/A
West	CHR-CC-P-West	N/A	0.24	0.208

* This sample was not part of a composite sample because it was located in the center of the grid, and therefore, was not located in a quadrate.
N/A - Not analyzed.

Chapter 8.0

Waste Management

Waste from Project Chariot included contaminated soil from the disposal mound and test-plot area, remediation-derived waste, sanitary trash, and construction refuse. Remediation-derived waste included such things as plastic sheeting, rainwater removed from the excavation area, and materials used in decontamination. Waste was packaged into B-25 containers for disposal at the NTS. The following is the number of B-25 containers that were used for packaging these various types of waste:

- 52 Mound soil
- 1 Mound soil and remediation-derived waste
- 3 Test-plot soil
- 2 Test-plot soil and remediation-derived waste
- 3 Remediation-derived waste
- 13 Sanitary trash and construction refuse.

Approximately 115 m^3 (150 yd^3) of contaminated soil (including water in the soil matrix) were removed from the disposal mound. Debris (i.e., wooden planks and plastic sheeting) from the original tracer study was also packaged with the contaminated soil. Approximately 9 m^3 (12 yd^3) of contaminated soil (including vegetation and water in the soil matrix) were removed from the test-plot area.

Specific questions concerning the total quantity of Cs-137 removed were raised by the representatives of the local communities. Based on the volume of soil removed and the associated Cs-137 activities, it has been determined that approximately 1×10^8 Bq (3 mCi) of Cs-137 was removed and shipped to the NTS. This value is fully consistent with the total activity of Cs-137 expected to remain from the tracer studies based on historic information (see Section 1.2).

In order to dispose of low-level radioactive waste at the NTS, the waste acceptance criteria, as contained in NVO-325, Nevada Test Site Defense Waste Criteria, Certification, and Transfer Requirements, Revision 1, had to be met. Waste acceptance criteria address issues such as packaging, shipping, confirmation of the levels of hazardous and radioactive constituents, external-package radiation limits, and allowable quantities of free liquids. To demonstrate compliance with the waste acceptance criteria, an application to ship waste was submitted to DOE's Nevada Operations Office. Waste management operations at the Project Chariot Site proceeded after the application was approved. DOE/NV's Waste Management Division conducted a surveillance of waste management activities during soil removal operations at the Project Chariot Site.

8.1 Waste Containers

Although the Project Chariot Site waste contained radioactivity less than the DOT regulatory limit for low specific-activity waste, the B-25 containers used for waste storage and transport met this higher standard (Figure 8-1). These containers also met the definition of DOT strong, tight containers and comply with the criteria that the packages will maintain their integrity during handling and shipping. The B-25 containers are equipped with a patented Seal-Lock closure system that helps prevent the containers from opening in the event of an accident. An audit of the container manufacturer was conducted to ensure that the fabrication of the containers met requirements.

Before loading waste into the B-25 containers, they were inspected in accordance with the Project Chariot Site waste-handling SOPs for the Storage and Shipping of Low Specific-Activity Materials (Figure 8-2). Only B-25 containers that passed the inspection were permitted within the area designated for loading waste. Some B-25 containers were dented during transport and unloading and did not meet the stringent inspection criteria. These containers were marked with a conspicuous orange "x" from corner to corner and used for sanitary trash and construction refuse only.

8.2 Waste Packaging

Empty B-25 containers that satisfied inspection requirements were prepared in designated areas of the EZ, which were separate from excavation and filling operations at the disposal mound. Procedures for placing absorbent into the B-25 containers holding contaminated soil had been established before waste-packaging operations began. These procedures ensured that there was proper absorbent capacity to meet NVO-325's allowance for free liquids in waste containers.

Absorbent was also placed in B-25 containers that contained remediation-derived waste. This was done to absorb any free liquid that may have been released from the soil-covered remediation materials. In addition, ponded rainfall removed from the test-plot area and the ephemeral pond resulted in remedial-derived wastewater, which was placed into two B-25 containers with sufficient absorbent to comply with the waste acceptance criteria.

After each container was filled with waste, the lid was placed on the box, the Seal-Lock clips secured, and the tamper-indicating devices placed on the Seal-Lock clip at each corner. All filled B-25 containers were weighed, and a Package Inventory Form for each container was completed (Figure 8-3). Outside surfaces of the B-25 containers were surveyed and swiped. After results from

Figure 8-1
B-25 Waste Container for the Storage and Shipping of Low Specific-Activity Materials

DESCRIPTION

Classification	Low specific-activity waste container
Package type	CFR specification "Strong-Tight"
Capacity	90 cubic feet
Material	ASTM A-569 low carbon, hot-rolled steel
Gross Weight (Empty)	920 pounds
Payload	10,000 pounds
Max Loaded Weight	10,920 pounds

ADDITIONAL INFORMATION

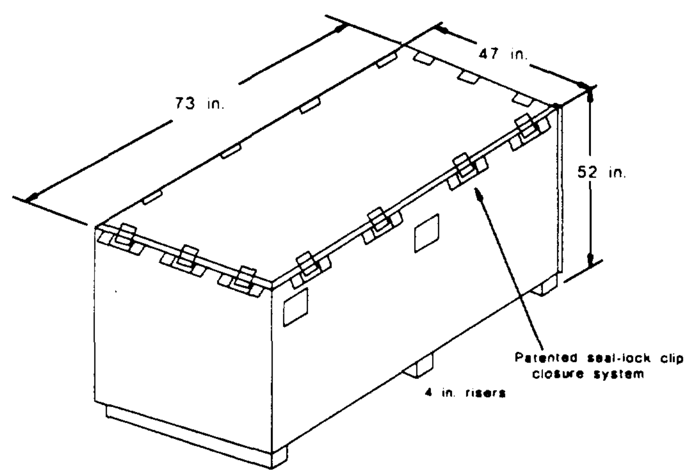
Meets general container requirements (49 CFR 173.24) for asbestos, ORM, and hazardous-waste materials.

Patented, exclusive "seal-loc" positive closure system to preclude inadvertent opening.

Optional removable risers.

Optional anti-springback retention system for compactor application.

Final protective finish to meet customer requirements optional shielding available.



U.S. Patent Numbers 4371092 AND 4426927
(REFERENCED FROM CONTAINER PRODUCT CORPORATION)

the swipes indicated no radiation levels above DOT limits, the B-25 containers were approved for release from the EZ and transported to a designated area beside the camp operations. The B-25 containers were later transported to the beach for transfer onto the barge (Figure 8-4). Uni-mats were placed underneath the B-25 containers to protect the beach area from damage (Figure 8-5).

8.3 Waste Disposal

The Project Chariot Site waste was sampled and analyzed to confirm that no hazardous constituents were present that would prohibit its transport to, and disposal at, the NTS. Laboratory analytical results indicated that the waste did

Figure 8-2
Waste Characterization Officer Inspecting B-25 Containers

Figure 8-3
B-25 Container Being Weighed

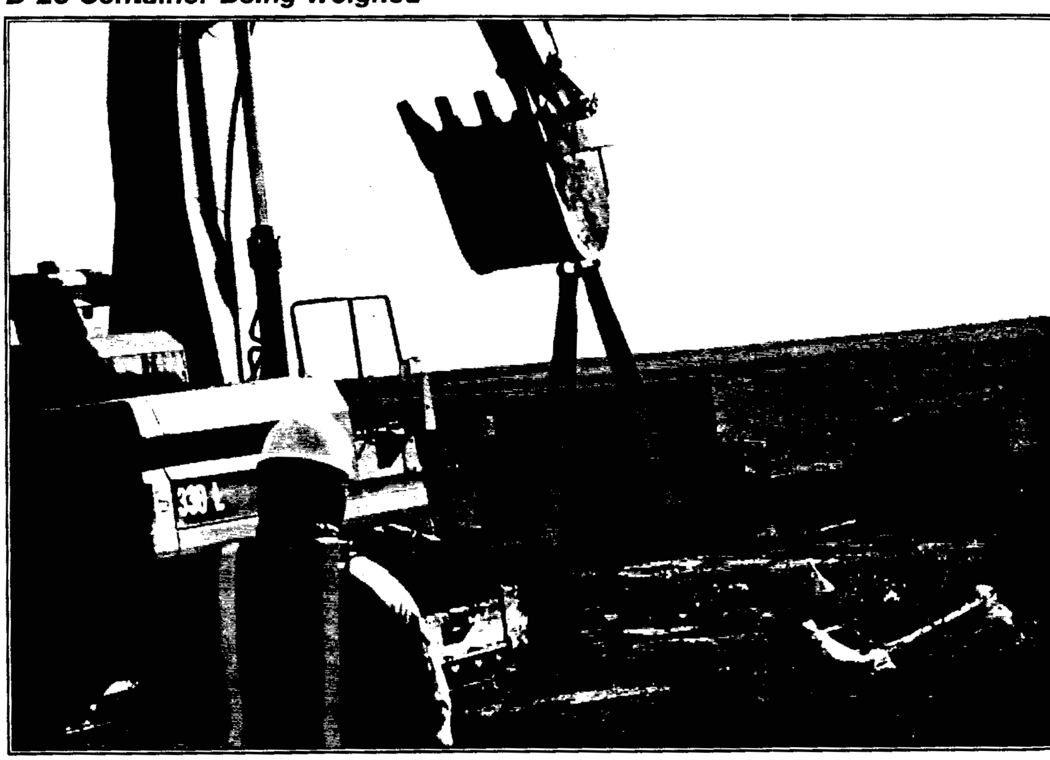


Figure 8-4
Transport of B-25 Container to the Staging Area at the Beach

Figure 8-5
B-25 Containers Sitting on Uni-Mats

not contain hazardous constituents. The analytical results were received before the waste was transported. This ensured that DOT regulatory requirements were met for the transport of the waste.

Upon arrival at the NTS, the B-25 containers were again surveyed and inspected. All B-25 containers containing soil and remedial-derived waste were unloaded and deposited at the Waste Operations Department Storage Yard, located within the NTS. The waste was stored in this controlled area, pending the final internal and DOE waste management program audits. After these audits, the waste was disposed in the RWMS at the NTS. The RWMS is an approved shallow-land burial facility for the disposal of low-level radioactive waste.

There was a separate shipment of B-25 containers with sanitary trash and construction refuse, which included materials such as absorbent boxes and geotextile fabrics. Waste acceptance personnel at the NTS required that the sanitary trash also be documented as clean (i.e., not contaminated) prior to disposal in the 10C Sanitary Landfill at the NTS. This certification was achieved through radiation surveying and process knowledge. Only debris that was generated outside the EZ and decontaminated and surveyed or that was in contact with clean soil within the EZ was disposed as sanitary trash.

Chapter 9.0 Restoration and Demobilization Activities

9.1 Site Revegetation

Along with restoring the mound site, all material and supplies were cleaned up and returned to Base Camp. The support tent, incinolet toilet, and generator were dismantled, and the entire area of the EZ and CRZ was cleaned of all trash and debris. The silt fence on the downgradient side of the excavation area was left in place until reseeding was completed.

After the regrading and removal of the mound facilities, reseeding of the disturbed areas was started. With direction from an ADNR Representative, seed and fertilizer were distributed over the disturbed area. The following seed mixture was applied:

43 percent	Bering Hairgrass
32 percent	Arctared Fescue
12 percent	Alyeska Polar Grass
7 percent	Egan Slough Grass
6 percent	Tundra Blue Grass

The application of the seed mixture was approximately 14 kilograms (kg) (30 lb) per acre. Free-flowing, granular 20-20-10 fertilizer was applied at a rate of 270 kg (600 lb) per acre. One layer of Excelsior™ blankets was secured over the seeded and fertilized area (Figure 9-1). At direction of ADNR, the former test-plot area was not reseeded in the same manner as the other areas. Instead, it was turned into an experimental reseeding area.

The silt fence was removed after the reseeding of the mound area was finished, and the crossing at Snowbank Creek was dismantled (Figure 6-2). Sandbags were returned to Base Camp, emptied, and burned. Because the area of the crossing at Snowbank Creek was extremely muddy, extra seed and fertilizer were distributed over this area. Also, two layers of Excelsior™ blankets were secured along the banks of Snowbank Creek. The entire trail back to camp was then seeded in the same manner (Figure 9-2). A trip will be scheduled in August 1994 to inspect for successful revegetation.

9.2 Operations Demobilization

After reseeding the trail and securing the Excelsior™ blankets, demobilization began. All surplus material and supplies were inventoried and loaded into sea containers. The Uni-mats were burned with the approval of ADEC. All

Figure 9-1
Excelsior™ Blankets

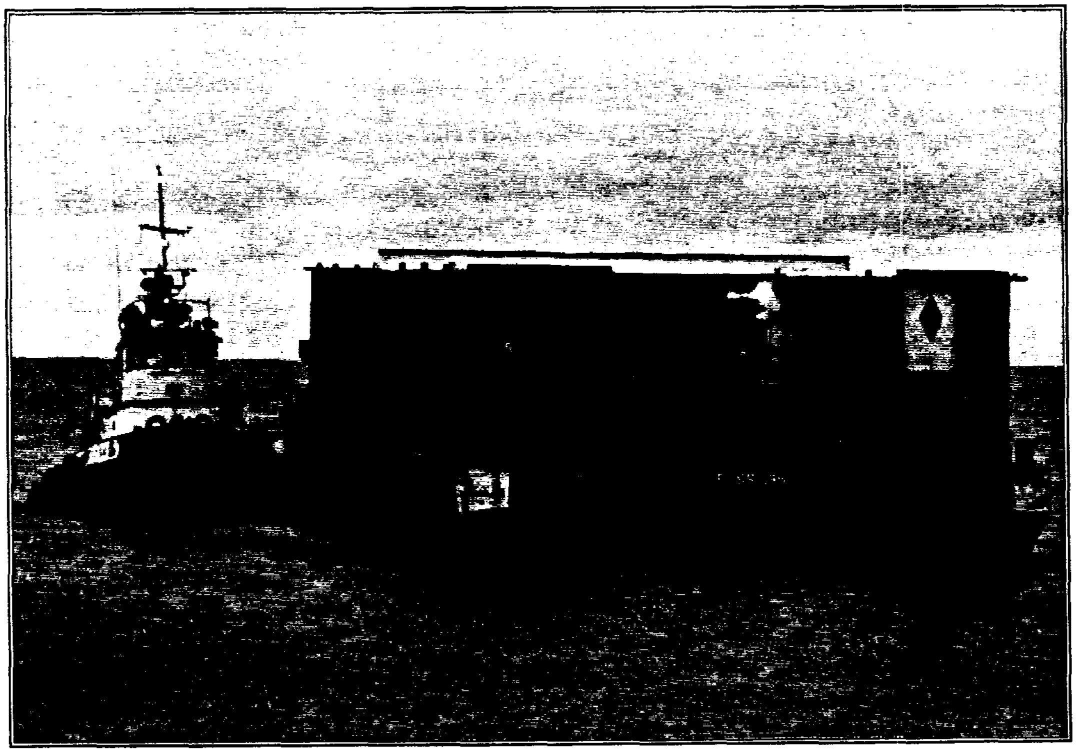
Figure 9-2
Excelsior™ Blankets Being Placed on Trail

equipment and materials, including the loaded B-25 containers, were moved to a temporary holding area at the beach to prepare for barge loading. The barge arrived on September 3, 1993 (Figure 9-3), and loading began. However, late in the afternoon, the weather changed, and loading operations were halted. The barge was able to return to shore on September 5, 1993, and the remainder of the equipment was loaded. The tug and barge then departed the Project Chariot Site, heading for Seattle, Washington.

The barge arrived in Seattle on September 25, 1993, and was unloaded at the Foss Terminal on September 27 and 28, 1993. Rental equipment was returned to the appropriate vendors in Anchorage and Seattle. Surplus material and supplies were shipped to Las Vegas for storage. The B-25 containers were trucked to the NTS for disposal.

DOE officials returned to Kotzebue in October 1993 and met with the Native allotment holder, from whom the land was leased, to verify that the land had been restored to acceptable preremedial conditions. The first major snow storm of the season prevented them from getting to the Project Chariot Site. Due to the adverse weather conditions, participants, including the Native allotment holder, agreed that the site visit should be postponed until a later date. The site visit was conducted in early August 1994.

Figure 9-3
Arrival of the Barge



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Chapter

10.0 Quality Assurance/ Quality Control Practices

All activities affecting the quality of the data gathered during the Project Chariot Tracer Study Site Assessment and Remedial Action were subject to quality requirements defined in the Quality Assurance Project Plan (QAPjP) and procedural requirements specified in the FSP. Quality Assurance personnel were on site for the duration of the project and conducted multiple surveillances (reviews of specific activities) that were formally documented. The DOE Project Manager performed surveillances of selected activities. Any differences between the requirements and the work as performed (deficiencies) were identified, evaluated, and corrected. None of the deficiencies caused the data collected to be suspect or invalid.

10.1 Personnel Training

Quality-assurance training requirements for personnel were based on the assignments given the individual. Sampling and survey personnel were required to receive a general orientation to the Quality Assurance Program, to read and understand the SOP for the assigned activities, and to be familiar with the equipment to be used in the performance of the tasks assigned. Training on Resource Conservation and Recovery Act and NVO-325 requirements was required for all personnel working within the EZ and for the work-site supervisors.

10.2 Equipment Calibration and Response Checks

All test and measuring equipment was calibrated to nationally recognized standards, primarily NIST-traceable sources. This included all radiation detection and measuring instruments and the scales for weighing the waste containers.

To assure validity of radiation-detection field-instrument measurements, background and source checks were performed daily prior to equipment use and at the completion of each day's activities. Statistical control charts using count rates were generated for each instrument, and performance of the instrument was compared to the limits established by these charts. If the count rate was greater than three standard deviations from the mean, it was removed from service, tagged, and physically separated from properly operating instruments to prevent its use.

Calibration of the on-site laboratory gamma-counting systems was performed each day prior to use. Additional source checks were performed between each sample count to monitor effects of temperature changes within the laboratory tent. Upon determination of the temperature range within which the system could operate unaffected, the frequency of the source checks was reduced to once every ten samples, and the temperature was monitored.

10.3 Quality Control Samples

Multiple types of QC samples were used to evaluate the data quality of the project. Field QC samples provided an estimate of the error or uncertainty associated with the sampling effort. Laboratory QC samples were used to determine the accuracy and precision of each process and to detect if contamination of a system or sample occurred. The QC sample types and their uses are discussed in the following sections.

10.3.1 Field Quality Control Samples

A field duplicate is one of multiple samples collected at the same location, immediately after the routine sample, using the same technique. This type of sample was collected to assess the consistency of the sampling technique and the precision of the analytical process. Cesium-137 results for these samples were all below the MDA, indicating adequate consistency in both the sampling and analytical activities.

A trip blank is a vial of organic-free water that is shipped with sample vials for collection of volatile organics samples. This type of sample is used to determine if diffusion of organic contaminants into sample containers has occurred during shipping and storage. By oversight, these samples were not shipped with the containers to the Project Chariot Site. However, because no elevated value of volatile organics was found in the Project Chariot waste samples, the need to pinpoint the source of volatile organics was overridden, and the absence of the trip blanks did not affect the project.

A split sample is a portion of a single sample that has been well mixed and divided into multiple containers to be analyzed by different laboratories. Samples were collected by DOE personnel and, when requested and the volume allowed, split with ADEC and Foster Wheeler Representatives. Field splits were prepared for soil, water, and sediment samples. Biota samples were split in the on-site laboratory after drying and grinding or milling to achieve as uniform a sample mix as possible.

Extra quantities of soil were collected with waste-characterization samples to provide sufficient sample for matrix spike and matrix spike duplicate analyses that are required by laboratory protocols. These analyses are discussed in Section 10.3.3.

10.3.2 On-Site Laboratory Quality Control Samples

Laboratory duplicates are analyzed to determine method and counting precision. Since samples were only dried and ground before being counted in the on-site laboratory, laboratory duplicates were limited to 1 in every 20 samples (or a minimum of 2 per day). In each case, the sample was counted twice to determine the precision of each gamma counting system. The typical relative percent difference stated in the QAPjP for the on-site laboratory is ± 30. The results of duplicate counts where Cs-137 was detected exceeded the typical value twice; once by four percent and once by ten percent. Since this was not an acceptance value, it had no impact on the project.

Laboratory control standards were counted daily to determine the accuracy of the systems. The accuracy ranged from 98- to 110-percent recovery, well within the typical recovery percentage range of 70 to 130.

Additionally, a petri dish (the type of sample container used) of clean sand was analyzed periodically as a blank sample to ensure there was nothing in the sample container material or on the detector contributing to incorrectly high sample values. In all cases, detected Cs-137 values were less than the MDA.

10.3.3 Off-Site Laboratory Quality Control Samples

A method blank is a volume of deionized, distilled water processed by the same method as the sample group with all reagents of the process added. This type of QC sample is used to determine if contamination is introduced into samples from the reagents used in the procedure or from other samples. No contamination was indicated that would affect the result of any sample.

A laboratory control sample is a spiked blank sample that is processed the same as other samples through the entire sample preparation and analysis procedure with each group of samples. The recovery of the spike is used to determine the accuracy for each sample group for each analysis that is performed.

The accuracy data for each sample type and analysis is provided in Table 10-1. All soil recovery values except for gross alpha are within the typical recovery ranges listed in the QAPjP. The high recoveries for that analysis indicate that the reported gross alpha results for some samples may be somewhat higher than the activity actually present in the field samples. Since those results were not unusually high for soils, the high recoveries did not significantly impact the project samples.

Laboratory duplicates are two or more portions of the same sample that are processed as separate samples for the same analysis using the same method. The data from these samples provide a measure of the precision of the method. Because most of the sample results are below or very near the instrument

Table 10-1
Radiological Analyses Accuracy Data

Matrix	Parameter	Mean % Recovery	High/Low Range
Biota	Cs-137	104.4	106/96
	Am-241	97.1	104/79
	Pu-239/240	99.7	107/89
	Sr-90	115.3	149/72
Soil	Gross Alpha	129.7	160/98
	Gross Beta	111.6	118/100
	Cs-137	103.8	106/98
	Am-241	97.2	103/90
Water	Gross Alpha	96.4	108/89
	Gross Beta	104.7	116/99
	Cs-137	103.7	120/94
	Am-241	94.8	103/84

detection limits, statistical analysis of precision was not useful. However, there was good agreement between samples for these levels of activities.

Matrix spikes and matrix spike duplicates were analyzed for chemical constituents in the waste characterization samples only, as required by the EPA protocols. A matrix spike is the same as a laboratory control sample except the spike is added to a separate portion of the actual sample material (e.g., water or soil). The matrix spike sample provides information concerning the accuracy of the analytical method for each type of sample material and indicates any method interferences the material may introduce.

A matrix spike duplicate is a portion of the spiked sample material that is used to determine precision of these analyses on this particular sample material. The data from these QC samples indicated no significant interferences. Both of these types of samples were found to be within the limits set by EPA for these protocols, as provided in the QAPjP.

10.4 Confirmation of On-Site Laboratory Results

During the planning stage of the project, there were concerns whether the on-site laboratory temperature and electrical supply could be controlled to prevent fluctuations that would affect the instrument performance. Controls for temperature and electrical power supply were adequate during the project. According to requirements of the planning documents, approximately ten percent of the soil samples that the on-site laboratory analyzed for gamma emissions were split and sent to the off-site laboratory for confirmatory gamma analysis.

The results of the on-site and off-site laboratories, which are provided in Table 5-2 show a close correlation of results, confirming that the on-site laboratory instruments were not significantly affected by any environmental conditions. The radioisotope activities reported are not on a decay-corrected basis.

10.5 Data Validation

A selection of samples and analysis were validated by the IT Field Analytical Service group in Knoxville, Tennessee, which is separate from the off-site laboratory that performed the analysis and from the Las Vegas office, which performed the assessment and remediation work. Validation reviews indicated one biota sample result was rejected, but all others were qualified as usable. Most results were qualified as usable. Most results were qualified as below or near detection limits.

Chapter 11.0 Health and Safety

In general, site operations were performed in a safe, conscientious manner. No accidents or injuries occurred that were recordable under the definitions and requirements of the Occupational Safety and Health Administration.

Safety oversight was provided by the Site Safety Officer and an alternate Safety Officer through the duration of site operations. Health and safety activities included:

- daily inspections of work sites and operations
- setup and monitoring of site communications
- coordination of site emergency medical services
- evaluation and decontamination of personal protective equipment (PPE)
- performance and evaluation of Tailgate Safety Meetings
- monitoring of personnel performance and stress evaluations
- monitoring of all personnel while outside the camp
- control of firearms
- evaluation of site operations for compliance with the SSHSP.

The most significant concerns were all-terrain vehicle (ATV) operation, heavy-equipment operations, potential confrontations with bears, and firearms use and control. Weather conditions, such as temperature and wind velocity, were monitored daily. Although it was cold and windy much of the time during field activities, weather conditions did not pose a significant danger to personnel.

11.1 Site-Specific Health and Safety Plan

The SSHSP prescribed the procedures that were to be followed during the site assessment, remedial action, and related activities at the Project Chariot Site. The few operational changes to the SSHSP that were made in the field to better protect the health or safety of personnel, the public, or the environment, were made with the prior approval of DOE.

The provisions of this plan were mandatory for all personnel assigned to the project. All visitors, oversight and media personnel, and others at the work site were also required to abide by the requirements of this plan.

11.2 All-Terrain Vehicle Operation

All-terrain vehicles were used for transportation at the site. Each ATV operator received training in the safe operation of the vehicle at the start of project operations. All-terrain-vehicle use on the site was primarily intended for sampling operations, personnel and equipment transport between the base camp and the mound-excavation site, and transport in support of project operations. All site personnel leaving the camp were required to sign a log sheet, travel with a companion, and communicate with the base camp via radio at designated intervals.

11.3 Heavy Equipment Operation

An excavator, two front end loaders, and other heavy equipment were used on the site. These pieces of machinery presented hazards to site workers due to the large size, limited visibility of the operator, the noise, and the confined area of operations. All such vehicles were:

- equipped with back-up alarms
- equipped with a fire extinguisher
- assisted by a spotter, who communicated by radio or hand signal with the operator
- operated only by appropriately trained personnel

Heavy-equipment operations were performed in two primary areas: the EZ and to and from the mound-excavation site. All heavy equipment was received and maintained in proper working order and was visually inspected by the Site Safety Officer and the operator on a daily basis. No incidents or procedural health and safety variances occurred involving heavy equipment operations.

11.4 Monitoring of Personnel While Outside the Camp

Some sample-collection activities took place away from the majority of site operations in Ogotoruk Valley and adjoining areas. Workers in these remote areas were accompanied by a bear guard and maintained radio communication with the base camp to the limits of effective range of the hand-held units. Each team leaving the Ogotoruk Valley took sufficient food and other supplies for at least three days in the event inclement weather or mechanical failure stranded them away from the Base Camp. Additionally, each group leaving the Ogotoruk Valley or going to remote areas of the valley was required to report the location, activities, and estimated time of return to the base camp administrator prior to the group's departure. They also reported their return to the base camp administrator.

11.5 Biological Hazards

The primary biological hazards on the site were expected to be the possible presence of the grizzly bear or polar bear, as well as various small mammals that may carry rabies and/or attract bears. Other animals that may be found in the area, musk ox and caribou, were not expected to present a hazard to site personnel.

One person was assigned duty for bear guarding at the Base Camp and mound during all site operations, and a guard accompanied personnel performing biota, sediment, soil, and surface water sampling and radiological surveys.

All possible measures were taken to avoid disturbing or interfering with bears in the area. Site operations would have been suspended and all personnel moved to shelter if a bear were to have been observed in the immediate area of the site operations. The bear guards were to destroy bears *only* if the animals presented an *immediate* threat to site personnel. Avoidance with the animals was the standing policy for all operations.

Another potential hazard was the presence of small mammals (e.g., foxes and squirrels) on site. Any feeding, harassment, or other contact with these animals was expressly prohibited. In addition to the possibility that the animals may have been infected with rabies, attracting the animals by feeding them may also have attracted bears. All food, garbage, or scraps were stored to protect them from both bears and small mammals at all times. Policing of the camp area was monitored by the Site Safety Officer.

11.6 Firearms Use and Control

Firearms were present on site for the following purposes:

- bear protection
- avian specimen collection
- small-mammal specimen collection.

Firearm use and control was one of the few areas requiring operational changes in the field. These changes involved three primary areas of concern: safe use of firearms during biological sample collection, safe handling of firearms during bear-guard duties in the field and in camp, and effective control and security of firearms during nonuse periods. Biological-sample collection activities were performed without incident, and firearm control and security measures evolved over the first few days of field operations. A variance was requested to the SSHSP to allow the bear guards to retain firearms rather than storing them in the Project Office. This variance was approved by DOE as being in the best interest of site personnel. Specifically, it was determined that the bear guards could respond to a bear incident more quickly if they had immediate access to their firearms.

Provision of bear guards was strictly for the protection of site personnel in extreme circumstances. Hunting and target shooting, for any reason, was specifically prohibited on or around the site. No firearms other than those required for the above purposes were permitted on the site. The Site Safety Officer verified, and so noted in the field log, the transfer of ammunition and any expenditure of ammunition, during the course of field operations.

A small-caliber handgun was required during mammal collections. The gun was carried and used only by the senior task leader, who was also responsible for locking the gun in the Project Office at night. When not in use, the safety was engaged and the trigger lock applied. The firearm was not carried at any other time or in any other place, except as needed for mammal collection.

A 12-gauge shotgun was required for avian specimen collection. The shotgun was carried and used only by the senior task leader, who was responsible for keeping it securely locked away at night in the Project Office gun cabinet. The safety was engaged at all times until immediately prior to use, and it was reengaged immediately following use.

The avian specimen-collection activity was coordinated by the Biota Task Manager and Site Safety Officer to ensure no other activities were being conducted in the collection area, specifically down range in the field of fire. All collection activities were performed in outward-bound routes from the Base Camp and other site activities.

A log was maintained on site recording each use of the firearm(s) including the name of the user; date, time and location of use; number of times discharged and for what purpose; and the time removed from locked storage and time returned to locked storage. Each use entry in the log was countersigned by the Site Safety Officer and included a count by that individual of the number of cartridges issued to the user, number of rounds expended, and number of rounds remaining in the supply.

11.7 Monitoring of Radiation Levels and Personnel Decontamination

A microroentgen meter was used to assess gamma fields during operations. A microroentgen meter can easily detect small increases in the gamma exposure above background. An ion-chamber dose rate meter was available in the event that exposure rates were higher than the range of the microroentgen meter, although the need did not arise.

Decontamination personnel surveyed individuals exiting the EZ while in their PPE. After the individual was surveyed and contamination was not detected, the person proceeded to the boot wash area where the PPE was removed and placed in a lined receptacle. When PPE was found to be contaminated, it was immediately decontaminated. The method by which contamination was removed is as follows:

- remove gross contamination manually
- wipe contaminated area with a moist cloth
- resurvey affected area
- repeat, if necessary.

Equipment that was used in the EZ accumulated gross contamination (i.e., soil). In addition to the above procedures, swipe samples were collected for the Caterpillar® 966 Front End Loader and the Caterpillar® 330L Excavator. The results of the swipe samples indicated that the front end loader and the excavator were free of contamination. All equipment, including the front end loader and the excavator, was certified radiologically clean prior to release from the EZ.

Thermoluminescent dosimeters (TLDs) were worn by each person working directly with soil removal. The TLDs were issued for the full duration of the soil-removal activities. All TLD results were negative for radiation exposure and are being made available to the respective TLD wearer.

During initial ground penetration, continuous monitoring with the gamma and beta radiation detectors was conducted. Thereafter, monitoring was carried out approximately every half hour.

11.8 Air Monitoring

Excavation operations on the Project Chariot Site had the potential for generating fugitive dusts potentially contaminated with low levels of various radioisotopes. Three high-volume air samplers were used to determine the presence of contaminated dusts and the levels of any potential radioactive contaminants. Two high-volume air samplers were located within the EZ approximately 18.3 m (60 ft) apart. An additional sampler was placed about 4.6 m (15 ft) outside the EZ. Each sampler was calibrated prior to the beginning of excavation.

Each high-volume air sampler collected fugitive-dust emissions from the excavation operations on filter paper. Results from the high-volume air samplers indicated no contaminated fugitive-dust emissions from the excavation area.

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Chapter 12.0 Summary/Conclusions

During the summer of 1993, the assessment and remediation of the Project Chariot Site was performed using a streamlined approach to waste-site decision making called the Observational Approach (OA). The assessment and remedial activities at the Project Chariot Site required an approach that provided for simultaneous characterization and remediation in order to complete field activities within one season. The extreme weather conditions at the site limited site accessibility and operations to two months.

12.1 Objectives Achieved

The following objectives of the assessment and remedial activities at the Project Chariot Site were achieved:

- The remedial action was performed in a safe, environmentally sound, and cost-effective manner.
- The soil disposal mound was remediated in accordance with the DOE-prepared and ADEC-approved Site Assessment and Remedial Action Plan.
- Contaminated soil from the mound and test-plot area was excavated, packaged, and shipped off site in accordance with ADEC-approved plans.
- A radiological survey and confirmatory sampling of the excavated soil mound and the test-plot area were performed to verify that the tracer-study radioisotopes had been removed.
- ADEC's on-site approval of final closure was secured for both the mound and test-plot area (See Attachment B).
- Sediment and surface water sampling and analysis were performed on Snowbank and Ogotoruk Creeks to confirm the lack of transport of radioisotopes.
- Samples of selected biological organisms were obtained from the Project Chariot area to make an informed decision as to the radiological significance of the tracer study upon the biota.
- Background soil and biota samples were collected from undisturbed locations in Ogotoruk Valley and Kisimilok Valley that displayed soil and vegetation characteristics similar to the area of the disposal mound.

- An aerial survey covering approximately 100 km^2 (40 mi^2) of Ogotoruk Valley detected only radioactivity from naturally occurring gamma emitters. No man-made radiation anomalies were detected.

12.2 Site Assessment and Remediation

Before field activities began, it was important to establish a remediation clean-up level for the Project Chariot Site. An analysis of the risks at the site was conducted to establish the appropriate clean-up level. The risk analysis is presented in the Project Chariot 1962 Tracer Study Site Assessment and Remedial Action Plan, Appendix C.[2] Based on the exposure and risk analysis, a clean-up level of 0.4 Bq/g (10 pCi/g) for Cs-137 was established for soils at the Project Chariot Site. The derivation of this clean-up level is discussed in Appendix C of the Project Chariot 1962 Tracer Study Site Assessment and Remedial Action Plan.[2]

The primary contaminants of concern at the Project Chariot Site were Cs-137 and Sedan fallout radioisotopes, which were used in the 1962 tracer-study experiments. Therefore, the site assessment and remedial-action focused on removing soil containing Cs-137 and Sedan fallout from the former test-plot area and disposal mound location.

The site assessment at Project Chariot included the collection and analysis of surface water, sediment, and biota samples. The average activities for all surface water samples analyzed are

Ogotoruk Creek

Cesium 137	8.13 (pCi/l)
Gross Alpha	0.34 (pCi/l)
Gross Beta	1.75 (pCi/l)

Lower Snowbank Creek

Cesium 137	8.17 (pCi/l)
Gross Alpha	1.06 (pCi/l)
Gross Beta	1.40 (pCi/l)

Upper Snowbank Creek

Cesium 137	7.01 (pCi/l)
Gross Alpha	0.72 (pCi/l)
Gross Beta	1.61 (pCi/l)

Ephemeral Pond

Cesium 137	7.19 (pCi/l)
Gross Alpha	14.01 (pCi/l)
Gross Beta	11.26 (pCi/l)

Based on the analytical data provided for surface water samples, only one sample was found to be above the state of Alaska Drinking Water Criteria for gross alpha activity. This was collected at the ephemeral pond located adjacent to the mound area. The water drawn from this location does not represent a potable source and is only present intermittently. Based on the remedial activity at the disposal mound, the potential source of this contamination has been removed. Additionally, the area of the ephemeral pond was regraded and revegetated after the remediation of the disposal mound was completed, potentially eliminating future ponding of water in the same area.

The average activities for all sediment samples analyzed are

Ogotoruk Creek

Cesium 137	0.06 (pCi/l)
Gross Alpha	7.62 (pCi/l)
Gross Beta	23.66 (pCi/l)

Lower Snowbank Creek

Cesium 137	0.43 (pCi/l)
Gross Alpha	9.11 (pCi/l)
Gross Beta	20.40 (pCi/l)

Upper Snowbank Creek

Cesium 137	0.06 (pCi/l)
Gross Alpha	5.98 (pCi/l)
Gross Beta	18.36 (pCi/l)

Ephemeral Pond

Cesium 137	0.13 (pCi/l)
Gross Alpha	9.49 (pCi/l)
Gross Beta	18.02 (pCi/l)

None of the sediment samples collected exhibited activity levels greater than 1.80 pCi/g for Cs-137, 28.58 pCi/g for gross alpha, or 35.57 pCi/g for gross beta. The radioisotopes and the activity levels detected are consistent with the geologic make up of the Ogotoruk Valley. Of the radioisotopes found, most can be accounted for by the natural decay of three parent isotopes: uranium 235 and 238, and thorium 232. Analytical results of sediment samples show that the radioisotopes and the detected activity levels were at background levels.

Analytical results for the vegetation samples collected indicated that very low levels, usually in the range of 0.2 - 1.0 pCi/g Sr-90 and < 0.10 pCi/g Cs-137, exist over the region. Highest values for Sr-90 occurred in lichens. However, the lichens' ability to concentrate fallout radioisotopes has long been known and studied because of the importance of lichens as a carrier of radioactivity in the lichen-caribou- human food chain.[13, 14] Analysis of the animal samples collected showed that most radioisotopes detected had their origin in natural sources or from worldwide fallout. This fallout was primarily deposited during and following the 1961 to 1963 period of atmospheric nuclear weapons testing.

Compared to other locations in Ogotoruk and Kisimilok Valleys, no unusual amounts of Sr-90; Cs-137; Pu-238, 239, and 240; and Am-241 were detected in comprehensive sampling of plants and animals from the disposal mound. Cesium-137 concentration in sedge growing on the test-plot area was higher than at other locations, but was still within acceptable ranges. Cesium-137 was not detected in adjacent willows nor in tundra voles or ground squirrels trapped on or adjacent to the test-plot area, indicating that migration of contaminants had not occurred. Strontium-90 and Cs-137 concentrations in food items of local importance were well within acceptable limits.

12.3 Soil Disposal Mound

Cesium-137 contamination at the disposal mound was found to be approximately 4 ft below the surface. The Cs-137 was not uniformly mixed, but ranged in concentration up to 6,000 pCi/g. The disposal mound area was excavated to below the established clean-up criteria, with the highest closure sample containing 3.16 pCi/g of Cs-137. There was no measurable exposure rate above background on or near the disposal mound, nor was any Cs-137 indicated by measurement of the mound surface with the MCA system. Soil, vegetation, and small mammal samples taken on the surface of the mound indicated no Cs-137 contamination.

The lack of measurable exposure rate above background, as well as the absence of Cs-137 contamination in the surface soil, vegetation, and small mammal samples, indicates that it is highly unlikely that any individual received above-background exposure or dose from the material in the disposal mound. The past risk from the disposal mound is also essentially zero because the 4 ft of soil covering the Cs-137 contamination acted as an exposure shield. The disposal mound was excavated to well below the established clean-up criteria. Any future risk from the disposal mound area is expected to be zero.

12.4 Test-Plot Area

The exposure rate of the Cs-137 test-plot area during the original tracer studies would have been approximately 200 milliroentgens per hour (mR/hr). The cleanup by USGS personnel at each of the test plots would have reduced the exposure rate to about 100 microroentgens per hour (μR/hr). Based on the radiation detection instruments used by the USGS, this level was interpreted to be a reduction to background because standard radiation detection equipment in the 1960s was not able to detect radiation at levels as low as those possible with modern equipment. The instrumentation used in the 1993 Project Chariot site assessment and remediation was capable, by looking only at Cs-137 energy, to detect 1 μR/hr.

Only three test plots, 105, 106 and 107, were expected to have residual Cs-137 radioactivity. Over the 30-year period since the original tests, the estimated 100 μR/hr exposure rate at these three Cs-137 test plots was expected to be reduced by approximately one-half due to decay and possibly another one-third due to weathering of the soil. The radioisotopes at the other test plots would have decayed to background level in the first year after the plots were abandoned.

At the time of the 1993 remediation activities, the exposure rate was measured 1 meter (3.28 ft) above the ground at the location of the highest radiation activity. The highest exposure rate measured was 19 μR/hr. The average background exposure rate for the area is 8 μR/hr. This exposure rate indicates that the additional exposure rate due to the Cs-137 contamination was 11 μR/hr, a value generally consistent with the value expected from historic information.

No contamination was found at a depth greater than 6 in. at the test-plot area, with the highest concentrations usually near the surface. No contamination was found by a surface scan outside the excavated area. The test-plot area was excavated to below the established clean-up criteria, with the highest closure sample containing 2.55 pCi/g of Cs-137.

The exposure rate and risk from the surface contamination of the Cs-137 test plots would not have been significant over the 30 years. As previously mentioned, the exposure rate at the Cs-137 test-plot area immediately after the 1962 studies was probably less than 100 μR/hr at the center. The exposure rate would have been at background levels approximately 30 ft away from the center. Assuming a worst case scenario, a dose of 1 mrem, or about 1 percent of the annual dose received due to background radiation, would have been received by standing in the exact center of the test-plot area for 10 hours. At the time of the 1993 excavation, the same 1-mrem dose would have required standing in the exact center of the test-plot area for 55 hours.

The Project Chariot Site would be an area used for subsistence hunting. However, the area of the Cs-137 test plots is an unlikely camp site because of its location within 2 ft of Snowbank Creek. In the summer, the area is water soaked and becomes muddy on the surface after walking the same path several times. The area was also covered with willows, which would make it an unlikely campsite. Higher ground, about 100 ft away, is more suitable for camping. Since activity, such as stalking game, is more random in nature, it is not expected that visitors to the valley would spend 10 hours a year over the last 30 years at the area of highest radioactivity. The expected dose from the test-plot area to a single individual is, therefore, likely to be significantly less than 1 mrem over the last 30 years. In comparison, an individual receives approximately 8 mrem from a chest X-ray.

The past risk to any individual from the test-plot contamination is well within the range of national and international guidance. The yearly dose allowable to the public in the United States is 100 mrem/yr.[4] Since the test-plot contamination was removed to below the established clean-up criteria, no significant future exposure or risk is expected.

Chapter 13.0 References

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Attachment A
Aerial Radiation Survey Report

EG&G
ENERGY MEASUREMENTS

EGG 11265-1053
UC-702
APRIL 1994

THE
REMOTE
SENSING
LABORATORY
OPERATED FOR THE U.S.
DEPARTMENT OF ENERGY BY EG&G/EM

AN AERIAL RADIOLOGICAL SURVEY OR THE CHARIOT SITE AND SURROUNDING AREA

CAPE THOMPSON, ALASKA

DATE OF SURVEY: JULY 1993

ACKNOWLEDGEMENTS

The survey crew of EG&G Energy Measurements, Inc., would like to specially acknowledge and express deep appreciation for the support from the North Slope Borough, businesses and personnel of the town of Kotzebue that supported the effort, the state of Alaska Mr. Wilfred Lane (Chariot site owner), and the Chariot site workers.

ABSTRACT

An aerial radiological survey to collect radiation data from gamma emitting radionuclides over the Chariot site and associated areas was conducted during the period July 12 through July 23, 1993. Data were collected over three areas including the Ogotoruk (Chariot site) and Kisimilok Creek (background check area), valleys near Cape Thompson, Alaska. Data were also collected over a small area used for detector system assembly and testing near the base of operations at Kotzebue, Alaska.

The collected data were analyzed for identity, distribution, and quantity of gamma emitting radionuclides that may have been present as a result of the experiments conducted at the Chariot site in 1962.

Analysis of the data revealed the presence of only naturally-occurring gamma emitting radionuclidies. Low levels of cesium-137, typical of worldwide fallout distributions and concentrations, were detected over all the surveyed areas. The collected data were converted to equivalent exposure rate levels presented in units of microroentgens per hour at 1 meter above the ground.

The typical exposure rate ranges were 10 to12 μR/h in the Ogotoruk valley, 8 to 10 μR/h at the burial mound (the point where all the experimental materials were buried), 8 to 10 μR/h in the Kisimilok valley, and 8 to 10 μR/h in the test area covered at Kotzebue. The exposure rates are within the range of exposure rates found throughout the United States (1 to 15 μR/h). Special low level flights were made over the burial mound and other selected areas; only naturally occurring-levels were detected during these flights.

CONTENTS

1.0 INTRODUCTION

An aerial gamma radiation survey was conducted in the state of Alaska over an area known as the Chariot site during the period July 13 through July 24, 1993. The Chariot site survey area is located near Cape Thompson, Alaska, in the Ogotoruk valley. Figure 1 illustrates the survey boundary and flight lines used to cover the area of interest. Surveys were also conducted over the Kisimilok Creek valley and a small area of Kotzebue, Alaska; these data will be used for qualitative comparisons to the Ogotoruk valley data. The survey was conducted by the EG&G Energy Measurements, Inc. (EG&G/EM) Remote Sensing Laboratory (RSL) for the United States Department of Energy (DOE). EG&G/EM has conducted radiological surveys of this type since 1959 in many areas of the world. The survey encompassed approximately 40 square miles (102 square kilometers) that included 37 square miles of the Ogotoruk valley in which the Chariot site is located, a small, 2-square-mile area in the Kisimilok Creek valley south of the Chariot site, and a 1-square-mile area used for periodic system characterization in the city of Kotzebue, Alaska.

2.0 SITE DESCRIPTION

The Chariot site/Ogotoruk valley is approximately 125 miles northwest of Kotzebue, Alaska, and 35 miles southeast of Point Hope, Alaska, on the coast of the Chuckchi Sea. Its rolling terrain is comprised mostly of tundra, with other small vegetation sparsely strewn throughout. A variety of fauna abound in the area including bear (brown and grizzly), musk-ox, caribou, and voracious mosquitoes. The Kisimilok Creek valley is similar in all aspects to the

Ogotoruk valley and is located about four miles south thereof. The small area surveyed in Kotzebue had tundra type vegetation with bare spots where grading was being done.

3.0 OPERATIONS

The base of operations for the survey was Northwestern Aviation, located at the Kotzebue Airport, Kotzebue, Alaska. Operations were conducted according to the mission plan issued to officials in the state of Alaska on July 14, 1993. Two crew shifts were used to minimize the time required to conduct the survey and maintain crew rest requirements. It is rather the exception than the rule to have as much separation between the base of operations and the survey site (125 miles). Aircraft refueling and limited equipment maintenance were conducted at the Chariot campsite; the site provided excellent accommodations and support services for the crew and operation. Data processing and analysis were conducted at the Kotzebue base of operations.

The survey was conducted to collect gamma radiation data using a sodium iodide gamma ray detection system, Radiation Environmental Data Acquisition and Recorder (REDAR), mounted on a Messerschmitt-Bolkow-Blohm (MBB) BO-105 helicopter. The system was flown at an altitude of 150 feet (46 meters) along parallel flight lines spaced 250 feet (76 meters) apart; the helicopter speed was 70 knots (36 meters per second). The position and aircraft steering information were provided by a Global Positioning System (GPS). Flights were made to maintain separation of one-half mile from Crowbill Point, a seabird habitat. Gamma radiation data were collected in one-second intervals over the areas previously described, encompassing about 40 square miles. A list of the survey parameters may be found in Appendix A.

4.0 DATA PROCESSING AND ANALYSIS

The objectives of the processing were to: 1) generate contour maps that establish the spatial distribution of the gamma radioactivity, 2) identify gamma emitting radionuclides, and 3) estimate the quantity of radionuclides present. The count rate data produced by gamma rays were evaluated for each data point (1 point every 120 feet of flight) and the results contoured to generate radiation profile maps of the surveyed areas. The contour maps were generated by plotting count rate data collected each second of flight over the areas of interest versus x, y position coordinates provided by a GPS. Count rate contour maps were generated for total activity (terrestrial + cosmic), terrestrial activity, and man-made source activity. The count rates were converted to units of microroentgens per hour (μR/h). These units of measure represent the equivalent exposure rate in air at one meter above ground level (AGL).

A conversion factor of 1,091 cps/μR/h was estimated for the surveyed areas based on data taken over a calibrated test line in Las Vegas, Nevada. This value converts the count rate data measured at 150 feet over the surveyed areas to equivalent exposure in air one meter AGL. These exposure rate values can be converted to equivalent annual tissue dose (mrem/yr) at ground level by applying a factor of 8.38 mrem/yr/μR/yr to the exposure rate data. The typical annual dose to humans is approximately 125 mrem/yr.

Data processing was conducted at the Kotzebue base of operations using a mini version of the Radiation Environmental Data Acquisition Computer (REDAC) analysis system used at RSL in Las Vegas, Nevada.

In terms of the exposure rate due to total natural terrestrial activity, the detector system used at the Chariot site can detect changes as small as 0.5 μR/h. The system is also capable of repeating measurements within 5%. The detectability of specific sources is dependent upon their energy, geometry, and distance of the platform from the source. Since cesium-137 (^{137}Cs) was the source of interest at the Chariot site, its minimum detectable activities (MDAs) are listed in this section and in Appendix B, Figure B-2. The minimum detectable ^{137}Cs activities for eight 2- × 4- × 16-inch NaI detectors at a survey altitude of 150 feet are:

1. Point Source .... 1 mCi
2. Surface .... 0.07 μCi/m^2
3. Exponential α =.1 and soil sample depth = 1 cm .... 1 pCi/gm
4. Uniformly distributed with depth .... 1 pCi/gm

5.0 RESULTS

Isoradiation contour maps were generated for total activity, total terrestrial activity, man-made activity, and ^{137}Cs gamma emitters. These contour maps were scaled and overlaid on maps and photographs to relate the terrain with its corresponding radiation contours. Also, gamma energy spectra were generated over all areas of interest in each surveyed area to identify the gamma emitting radionuclide.

Within the 40 square miles surveyed, no man-made anomalies were detected. The only activity detected was from the naturally-occurring gamma emitters uranium-238 (^{238}U) and progeny, thorium-232 (^{232}Th) and progeny, and potassium-40 (^{40}K).

To increase the sensitivity of the system, special areas were flown at lower altitudes and slower speeds, in particular, Snowbank Creek, the mound, and portions of Ogotoruk Creek. Hovers were also made in these areas to further increase the system sensitivity. No man-made radionuclides were detected with these configurations, either. The most noticeable difference in the areas surveyed was that the exposure rate levels were higher in bare spots and creek beds (generally with little or no vegetation) than in the tundra and vegetated areas.

Figures 2, 3, and 4 illustrate the exposure rate contour maps for the Ogotoruk valley, Kisimilok Creek valley, and the Kotzebue test area, respectively.

Contributors to the gamma exposure rate can be identified in the gamma energy spectrum, Figures 5a-5e. These spectra were processed from data taken over the Chariot site proper (5a), the burial mound (5b), the Ogotoruk Creek bed (5c), the Kisimilok Creek valley (5d), and the test area at Kotzebue (5e). Each spectrum revealed the identity of only naturally-occurring gamma emitting radionuclides, *i.e.*, ^{238}U and progeny, ^{232}Th and progeny, and ^{40}K. The worldwide fallout levels for ^{137}Cs, now considered to be a part of the natural background, seemed to be somewhat less than typical fallout levels in all the areas surveyed except Kotzebue, where typical levels were detected. The increased levels of exposure rate in the Ogotoruk Creek bed were determined to be due to higher levels of thorium and potassium in that area. Table 1 summarizes the equivalent exposure rate results of the survey.

The values listed in Table 1 include a 3.8 μR/h (about 33 mrem/yr) estimate of the exposure rate due to gamma radiation of cosmic origin.

Table 1. Area Coverage and Exposure Rate Estimates at One Meter Above Ground Level

Area	Exposure Rate Typical Range (μR/h)	μR/h Range (maximum)	Coverage
Chariot	8 - 10	6 - 12	36 mi^2
Background	8 - 10	6 - 12	2.5 mi^2
Kotzebue	6 - 8	6 - 8	1.0 mi^2
Burial Mound	8 - 10	8 - 10	Hovers[a]
Snowbank Creek	8 - 10	6 - 10	Several low passes[a]
Ogotoruk Creek	10 - 12	6 - 12	Several low passes[a]
Special Areas	8 - 10	6 - 10	Several Passes[a]
Tundra	6 - 8	6 - 10	30 mi^2

[a]These flights were made in addition to the normal survey flights.

6.0 NATURAL BACKGROUND RADIATION

Natural background radiation originates from several different sources.[1] Natural terrestrial isotopes, airborne radon gas, and cosmic rays are the three sources generally considered to comprise the natural background radiation field. The other two contributions to the full spectrum of data measured with airborne systems similar to that used during the Chariot survey are man-made terrestrial isotopes and contributions from the measurement system.

Long-lived radionuclides present in the earth's crust are usually the largest source of background radiation. Naturally-occurring isotopes found in the soil and bedrock consist mainly of radionuclides from the uranium and thorium decay chains, and radioactive potassium. The most prominent natural isotopes usually seen in aerial spectra are ^{40}K (0.12% of natural potassium), thallium-208 and actinium-228 (daughters in the ^{232}Th chain), and bismuth-214 (a daughter in the ^{238}U chain). Although it is considered a man-made radionuclide, a measurable amount of ^{137}Cs is found (initially as a surface deposition and then migrating several inches into the soil) throughout the world as a result of the nuclear testing conducted in the atmosphere. The naturally-occurring isotopes and ^{137}Cs fallout typically contribute 1-15 μR/h to the background radiation field (Figure 6). The measurements are based on average, ground-based exposure rates measured in several cities of the state. The measurements shown for the state of Alaska include the ground-based and aerial measurements.

Radon (a noble gas) is a member of both the uranium and thorium decay chains. After being created in the soil from its parent isotope, radon can diffuse through the soil and become airborne. While the isotopes of radon have relatively short half-lives, their daughters may become attached to dust particles in the atmosphere and contribute to the airborne radiation field until the dust eventually settles to the ground. The contribution of radon and its daughters to the background radiation field depends on several factors, including the concentration of uranium and thorium isotopes in the soil, the permeability of the soil, and the meteorological conditions at the time of measurement. Typically, airborne radiation contributes 1-10% of the natural background radiation level.

Cosmic rays entering the earth's atmosphere are a third source of background radiation. High energy cosmic rays (principally protons, alpha particles, and some heavier nuclei) interact predominantly with atoms in the upper atmosphere to produce showers of secondary radiation. The contribution of cosmic rays to the background radiation field varies with altitude and geomagnetic latitude. The earth's magnetic field traps some of the cosmic rays, so a larger fraction of them reaches the poles than the equator. In the continental United States, values range from 3.3 μR/h at sea level in Florida to 12 μR/h at an altitude of 3,000 meters in Colorado.[2]

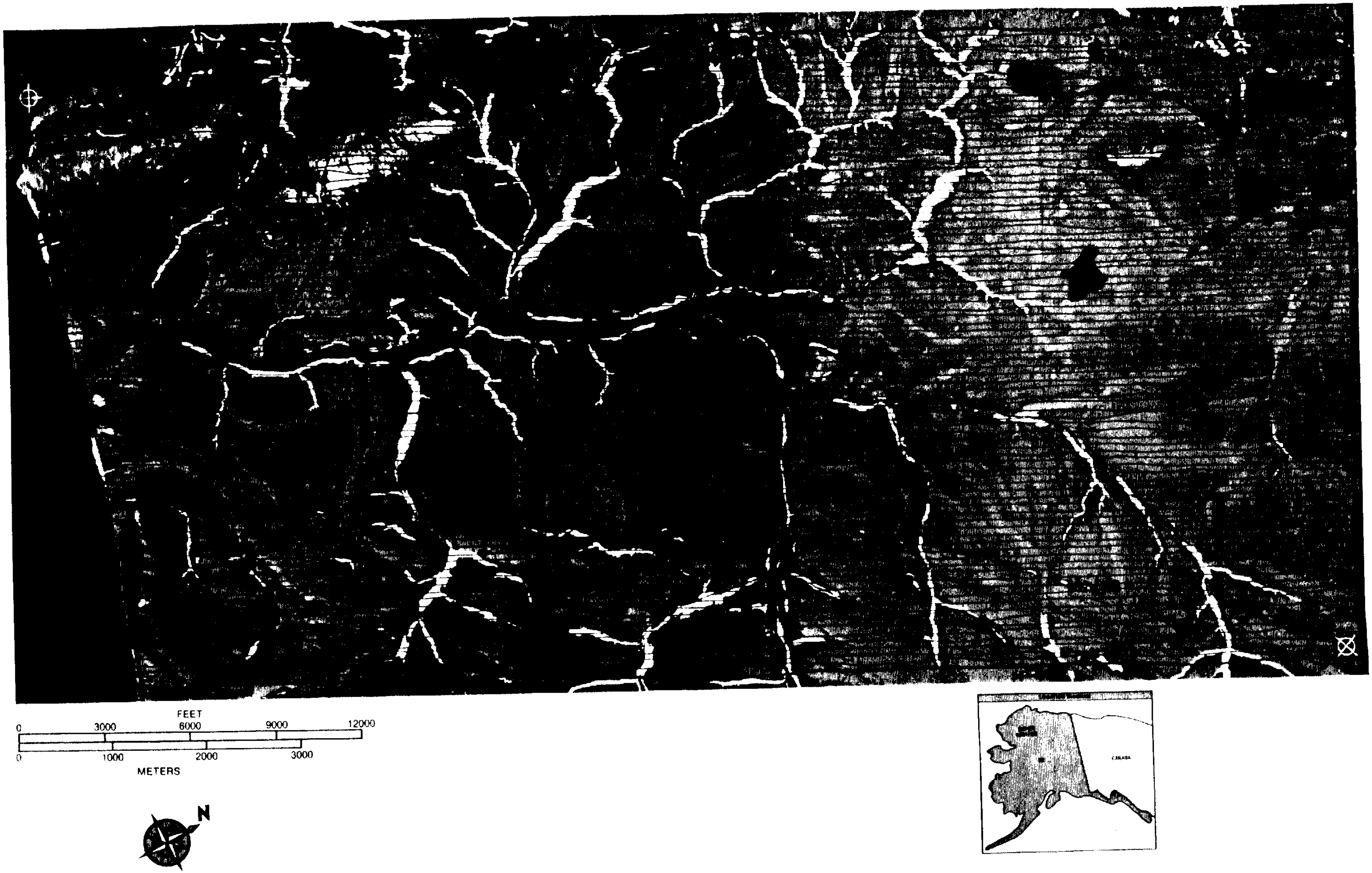
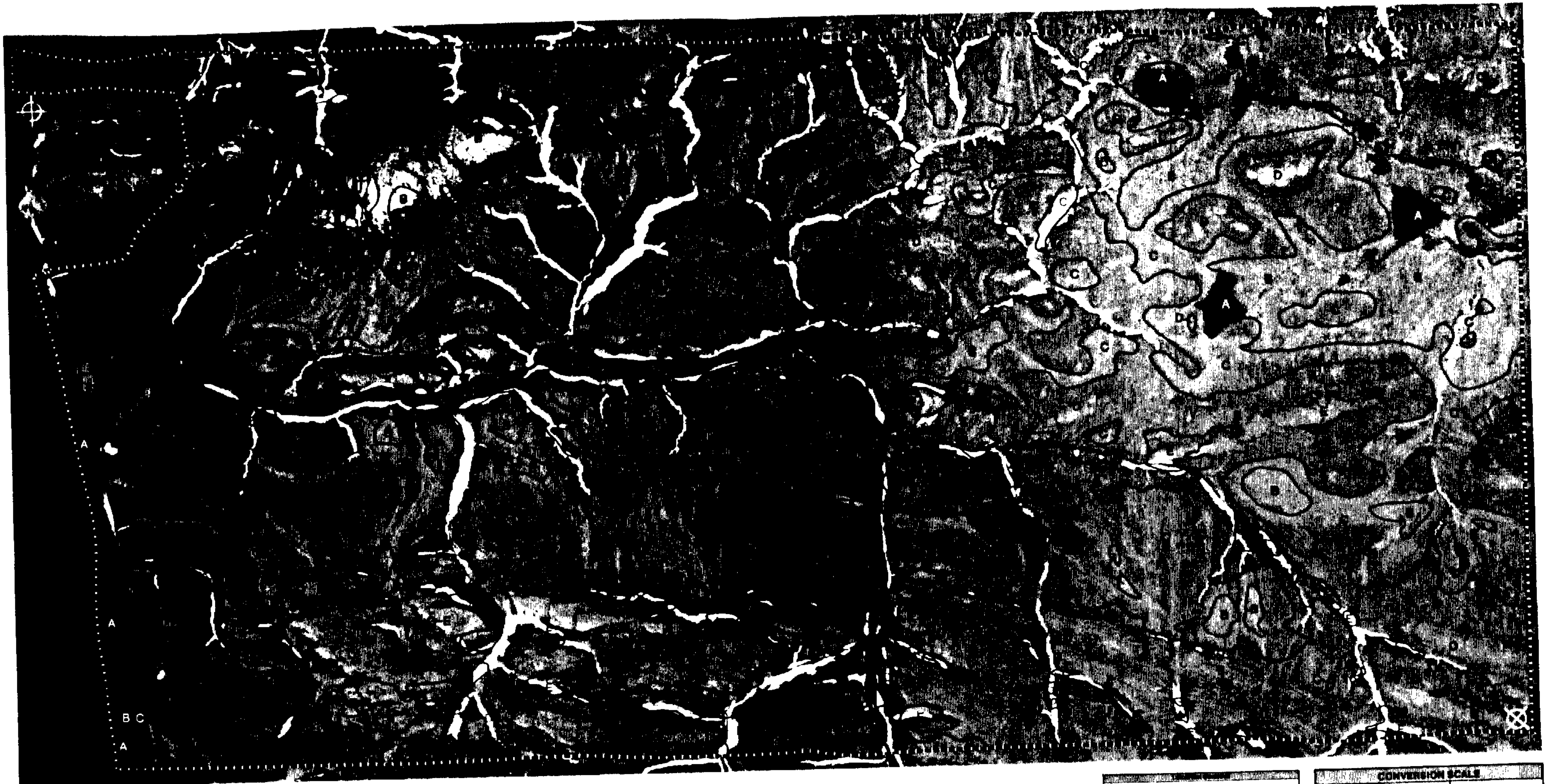
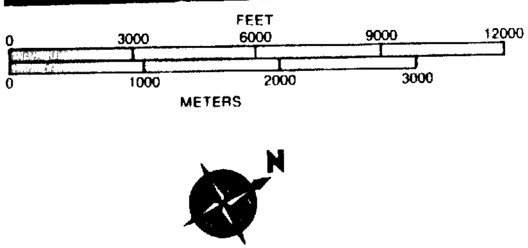
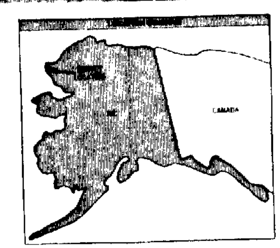


FIGURE 1. *SURVEY BOUNDARIES AND FLIGHT LINE COVERAGE OVER THE OGOTORUK VALLEY*







LETTER LABEL	TERRESTRIAL EXPOSURE RATE (μR/h)	TOTAL EXPOSURE RATE* (μR/h)
A	0 - 1	4 - 5
B	1 - 3	5 - 7
C	3 - 5	7 - 9
D	5 - 7	9 - 11
E	7 - 9	11 - 13

CONVERSION SCALE

*Includes an estimated 4μR/h due to cosmic ray contributions

FIGURE 2. EXPOSURE RATE CONTOUR MAP OF THE OGOTURUK VALLEY (LOCATION OF THE CHARIOT SITE) OBTAINED FROM THE JULY 1993 AERIAL RADIATION SURVEY

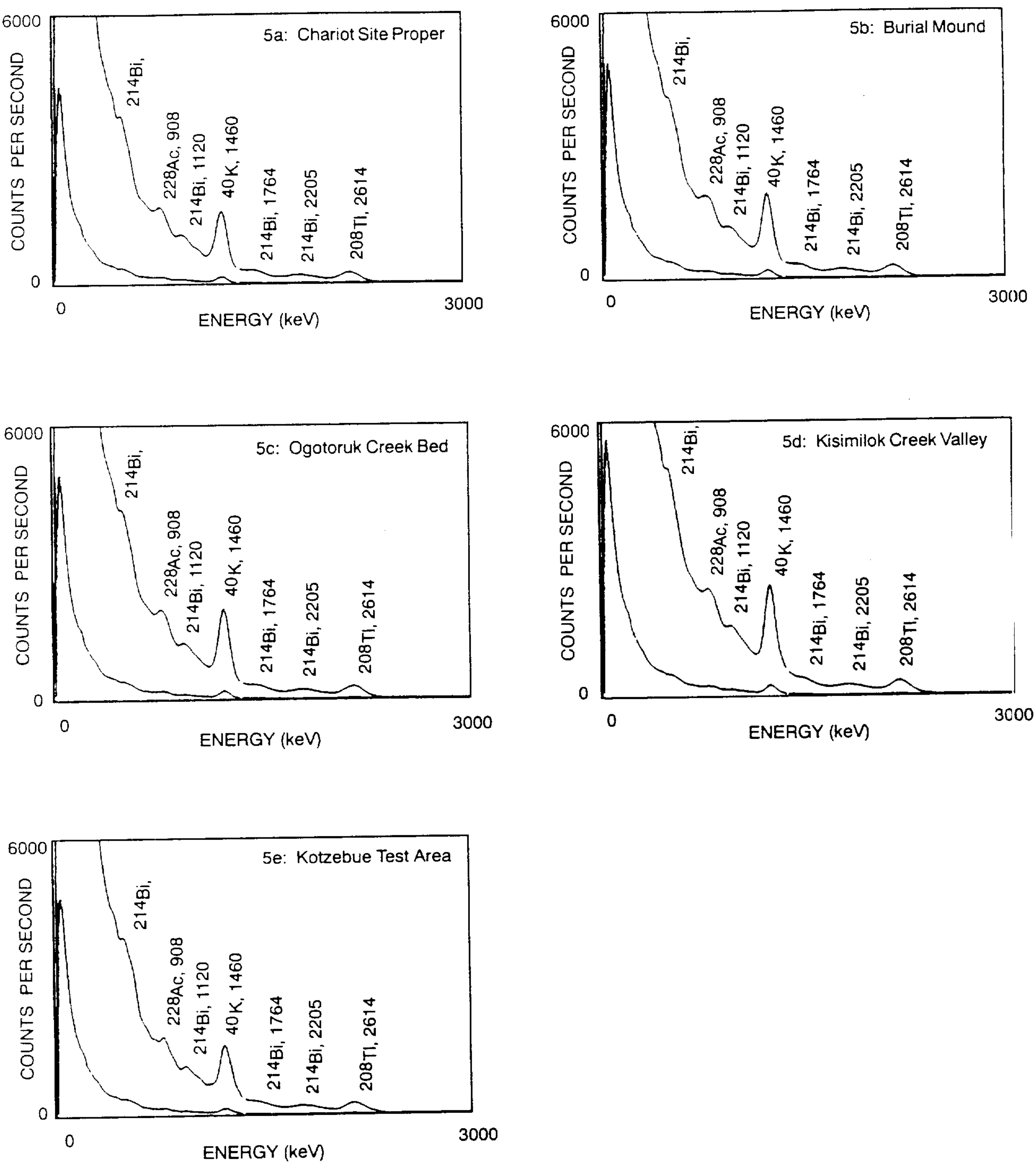


FIGURE 5. ***GAMMA ENERGY SPECTRA OF THE GAMMA EMITTING RADIONUCLIDES DETECTED DURING THE ALASKA SURVEY***

FIGURE 6. TYPICAL *EXPOSURE RATE RANGES OF CITIES OF THE UNITED STATES (μR/h). The cosmic exposure rate ranges from 3-7 μR/h, and the city elevations from 10 ft to 7,000 ft.*

APPENDIX A

SURVEY PARAMETERS

Survey Site:	Chariot Site
Survey Location:	Cape Thompson, Alaska
Survey Area:	102 km^2 (40 mi^2)
Survey Date:	July 13-24, 1993
Survey Altitude:	150 ft (46 m)
Line Spacing:	250 ft (76 m)
Line Direction:	East-West
Lines Surveyed:	102
Detector Array:	Eight 2- × 4- × 16-in NaI(T*l*) detectors
Acquisition System:	REDAR IV
Survey Aircraft:	MBB BO-105 helicopter
Project Scientist:	E.L. Feimster
Data Processing:	

Man-Made Energy Window: 38-1,394 keV
Gross Count Energy Window: 38-3,026 keV
Conversion Factor: 1,091 cps/(μR/h) at 150 feet
Cosmic Ray Contribution: 3.8 μR/h

APPENDIX B

DETECTABILITY LIMITATIONS FOR A 5-Ci ^{137}Cs SOURCE BURIED IN THE SOIL

Many questions were raised concerning the ability of the survey system to detect 5 Ci of ^{137}Cs buried beneath soil such as the burial mound at the Chariot site. This Appendix explains the detectability limitations of the aerial system used at the Chariot site for a 5-Ci ^{137}Cs source buried in the soil. The cross section for ^{137}Cs gamma rays (661.9 keV) in soil with density 1.5 gm/cm^2 is .078 cm^2/gm, a mean free path of 9 cm. If a 5-Ci ^{137}Cs source were buried at various depths, its activity measured at the surface over the point of burial would be attenuated as follows:

$$Cs_{Activity(Ci)} = 5\ Ci\ \ e^{\left(.0781 \cdot 1.5 \cdot Depth_{soil}\right)} \tag{B-1}$$

As illustrated in Figure B-1, a 5-Ci ^{137}Cs source buried at 2.38 feet would measure about 1 mCi at the surface over the point of burial, the minimum detectable activity (MDA) of the aerial detector system using the configuration and flight parameters used for the Chariot site survey. Aerial system MDAs are illustrated in Figure B-2.

To obtain the conversion factor, the exposure rates of a pressurized ion chamber were compared to the count rates of the detector system flown at various altitudes over the Las Vegas, Nevada, calibration range. The algorithm derived from the test range data to convert count rate to exposure rate is written as:

$$Conversion\ \ Factor = 1440\ \mathrm{e}^{-(.001957 \cdot Survey\ \ Altitude)} \frac{cps}{\mu/h} \tag{B-2}$$

The algorithm above was adjusted for the conditions of the test range used near the Chariot and Kotzebue sites. A conversion factor of 1,091 cps/μR/h was estimated for the Chariot and Kotzebue areas. The algorithm that converts count rate to exposure rate for the Chariot, background, and Kotzebue sites is written as follows:

$$\mu R/h = \frac{(Measured\ \ Count\ Rate\ -\ Nonterrestrial\ \ Contributions)}{1091}\ e^{(.00183 \cdot SurveyAltitude)} \qquad (E\text{-}3)$$

Table B-1 lists a rough estimate of the equivalent annual dose corresponding to the exposure rates in Table 1.

Table B-1. Rough Estimate of the Equivalent Annual Dose Ranges of the Surveyed Areas (mrem/yr)

Area	Annual Dose Typical Range (mrem/yr)	Annual Dose Full Range (mrem/yr)
Chariot Site	70 - 85	50 - 100
Background Area	70 - 85	50 - 100
Kotzebue	50 - 70	50 - 85
Burial Mound	70 - 85	70 - 100
Snowbank Creek	70 - 85	70 - 100
Ogotoruk Creek	85 - 100	50 - 100
Special Areas	70 - 85	50 - 100
Tundra	50 - 70	50 - 100

The typical annual dose to humans is about 125 mrem/yr. The exposure rate and annual dose ranges within the United States are from 4 to 23 μR/h and 33 to 200 mrem/yr.

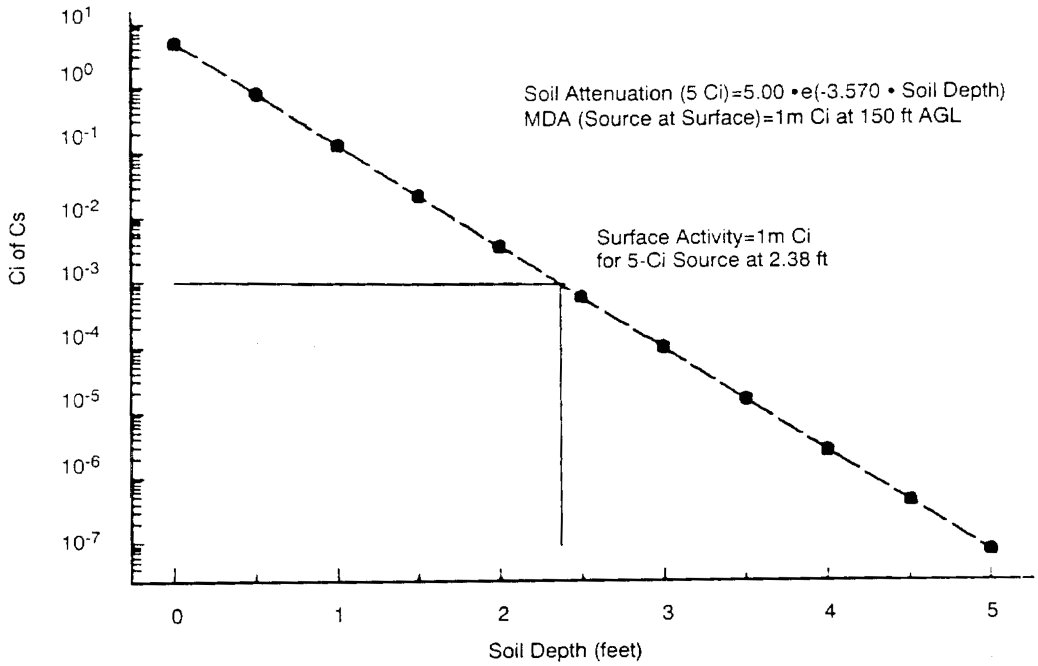


FIGURE B-1. ***DETECTOR LIMITATION CURVES FOR A 5-Ci BURIED ^{137}Cs SOURCE***

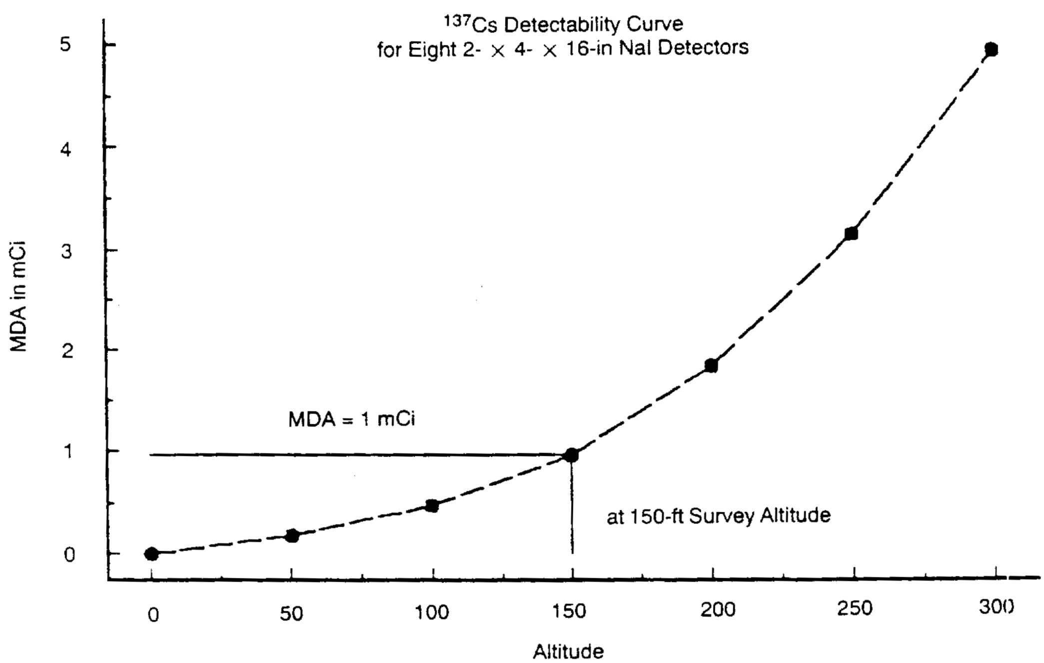


FIGURE B-2. ***MINIMUM DETECTABLE ACTIVITY CURVE FOR ^{137}Cs***

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Attachment B
Alaska Department of Environmental Conservation Clean Closure Certificate

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STATE OF ALASKA

WALTER J. HICKEL, GOVERNOR

DEPT. OF ENVIRONMENTAL CONSERVATION

Telephone: (907) 451-2360
Fax: (907) 451-2187

Northern Regional Office
1001 Noble Street, Suite 350, Fairbanks, AK 99701-4980

NRO File: 475.25.001

August 23, 1993

Mr. Kevin Cabble
DOE Nevada Operations Office
Environmental Restoration Division, ERD
P.O. Box 98518
Las Vegas, NV 89193-8518

Dear Mr. Cabble:

RE: Closure of Project Chariot Soil Disposal Mound

The Department has reviewed the results of the soil disposal mound post-excavation sampling. Results of the sampling indicate that the cleanup level of less than 10 pCi/g has been achieved. Based on sampling results and our field team's observations, the Department approves the closure of the soil disposal mound.

If you have any questions, please give me a call at 907-451-2172.

Sincerely,

Douglas H. Dasher

Douglas H. Dasher
Environmental Manager I

DHD/jg h:\eq\capet\closur.mou

cc: Aikens, J. - NSB
Greene, C. - NAB
Hawley, R. - Kivalina
Koonuk, R. - Pt. Hope
McGee, P. - ADEC/NRO
Schaefer, J. - Pt. Hope
Stone, D. - Pt. Hope

STATE OF ALASKA

WALTER J. HICKEL, GOVERNOR

DEPT. OF ENVIRONMENTAL CONSERVATION

Northern Regional Office
1001 Noble Street, Suite 350, Fairbanks, AK 99701-4980

Telephone: (907) 451-2360
Fax: (907) 451-2187

NRO File: 475.25.001

August 26, 1993

Mr. Kevin Cabble
DOE Nevada Operations Office
Environmental Restoration Division, ERD
P.O. Box 98518
Las Vegas, NV 89193-8518

Dear Mr. Cabble:

RE: Closure of Project Chariot cesium 137 plot

The Department has reviewed the results of the cesium 137 plot post-excavation sampling. Results of the sampling indicate that the cleanup level of less than 10 pCi/g has been achieved. Based on sampling results and our field team's observations, the Department approves the closure of the cesium 137 plot..

If you have any questions, please give me a call at 907-451-2172.

Sincerely,

Douglas H. Dasher

Douglas H. Dasher
Environmental Manager I

DHD/jg h:\eq\capet\closur.mou

cc: Aikens, J. - NSB
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Hawley, R. - Kivalina
Koonuk, R. - Pt. Hope
McGee, P. - ADEC/NRO
Schaefer, J. - Pt. Hope
Stone, D. - Pt. Hope

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CHECKED BY	APPROVED BY
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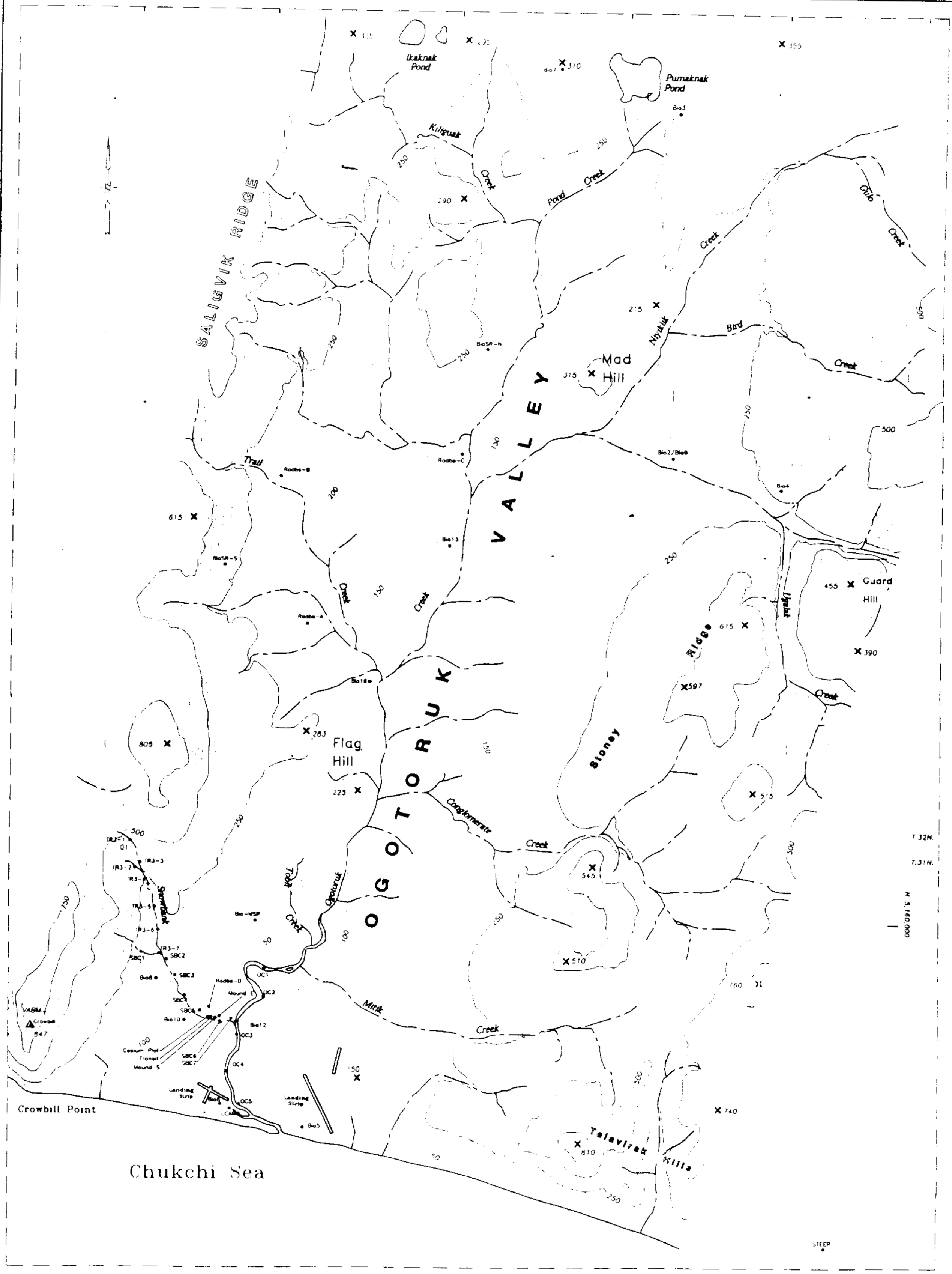

LEGEND

500 Contour elevation (feet)
Contour interval 50 feet

X 295 Ground surface elevation (feet)

— Creek

Pond

• Sample

SCALE OF FEET

PLATE 1
SAMPLING STATION LOCATIONS

PROJECT CHARIOT
CAPE THOMPSON REGION, ALASKA