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ENEWETAK RADIOLOGICAL SUPPORT PROJECT

FINAL REPORT



SEPTEMBER 1982

UNITED STATES DEPARTMENT OF ENERGY
NEVADA OPERATIONS OFFICE
LAS VEGAS, NEVADA

FOREWORD

This final report thoroughly documents the technical and logistic accomplishments of the Enewetak Radiological Support Project. The reader will readily recognize the magnitude and significance of the effort. This document duly recognizes all aspects of the project except one, possibly the most important though not so obvious to the casual reader. This was truly a cohesive scientific "expedition" because of the achievements, both personal and collective, of all the participants from a variety of governmental and private agencies. Particularly impressive to visitors at Enewetak was the ability of this group of scientists, technicians and support personnel to work in an environment relatively hostile to the required sophisticated technology. Despite adverse conditions, this team collected samples of soil, performed radiochemical analyses on the samples, applied statistical analysis to the data, interpreted the results and provided guidance to the Joint Task Group virtually overnight so that the daily activities for removal of contaminated soil could continue. This concerted effort under the leadership of the Nevada Operations Office is remarkable; its absence would have severely hampered the accomplishments detailed in this report.

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Manager, Environment, Health
and Safety Research
Battelle - Pacific Northwest Laboratory

July, 1982

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PREFACE

The work reported here may be said with some precision to have had its inception in September, 1975 with an agreement between the Energy Research and Development Administration (ERDA) and the Defense Nuclear Agency (DNA), committing ERDA to provide technical support to DNA in the cleanup of Enewetak. But in truth the effort had become an inevitable moral obligation of the United States many years earlier, in 1947, when the People of Enewetak were persuaded to leave their homeland to make way for our nation's atmospheric nuclear test activities. It might be said to have begun in April 1972 when Ambassador Franklin Haydn Williams and High Commissioner Edward E. Johnston promised the return of Enewetak to the administration of the Trust Territory. Or it might be said to have begun at Enewetak on May 20th, 1972, on the occasion of the first visit of the Enewetak leadership to their home atoll after 26 years away. On that latter occasion, Enewetak Magistrate Smith Gideon closed a four-day conference by saying to the United States officials, "We know that your people are going to help in cleaning up the place and preparing for our return to our home islands."

It was five years later that the mobilization for the cleanup occurred, and work began in earnest to prepare for the return. The intervening time had been used in surveying, establishing criteria, obtaining Congressional authorization and funding, planning, acquiring resources and developing equipment and techniques.

Radiological support to the cleanup was assigned as a mission to the ERDA Nevada Operations Office, which formed a project team known as the Enewetak Radiological Support Project (ERSP). For the most part, this is the report of that Project from its first authorization on February 23, 1977, to the completion of the cleanup. At this writing the ERSP remains in being on at least an informal basis, and will until this report goes to press.

A few brief words about the role of the ERSP are in order. The key word in the Project name is support. The Project Manager and his several Deputies did not direct the atoll cleanup action. They recommended, advised and assisted Department of Defense officials in carrying out the Congress' mandate for the cleanup. The Project takes full responsibility for its advice and recommendations, but often the decisions of the Director, DNA, the Commander, Field Command or the Commander of the Joint Task Group necessarily took into account overriding considerations of a non-technical nature. In these cases it was the responsibility of the ERSP Manager to define and articulate alternatives and their likely consequences and then to fully support the decisions and actions of the DOD. Another function which the ERSP did not perform was the establishment of criteria and standards. These were given to us in guidance received from AEC, ERDA, and later, DOE Headquarters. The ERSP management team interpreted these criteria and standards in terms suitable for direction of the field effort.

A special note of acknowledgement is due Bert Friesen, who served as Editor and a major contributor to this volume. The other members of the ERSP team are acknowledged and credited as appropriate elsewhere in this report. I feel confident that I speak for all of them in observing that it has been a rare privilege and a stimulating challenge to be a part of so unique a project of such high importance to so deserving a group of people. We wish the People of Enewetak health, prosperity, happiness and peace in their ancestral home.

Roger Ray, Project Manager
Enewetak Radiological Support Project
Nevada Operations Office

ACKNOWLEDGMENTS

Jobs are done by people; difficult jobs require special people with interest and dedication a cut above the normal work-a-day world. Planning, execution, and wrap-up of the Enewetak Radiological Support Project involved two categories of special people: those who put in a tour of duty on Enewetak Atoll, and those who performed their duties without the opportunity to participate first hand in this unique experience.

Duty rosters maintained during cleanup on Atoll list all of the following individuals as participants in the Enewetak Radiological Support Project. To these special people, and the organizations they represented, we express deepest thanks for a difficult job done well.

We wish also to acknowledge, with a special "thank you," the many people who did what they were paid to do as a part of their job, and are not named below, without whom the task would have been vastly more difficult.

For simplicity, individuals within each organization are listed in alphabetical order. Because organizations change names and people move to new jobs, we show the organization/employee relationship in effect during execution of the project. The exception to this rule is that all DOE employees are shown as DOE even though they worked for ERDA during the first few months of the project.

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ABSTRACT

From 1972 through 1980, the Department of Energy acted in an advisory role to the Defense Nuclear Agency during planning for and execution of the cleanup of Enewetak Atoll. The Nevada Operations Office of the Department of Energy was responsible for the radiological characterization of the atoll and for certification of radiological condition of each island upon completion of the project.

In-situ measurements of gamma rays emitted by americium-241 were utilized along with wet chemistry separation of plutonium from soil samples to identify and delineate surface areas requiring removal of soil. Military forces removed over 100,000 cubic yards of soil from the surface of five islands and deposited this material in a crater remaining from the nuclear testing period. Subsurface soil was excavated and removed from several locations where measurements indicated the presence of radionuclides above predetermined criteria.

The methodologies of data acquisition, analysis and interpretation are described and detailed results are provided in text, figures and microfiche. The final radiological condition of each of 43 islets is reported.

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ABBREVIATIONS AND ACRONYMS

ADC	Analogue Digital Converter.
AEC	Atomic Energy Commission. AEC was abolished on 19 January 1975 and many functions transferred to the newly created ERDA (cf).
Am	Americium. Specifically, the isotope ^{241}Am when the mass number is omitted.
AS	Amersham-Searle.
AFRRI	Armed Forces Radiobiology Research Institute.
BAF	Brush Attenuation Factor. More accurately BCF (cf).
BCF	Brush Correction Factor. Factor applied to the in situ gamma measurement to adjust for the presence of vegetation in the detector field of view.
BX	Base Exchange.
C	Commander; cf CJTG.
CDC	Control Data Corporation.
CEQ	Council on Environmental Quality.
CHEM	Chemistry. Usually refers to the wet chemistry component of the Enewetak Radiation Laboratory complex.
Ci	Curie. The quantity of any radioactive species undergoing 3.7×10^{10} nuclear disintegrations per second (dis/sec). Millicurie = 0.001 curie = 3.7×10^7 dis/sec. Microcurie = 0.000001 curie = 3.7×10^4 dis/sec.
CJTG	Commander, Joint Task Group.
cm	Centimeter.
Co	Cobalt. Specifically the isotope ^{60}Co .
CONEX	Container Express. Metal shipping container with approximate dimensions 4' x 6' x 8'.
CONPLAN	Concept Plan. An information technique used within DOD to provide general guidance for justifying a proposed major project. See OPLAN.
cpm	Counts per minute.
cps	Counts per second.
CR	Congressional Record.
CRT	Cathode Ray Tube.
Cs	Cesium. Specifically the isotope ^{137}Cs .
DEIS	Draft Environmental Impact Statement.

DF Disposition Form. A memorandum form in common use by the military.

DIRDNA Director, Defense Nuclear Agency.

DNA Defense Nuclear Agency of the Department of Defense.

DOA U.S. Department of Agriculture.

DOD U.S. Department of Defense.

DOE U.S. Department of Energy (established on 1 October 1977; absorbed ERDA).

DOI U.S. Department of the Interior.

dpm Disintegrations per minute.

DRI Desert Research Institute. One component of the University of Nevada system.

EA Enewetak Atoll.

EC Enewetak Council.

EG&G DOE technical support contractor for ERSP field measurements, Las Vegas, NV.

EIC Eberline Instrument Corporation, Santa Fe, NM. Radiological support contractor for ERSP radiation instrument maintenance and calibration and for soil sample collection and analysis.

EIS Environmental Impact Statement.

EOD Explosive Ordnance Disposal.

EPA U.S. Environmental Protection Agency.

ERDA Energy Research and Development Administration; established 19 January 1975. Initial organization of ERDA included the AEC. Formation of the DOE included ERDA. ERDA was abolished on 1 October 1977 when the DOE was established.

ERSP Enewetak Radiological Support Project (of the U.S. Department of Energy).

Eu Europium. Specifically, the isotopes ^{152}Eu and ^{155}Eu .

FC Field Command (element of DNA located at Kirtland AFB, NM).

fCi Femto curies, 10^{-15} curies.

FCDNA Field Command, Defense Nuclear Agency.

FIDLER Field Instrument for Detection of Low Energy Radiation.

FPDB Fission Product Data Base.

FRC Federal Radiation Council.

FRST Field Radiation Support Team. A military element (Air Force) of the Enewetak Joint Task Group.

FWHM Full width at half maximum.

g Gram

GAR Gated Analogue Router.

GM Geiger-Muller

GZ Ground Zero. Land surface directly beneath or at the site of a nuclear test. SGZ and AGZ occasionally used to distinguish between tests at the surface and in the air.

h hour, as in R/h.

H&N Holmes & Narver, Inc., Orange, CA. Logistics and base support contractor for DNA and DOE.

HEPA High Efficiency Particulate Air (type of filter).

Hg Mercury.

HP Hewlett-Packard. Electronics manufacturer, including desktop computers and laboratory equipment.

HPGe High Purity Germanium - crystal for detection of gamma rays (also referred to as IG)

HQ Headquarters.

HV High voltage.

IAEA International Atomic Energy Agency.

ICRP International Commission on Radiological Protection.

IG Intrinsic Germanium (detector). Also referred to as high purity germanium (HPGe) detector.

IMF Instrument Maintenance Facility.

IMP Not an acronym, but a trademark owned by the DeLorean Manufacturing Company. Although actually the manufacturer's name for the tracked vehicle used to house the in situ measurement equipment, this term was often used to refer to the entire system.

JCS Joint Chiefs of Staff, DOD.

JTG Joint Task Group.

KAFB Kirtland Air Force Base.

keV Kilo electron volt.

KT Kilotons (nuclear tests are rated in thousands of tons of TNT).

LAB Laboratory. See RADLAB.

LASL Los Alamos Scientific Laboratory, Los Alamos, NM.

LARC Landing Amphibious Recovery Craft.

LCM Landing Craft, Mechanized.
 LCU Landing Craft, Utility.
 LLD Lower Limit of Detection.
 LLL Lawrence Livermore Laboratory, Livermore, CA (became LLNL in 1980).
 LLNL Lawrence Livermore National Laboratory.
 LN Liquid Nitrogen.
 m Meter.
 MAC Military Airlift Command.
 MARS Military Affiliate Radio System.
 mCi Millicurie.
 MDA Minimum Detectable Activity.
 MFR Memorandum For Record.
 ml Milliliter.
 MILCON Military Construction.
 MILVAN Military van. Military-owned container for transport of equipment and supplies.
 MLSC Micronesian Legal Services Corporation.
 mm Millimeter.
 MPC Maximum Permissible Concentration.
 MPRL Mid-Pacific Research Laboratory. (Formerly the Mid-Pacific Marine Laboratory, MPML.) Located at Enewetak, operated by the Univ. of Hawaii for the DOE.
 mR milli Roentgen.
 mrad millirad.
 mrem millirem.
 MUX Multiplex.
 NBS National Bureau of Standards.
 ND Nuclear Data (Corporation).
 NIM Nuclear Instrument Module.
 NRC U.S. Nuclear Regulatory Commission.
 NTS Nevada Test Site (of the DOE).
 NV Nevada Operations Office of the DOE (also NVO).

OMB Office of Management and Budget.

OPLAN Operations Plan. An operations plan is standard within DOD to provide specific guidance for conducting an approved major project. See CONPLAN.

ORNL Oak Ridge National Laboratory, Oak Ridge, TN.

PACE Pacific Cratering Experiments. Project included removal of soil down to coral rock in an area of 19 acres on the island of Sally.

PASO Pacific Area Support Office (of DOE/NV), Honolulu, Hawaii.

pCi Picocurie. 1×10^{-12} Curies.

pCi/g Picocuries per gram.

PHA Pulse Height Analyzer.

PGT Princeton Gamma Tech, manufacturer of HPGe gamma ray detectors.

PIMM Portable Instrument Maintenance Manual.

PLOWX Plowing Experiment (site on Janet).

PM Photomultiplier (tube).

PMEL Precision Measurement Equipment Laboratory (electronics technician).

PNL Battelle - Pacific Northwest Laboratory.

Pu Plutonium. Specifically, the isotopes ^{238}Pu , ^{239}Pu , and ^{240}Pu . Context may imply the sum of these Pu isotopes.

QA Quality Assurance.

QC Quality Control.

R Roentgen. A unit of exposure to ionizing radiation. It is that amount of gamma or X rays required to produce ions carrying 1 electrostatic unit of electrical charge in one cubic centimeter of dry air under standard conditions.

rad Radiation absorbed dose. The basic unit of absorbed dose of ionizing radiation. One rad is equal to the absorption of 100 ergs of radiation energy per gram of matter.

RADCON Radiation Control.

RADLAB Radiation Laboratory. (Complex of trailers in which a radiation laboratory was established and used by DOE and ERSP contractors at EA.)

RCC Radiation Control Committee (of the JTG).

REECO Reynolds Electrical and Engineering Company, Inc., operating contractor for the DOE at NTS.

rem A special unit of dose equivalent. The dose equivalent in rems is numerically equal to the absorbed dose in rads multiplied by the quality factor, the distribution factor, and any other necessary modifying factors.

ROM Read-only memory.

RSAIT Radiation Safety Audit and Inspection Team.

SAC Scintillation Alpha Counter.

SATCOM Satellite Communication.

SitRep Situation Report.

SN Serial Number.

SOP Standard (or Standing) Operating Procedure.

Sr Strontium. Specifically, the isotopes ^{85}Sr and ^{90}Sr .

TG Task Group.

Tl Thallium.

TRU The transuranic elements. Specifically, ^{238}Pu , ^{239}Pu , ^{240}Pu , and ^{241}Am .

TWX Teletype message.

TTPI Trust Territory of the Pacific Islands.

U Uranium. Specifically the isotopes ^{234}U , ^{235}U and ^{238}U .

UPS Uninterruptible Power Supply.

USAF United States Air Force.

Y Yttrium. Specifically the isotope ^{90}Y .

μ mu - Greek alphabet letter used to denote attenuation; also micro (10^{-6})

ρ rho - Greek alphabet letter used to denote density.

CHRONOLOGY OF SIGNIFICANT EVENTS

<u>DATE</u> Y M D	<u>EVENT</u>	<u>PAGE</u>
440217	American forces invade Enewetak Atoll (EA)	2
471202	People of Enewetak moved to Ujelang Atoll.	5
480418	First nuclear test at Enewetak (X-RAY).	8
521031	First test of thermonuclear device (MIKE).	8
580818	Last (43rd) nuclear test at Enewetak (FIG).	10
710700*	AEC radiological reconnaissance of EA (supporting PACE). . .	19
720200	Interagency meeting to discuss potential cleanup of EA	**
720418	U.S. announced EA jurisdiction to return to TTPI.	17
720512	Radiological reconnaissance of EA.	38
720518	First visit to EA by the people since 1947	18
720717	DNA directed to plan EA cleanup.	34
720817	First interagency meeting to plan cleanup.	34
720907	Second interagency meeting to plan cleanup	35
721012	Engineering and radiological surveys begun	36
721130	Director, DNA designated Project Manager for cleanup	35
730223	Meeting with Enewetak Council (EC) in Honolulu to discuss cleanup	
730415	Engineering survey results distributed.	36
730504	Meeting with EC in Majuro to learn people's desires	
730509	AEC established Task Group (TG) for Recommendations. . . .	39
730600	Master Plan meeting with Ujelang council in Majuro	
730625	Interagency meeting to review survey results	
731100	Enewetak Atoll Master Plan published	45
740101	Managerial Authority for EA transferred to DNA	
740201	Draft TG recommendations distributed for review	
740215	DNA presentation to AEC on cleanup philosophy	
740300	Radiological survey results distributed.	39
740306	Interagency meeting to discuss TG draft report	
740312	AEC response to DNA position	
740415	Draft EIS circulated for internal DNA, AEC review	
740419	Second draft of TG recommendation distributed	
740619	AEC TG recommendation published.	39
740820	DNA adopted TG recommendations	
740907	DEIS delivered to the people of Enewetak	46
740907	DOI promised early return to Japtan	
741207	Enewetak Council resolution requested title to Ujelang	
750103	DNA/DOI agreed on early return of people to Japtan	
750214	Conference on EA cleanup criteria	
750225	Enewetak Project policy meeting	
750300	Revised Master Plan published	
750415	Final EIS filed with Council on Environmental Quality.	46
750500	EIS accepted by EPA	
750910	DNA/ERDA interagency support agreement	50
751007	Congress authorized \$20 million for EA cleanup	47
760119	Draft Radiological Cleanup Plan issued for comment	
760200	DIR DNA released EIS despite interagency questions	
760716	Congressional authorization for EA cleanup	49

*Double zero (00) in day (D) column means the day of the month is unknown, or that a span of time was involved such that a fixed day has no meaning.

**Events listed without a page number are not discussed in this report.

<u>DATE</u>	<u>EVENT</u>	<u>PAGE</u>
760900	Draft Cleanup Concept Plan (CONPLAN) released.	50
760916	Intergovernment agreements on rights to EA	
761117	Interagency coordination conference in Majuro	
770100*	Final CONPLAN published.	50
770204	First OPLAN conference held at KAFB.. . . .	**
770309	Second OPLAN conference held at EA	
770314	Initial mobilization for cleanup began.	51
770315	Early return of 56 people of Enewetak to EA	
770429	OPLAN 600-77 distributed	50
770429	Interagency OPLAN resolution conference	
770628	ERDA - Marshall Islands Workshop	53
770700	In situ cleanup characterization survey begun.	51
770818	Bair Committee agreed cleanup plans were reasonable.	60
770900	EPA proposed guidance for transuranic cleanup.	57
771122	EPA Transuranic guidance signed by Administrator	
780106	DNA/DOE agreement to include all transuranics in cleanup . .	57
780400	LLL draft dose assessment distributed.	63
780428	EA Advisory Group recommended more stringent criteria. . . .	63
780504	DNA issue/decision conference.	57
790916	Dome completion ceremony on Island Yvonne (Runit)	
800409	Cleanup completion ceremony with Enewetak people	

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CHAPTER ONE: BACKGROUND
by Bert Friesen
Holmes & Narver, Inc.

1.1 INTRODUCTION

"The light - it was many times brighter than the sun. The mountains back of us showed as clear as in daylight. We were stationed ten miles away from the explosion. At the five-mile station, two men were knocked over by the blast. The immense ball of flame rapidly going up into the sky was followed by a cloud of dark dust. The hundred-foot steel tower on which the bomb was placed was completely evaporated. The surface sand around it for a thousand feet was melted into glass." (Compton, 1956.)

Thus was the birth of the Atomic Age witnessed in secrecy on 16 July 1945, with the first test of a nuclear bomb, code named Trinity, at Alamogordo, New Mexico. Three weeks later, on 6 August 1945 (local time), the second nuclear bomb was detonated over Hiroshima, Japan, followed by the third bomb over Nagasaki, Japan, on 9 August 1945 (local time). The successful detonation in combat of these powerfully destructive weapons brought a quick end to World War II. The devices had worked as planned but very little was known of either the immediate or the long-range aftereffects.

Although the war had ended and no further military use was anticipated in connection with WW II, military officials were anxious to learn much more about the newest weapon in their arsenal. Theoreticians could predict enough of the effects from a nuclear explosion to realize that additional testing would have to be conducted in an area far from any population centers to minimize the dangers of exposure to hazardous radiation. The fourth nuclear device, Test Able, was detonated about 500 feet above a fleet of surplus naval craft at anchor in Bikini lagoon on 30 June 1946. Test Baker followed on 24 July 1946. The Baker device was suspended beneath a small landing craft, LSM 60, with the burst point at 90 feet below water surface.

"The air burst (of Test Able), despite the damage it had inflicted, scarcely had prepared observers for the wrath of sound, light, and volcanic shock that erupted within the lagoon. At the moment of explosion, a giant bubble, brilliantly lighted within by incandescent materials, burst from the surface of the water to be followed by an 'opaque cloud' which quickly covered about half of the ships of the target fleet. Within seconds, the cloud had vanished and a hollow column, 2,200 feet in diameter and containing some 10 million tons of water, rose from the surface of the lagoon to a height of more than a mile. The 26,000-ton battleship, Arkansas, broadside to the LSM 60 but more than 500 feet away, was lifted and upended in the column before she was plunged to the bottom. At the base of the column was a tumult of foam several hundred feet high, and the descent of the water back into the lagoon set up a base surge from which rolled waves eighty to one-hundred feet high. The waves subsided rapidly as they proceeded outward, and the highest wave recorded at Bikini Island, three miles away, was seven feet, not sufficiently high to pass over the island or to cause damage there." (Hines, 1962.)

The brief chronology and quotations presented above set the stage for the rest of this document. Enewetak Atoll became a critical component of the very large and complex program of nuclear testing conducted by the United States from 1946 to 1958. Detonation of 43 nuclear devices at Enewetak Atoll created radiological conditions deemed too hazardous for unrestricted use of the atoll by future residents. The U.S. Department of Energy (DOE), acting in advisory and support roles to the Defense Nuclear Agency (DNA), participated in the radiological cleanup of Enewetak Atoll, undertaken to prepare the islands for their return to the people of Enewetak. Most of this report is devoted to a detailed description of the conduct by the DOE and its contractors of what became known as the Enewetak Radiological Support Project.

Readers are directed to other sources for additional background on nuclear testing in the Pacific or details on related topics. Hines presents an interesting account of the problems and successes of conducting radiobiological studies in the Pacific Proving Ground concurrent with nuclear testing. Compton and Groueff provide excellent views of how the atomic age was conceived and carried full-term to Alamogordo and Japan. The problems of dislocation experienced by the people of Bikini