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THE FOLLOWING pages (i.e., 444-471, inclusive) are excerpts from the book entitled, "THE RADIOLOGICAL CLEANUP OF ENEWETAK ATOLL", By THE DEFENSE NUCLEAR Agency, 1981. THE FORWARD IS ALSO INCLUDED TO PROVIDE OBJECTIVES OF Book. THIS IS THE BEST Running Description ON THE SUBJECT OF DISCONTINUATION OF RUNIT CLEANUP by the Defense Nuclear Agency FOUND TO DATE.

FOREWORD

For 8 years, from 1972 until 1980, the United States planned and carried out the radiological cleanup, rehabilitation, and resettlement of Enewetak Atoll in the Marshall Islands. This project represented the fulfillment of a long-standing moral commitment to the People of Enewetak. The cleanup itself, executed by the Department of Defense (DOD), was an extensive effort, involving a Joint Task Force staff and numerous Army, Navy, and Air Force units and personnel. The rehabilitation and resettlement project, carried out by the Department of the Interior concurrently with the cleanup, added complexity to the task and required the closest coordination — as did the important involvement of the Department of Energy (DOE), responsible for radiological characterization and certification. The combined effort cost about $100 million and required an on-atoll task force numbering almost 1,000 people for 3 years, 1977-1980. No radiological cleanup operation of this scope and complexity has ever before been attempted by the United States.

This documentary records, from the perspective of DOD, the background, decisions, actions, and results of this major national and international effort. Every attempt has been made to record issues as they developed, and to show the results, good and bad, of specific decisions, oversights, etc. Because this documentary may have considerable importance in the future, and because specific needs for data cannot be foreseen with accuracy, every attempt has been made to record in some detail all major facets of the operation and to reference key documents. Throughout the research, collection, and writing, four major types of potential users have been kept in mind. The documentary is designed:

— First, to provide a historical document which records with accuracy this major event in the history of Enewetak Atoll, the Marshall Islands, the Trust Territory of the Pacific Islands, Micronesia, the Pacific Basin, and the United States. To serve this end, the documentary addresses political, legal, administrative, and social issues; and it attempts to put the cleanup in perspective in terms of the prior history of Enewetak Atoll, World War II, the nuclear testing period, and the United Nations Trusteeship.

— Second, to provide a definitive record of the radiological contamination of the Atoll. It addresses the origins of the contamination on a shot-by-shot basis; the types, concentrations, and locations of contamination prior to the cleanup; the radiological cleanup decisions and their rationale; the cleanup processes themselves; and the resulting radiological situation, island-by-island. It is believed that this type of data will be useful over the coming decades as living patterns on the Atoll change, new radiological surveys are taken, improved health physics understanding becomes available, and new risk-benefit decisions are made. For this purpose this documentary will supplement the more technical data published by DOE.

— Third, to provide a detailed record of the radiological exposure of the cleanup forces themselves. As years pass, it will become increasingly important to the cleanup participants, to the U.S. Government, and to health physicists and radiation biologists, to have a meticulously accurate record of the radiological safety policies and procedures; an overview of personnel assignment practices; and a careful summarization of air sampler readings, film badge and thermoluminescent dosimeter exposures, bioassay samples, etc.

— Fourth, to provide a useful guide for subsequent radiological cleanup efforts elsewhere. It seems likely that there will be future requirements for radiological cleanup of extensive areas which present complex contamination problems. Since the Enewetak cleanup was a bellwether effort of its kind, the many lessons learned should provide useful guidance for those who will plan and execute future efforts. Information such as this is quickly lost if not permanently recorded.

In developing this documentary, every effort has been made to be accurate, balanced, and objective. However, since issues can appear in somewhat different light when viewed from different organizational perspectives, the reader should keep in mind that the authors generally have a DOD affiliation.

August 1980

ROBERT R. MONROE
Vice Admiral, U.S. Navy
Director, Defense Nuclear Agency

concentrations in other soil and merited special handling. He believed they represented "high-graded" material and, once brought under control, should not again be released but should be retained in DOE-ERSP custody until completion of the Runit effort. At that time, the DOE-ERSP would propose and obtain approval of a disposal plan. He recognized that it was highly probable that some particles remained in the Fig-Quince area and could be unknowingly placed in the dome or remain unexcised, but he believed that the fragments which had been found should remain under DOE control.[95]

The JTG J-2 and DOE-ERSP technicians on the atoll reviewed data available on the fragments from the FRST survey and other files and conducted a radiological sampling of the physical material. It was determined that the total of all material collected in bags measured approximately 60 millicuries of transuranics. The fragments themselves appeared to be weathered metal, some of which had concrete or soil attached, rather than high-graded plutonium. The transuranic content of the fragments, which had been the cause of concern, was relatively low.[96] Because of these findings, the bags of material were placed in the Donut Hole and choked with concrete slurry.[97]

RUNIT DEBRIS CLEANUP

Although the EIS required disposal of all hazardous debris and crater containment of all radiologically contaminated debris, the cleanup of debris on Runit had been accomplished less rigourously than on other islands. This was not intended, or realized, by the Director, DNA or Commander, Field Command. It was apparently fostered by the concept that, since Runit would be quarantined, cleanup of debris there was a low-priority task. Too, since the debris was near the crater and transportation was not complicated, the cleanup could be set aside until the end of the soil-cement phase was near. Both of these views turned out to be ill-conceived. In reports from the atoll in September 1978, the CJTG interpreted the tasking to clean Runit soil to 160 pCi/g using available resources as applying to debris cleanup as well.[98,99] This interpretation drew a strong response from the Director, DNA to the effect that all debris on Runit must be removed. Nevertheless, Runit debris cleanup continued to be given low priority by the USAE well into 1979.

Runit debris had been surveyed initially by the FRST in July 1977. Another debris survey was conducted for the radiological characterization of Runit in December 1977. Additional surveys were made in the latter half of 1978. Some of these surveys were directed primarily toward identifying hazardous areas for radiological safety and control, rather than toward identifying the appropriate disposition of each item. During the September 1978 survey, it was estimated that there were approximately 10,000 cubic yards of debris on Runit and its associated reef areas, 4,100 of which should be disposed of in the crater.[100] A resurvey 2 months later estimated that only 2,200 cubic yards need be disposed of in the crater.[101]

Some of the higher levels of gamma contamination (maximum intensity of 25 milliroentgens per hour) were found in a twisted metal debris pile on the reef just north the old runway. Other metal located in the area of the Blackfoot GZ had gamma readings up to 17 milliroentgens per hour.[102] Debris underwater and on the reef had to be surveyed and marked several times because wave action removed both the paint and the engineer ribbon used to code its radiological condition. Efficiency of this operation could have been increased greatly if the USAE had been tasked to provide equipment to remove debris as it was being surveyed.[103] By the end of 1978, only 1,724 cubic yards of debris had been cleaned up on Runit, most of it by the WBCT or during the removal of contaminated debris from South Runit in 1977.[104]

The delays in accomplishing Runit debris cleanup had adverse effects. The landing craft which had been beached near Station 1310 during the testing period to provide shore protection were sufficiently exposed in 1977 to have permitted complete demolition and removal. However, by late 1979, due to settling and shifting sands, only portions of the superstructures were exposed, and major excavation would have been required to remove them. These landing craft were not contaminated; therefore, it was decided to remove the exposed hazards only. The most serious adverse effect of the delays, however, was that red debris continued to be located after containment operations had been completed, requiring extraordinary measures for containment. These are described in a subsequent section. In all, 4,120 cubic yards of contaminated debris and 11,482 cubic yards of noncontaminated debris were removed from Runit and its reef.

RUNIT SOIL CLEANUP

Several alternatives for cleanup of contaminated soil on Runit were considered at the 4 May 1978 Enewetak Cleanup Planning Conference including:

a. No cleanup;
b. Clean all concentrations over 160 pCi/g immediately;
c. Clean all concentrations over 160 pCi/g after all other soil cleanup was complete; and

d. Clean all concentrations over 160 pCi/g concurrently with other soil cleanup, using resources not currently employed on other tasks. The amount of resources available for Runit cleanup would increase as other tasks were completed until, eventually, all resources could be devoted to Runit cleanup.

The last alternative was adopted, and the CJTG was directed to begin cleanup of contaminated soil on Runit concurrently with other operations, using equipment available at Runit when not in use on other activities. The CJTG also was directed to segregate contaminated soil into three stockpiles on Runit according to degree of contamination. The most contaminated, principally that excised on Runit, was to be used to sustain tremie operations while disposition of that having much lower levels would be decided later.[105]

As the work was actually carried out, however, the USAE concentrated on the crater containment mission on Runit, leaving contaminated soil and debris cleanup on Runit to be accomplished later. The USAE assisted the Navy WBCT in disposal of debris removed from the waters around Runit, but because other priorities required the use of available personnel and equipment, no other effort was made to clean Runit in 1978. To sustain tremie operations, soil transported from the other islands was used in filling the crater.

The delays in soil cleanup were discussed during demobilization planning conferences in August and November 1978. Soil cleanup appeared to be the one task which could require extending the project. The Commander, Field Command noted, in a message to the Services, that the 15 April 1980 project completion date in the draft demobilization plan was based on the assumption that soil removal would be completed on schedule. He also noted that, while he intended to exert every effort to hold to the 15 April 1980 date, there was much uncertainty involved in the remaining tasks.[106] During the 1-9 August 1978 Demobilization Conference, the Services were asked to address the issue of extending the project past 15 April 1980. They responded that it was possible to extend it until 30 September 1980, since they had funded the project through the end of fiscal year 1980.[107,108]

In December 1978, the CJTG presented to the Director, DNA, and the Commander, Field Command, his evaluation of the Runit situation. South Runit met the radiological guidelines for agricultural use without soil cleanup. Soil sampling had been completed in the Fig-Quince area and indicated varied levels of contamination mixed to depths in excess of 4 feet. Soil characterization had not been completed north of the Fig-Quince area and would require 12 days' work. An estimated 28 acres in the Fig-Quince area and 2 acres in other areas needed to be cleaned. The CJTG identified the following alternative solutions:

a. Remove all soil, surface and subsurface, above 160 pCi/g of transuranics. Estimated volume was over 9,500 cubic yards.
b. Remove all surface contamination above 160 pCi/g to a maximum depth of 40 centimeters (16 inches). This would limit the worst-case volume to 62,920 cubic yards.
c. Erect a barrier at the hotline and quarantine North Runit. Permit use of South Runit.
d. Dig a wide channel near the hotline to form two islands and quarantine the northern one. Permit use of South Runit.
e. Quarantine Runit forever.

The Director, DNA requested more IMP data on South Runit before making a decision.[109,110] The matter of Runit soil cleanup, however, was to be overtaken by more pressing developments.

At the 12 February 1979 Fission Products Survey Conference, the Director, DNA reaffirmed that 15 April 1980 was an ironclad end date but that "If we try to turn away from a job half done, we will be right back out there redoing the job with more people and more cost."[111] A briefing was presented on the status of the cleanup project which indicated it might possibly be completed well before the planned end date. Cleanup and transport of contaminated material from the islands other than Runit was 3 months ahead of the revised schedule. Tremie operations were being completed 2 months ahead of the revised schedule. Less than 12,000 cubic yards of contaminated soil remained in the stockpile or to be transported from the other islands. This would sustain soil-cement operations for slightly more than 2 weeks at the planned rate of 5,000 cubic yards per week. Cleanup of Runit, based on worst case estimates of 60,000 cubic yards, could be completed in only 12 more weeks, or by the end of May 1979, permitting the crater to be capped and demobilization to be started a month early (i.e., 15 September instead of 15 October 1979). The only apparent constraint was delivery of cement to sustain the maximum rate of soil-cement containment.[112] The USAE representative at the conference confirmed that USAE could excise and contain 5,000 cubic yards of soil per week on Runit if they had the cement.

The Director, DNA decided to expedite cleanup of Runit soil and to expedite delivery of the cement. At the end of the meeting, the discussion turned to Lujor, which had been cleaned only to visitation level (160 pCi/g), not to agricultural level (80 pCi/g), the use desired by the dri-Enewetak. The Director then directed the CJTG to develop plans for two options: Cleanup of Runit to 160 pCi/g and Lujor to 80 pCi/g, or cleanup of Runit alone.

The initial response from the JTG staff and the USAE to the proposed cleanup of Lujor was pessimistic because of anticipated difficulties with Lujor; i.e., channel access, poor beach and on island trafficability, etc.[115]

However, the CJTG took the more positive position that it was possible to clean up Lujor to under 80 pCi/g and the Fig-Quince area on Runit without extending the project.[116] The CJTG proposal was modified by Field Command to consider these alternatives:

a. Clean Runit to reduce transuranic contamination to the lowest level reasonably achievable within constraints of crater capacity and time and do nothing on Lujor.
b. Clean Lujor to meet the 80 pCi/g criteria (encapsulating the soil), while accomplishing as much excision on Runit as time and resources permit (encapsulating the Runit soil).
c. Clean Lujor to meet the 80 pCi/g criteria without encapsulating all of the Lujor soil, and concurrently excise and encapsulate Runit soil as time and resources permit.

Other considerations impacted on any expedited cleanup of either Lujor or Runit. These included soil removal requirements remaining at Boken (Irene), Enjebi, and the Aomon crypt; soil transport capability; status of crater fill; cement on hand; containment rate; and projection of crater dome height.

After careful deliberation of the Field Command and JTG inputs, COL Peters (Director of Enewetak Operations) briefed the Director, DNA on the recommended options on 8 March 1979. Alternative a, clean Runit only, could be completed in the time available, would maximize crater fill, and could be initiated without any channel clearance operations and without any need to consider boat transportation capabilities. However, there would be no guarantee that the island status would change, excavation to depths of 6 feet might be required, and the EIS requirement for Lujor would not be satisfied. Alternative b allowed containment of the Aomon, Enjebi, Boken and Lujor soil within the time and crater volume available, and it would change the status of Lujor to the benefit of the people and in accord with the EIS. However, it would place great demands on equipment already overtaxed, require channel clearance and additional IMPing, place excavation and transport operations under severe time constraints, and require additional bulk-haul boat configuration to get the job done in time. Alternative c had all of the favorable aspects of alternative b, plus it would permit intensive effort on both Runit and Lujor. It was less time constrained since the soil from Lujor would not necessarily be encapsulated. It still would have the problems associated with access to Lujor, trafficability, bulk-haul boats, and overall efficiency. Since the cleanup of Runit was of less benefit to the people than the cleanup of Lujor insofar as the ultimate usage was concerned, and since either alternative could be accomplished in time to allow the crater to be capped by 15 September 1979, the Director, DNA decided to implement alternative b, with a modification. It was modified to regulate the input of

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Runit soil to 1,000 cubic yards per week and not to exceed 12,000 cubic yards pending evaluation of the progress on Boken, Enjebi, Aomon and Lujor.[117] By this restriction on dome fill with the easier-to-transport Runit soil, the Director, DNA hoped to ensure that all Lujor soil would be encapsulated. On 13 March 1979, the CJTG received directions to proceed with concurrent cleanup of Lujor and Runit.[118]

As a practical matter, a limit had to be placed on the dome size to assure that it was completed in time to permit capping and the demobilization by 15 April 1980, the end date set by DNA. Field Command engineers had suggested that the POD design be followed and that the dome be extended inland as necessary to contain the additional volume required for the worst-case estimate of cleaning both Lujor and Runit. However, as a result of discussions during the 8 March 1979 briefing, the Director, DNA decided that soil-cement and capping operations would be directed toward a 25-foot dome.[119]

Upon receipt of the 13 March 1979 directions, the JTG proceeded to excise and encapsulate Runit soil at a rate which would sustain soil-cement operations while awaiting the delivery of soil from the other islands. Efforts were expanded to open a channel for boats into Lujor but the strong currents between Lujor and Aej continued to hamper the successful marriage of the LCUs with the boat ramp. However, it appeared that the LCM-8s would be successful in getting into Lujor, but with an attendant decrease in soil removal capability. By 24 March, approximately 2,400 cubic yards of Runit (Fig-Quince) soil had been contained and, with the troops on Runit accelerating the containment rate, the soil stockpile was almost depleted. The containment rate reached 4,220 cubic yards during that week, and soil was not arriving fast enough from Boken, Enjebi, Aomon and Lujor to sustain a stockpile.

The rate of containment for Runit soil caused concern at Field Command that whatever dome volume might remain for contingencies would be used for Runit soil. The fission products survey was uncovering additional subsurface contamination on Boken and Enjebi which had not been considered in selection of a dome volume. The CJTG was directed to halt, temporarily, the containment of Runit soil after 5,720 cubic yards had been excised in less than 3 weeks.

The CJTG then requested approval of a plan to maintain an effective containment rate, clean Lujor to agricultural levels, and make the most productive use of available resources to clean Runit. The plan provided for excising and containing Runit soil over 160 pCi/g at the rate necessary to sustain efficient soil-cement operations (3,000 to 5,000 cubic yards per week), while stockpiling the Lujor soil for subsequent containment or backfill of the Fig-Quince area as circumstances indicated. The suggestion was based on the fact that all of the Lujor soil was less than the 160 pCi/g level established for surface contamination on Runit.[120] The suggestion was nearly identical to the original alternative c proposed by Field Command earlier in March 1979. The suggestion was rejected again on the grounds that the EIS did not specifically authorize the spreading of low-level excised soil from one island on another island. The Commander, Field Command issued new guidance to the effect that maximum effort should be exerted to excise, transport, and encapsulate Lujor soil and to transport and encapsulate soil and debris from Enjebi and Aomon. No more soil from Runit would be encapsulated at this time. To carry out this guidance, the CJTG would be required to insure selective excision of Lujor soil and optimize usage of boats for soil transport to Runit.[121]

The Director, DNA and the Commander, Field Command anticipated that future action to reduce transuranic levels on Runit would be possible, at least to reduce the "hot spots"; i.e., the areas which indicate increased levels of activity after the first excision. The CJTG was tasked to develop a plan for the selective excision of hot spots on Runit, with the focus on the Fig-Quince area. In preparing the plan, full consideration was to be given to: impact of additional work on Runit on the soil removal effort on Lujor; availability of equipment, personnel, and time to complete the soil removal plan for the Runit hot spots; and, the impact of the plan on crater fill and crater capping operations.[122]

As a separate but related matter, the CJTG reported that excavation of the Cactus Crater lip on the island side of the containment structure would be necessary to permit adjustment in the keywall alignment and proposed that this soil be encapsulated as it was excavated. This soil was initially thought to be highly contaminated. Field Command guidance directed stockpiling of any soil from the crater lip until such time as the determination was made on the disposition of all Runit soil.[123] Actually, this crater lip soil proved, in subsequent tests, to have very low transuranic levels; i.e., 5 pCi/g.

By mid-May, Boken and Enjebi soil excavation and transport to Runit were complete. The Aomon crypt had been cleaned and backfill initiated. All Aomon debris had been hauled to Runit, and Aomon soil transport operations were underway, with 8,300 cubic yards of soil remaining to be transported. Soil excavation was almost complete on Lujor, and 4,900 cubic yards of an estimated 16,000 cubic yards of soil had been transported to Runit. Considering dome space remaining and estimated soil yet to be encapsulated, it appeared that there still would be approximately 5,600 cubic yards of space available for Runit soil when that operation was renewed.[124]

On 25-29 May 1979, the Commander, Field Command visited Enewetak to review the cleanup progress and conduct a change of command. Colonel Kenneth E. Halleran, USA, replaced Colonel Robert Bauchspies as the

Commander, JTG. MG Tate reviewed the JTG plan for the selective excision of the Runit hot spots. Recognizing that the available dome space of approximately 6,000 cubic yards would not accommodate all the contaminated soil from Fig-Quince, the JTG had developed a sequential plan for excising one-sixteenth hectare areas having transuranic readings over 160 pCi/g, working from hottest to coolest areas (highest to lowest readings). The initial excision would be limited to 2,000 cubic yards to minimize the possibility that all of the contaminated soil stockpiled at Lujor and Aomon might not be encapsulated. Dome capacity permitting, subsequent lifts would be made based on DOE re-IMPing on a one-quarter hectare grid and new areas of highest readings determined. This procedure would be continued until all one-quarter hectare areas had been reduced to less than 160 pCi/g or dome capacity no longer existed. Once encapsulation of all soil ceased and capping operations became the critical path, the USAE would place a 12-inch blanket of relatively clean soil (less than 160 pCi/g) over the Fig-Quince area.[125] This plan for selective excision of contaminated soil in the Fig-Quince area appeared to offer the best opportunity to make a substantial change in the radiological condition of Runit within the available crater dome volume, considering the potential loss of volume to other possible excision requirements on Boken and Lujor growing out of the DOE Fission Products Survey (subsurface). On 1 June 1979, the Commander, Field Command approved the JTG plan, emphasizing that completion of the soil removal and the containment operation was essential to the accomplishment of the cap completion by 15 September 1979 and subsequent demobilization on schedule.[126]

Once all Boken, Enjebi, Aomon, and Lujor soil had been encapsulated, and the Fission Products Data Base Survey had shown no further soil to be excised, the Runit excision plan was put into effect. Survey results before and after the selective lifts are shown in Figures 8-36 through 8-42. The final result, after removal of 5,015 cubic yards of soil, was a 75 percent reduction in surface contamination in the Fig-Quince area.[127] Although this was probably the most highly contaminated soil excised on the atoll, no air sampler readings exceeded the action level of 10 percent of the maximum permissible concentration (MPC), with the highest reaching 0.04 MPC. On 26 July 1979, soil cleanup operations were terminated on Runit, and final capping of the dome commenced. A final radiological characterization of the Fig-Quince area was made by DOE-ERSP, and a 12-inch blanket of clean soil was placed over the excised area. As a final check, a complete surface characterization of Runit, using the IMP, was made by DOE-ERSP in December 1979.

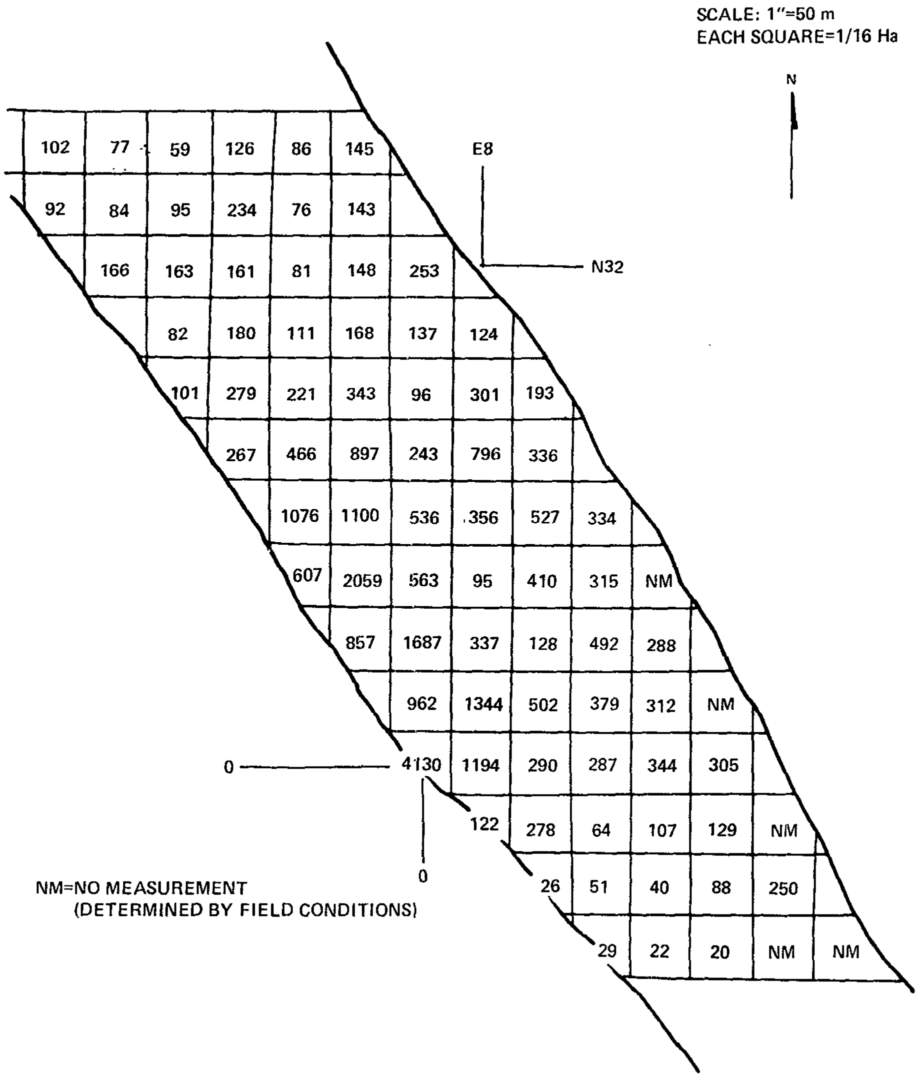

FIGURE 8-36. RUNIT FIG/QUINCE AREA PRE-LIFT TRANSURANICS.

SCALE: 1″=50 m
EACH SQUARE=1/16 Ha

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ANSURANICS.

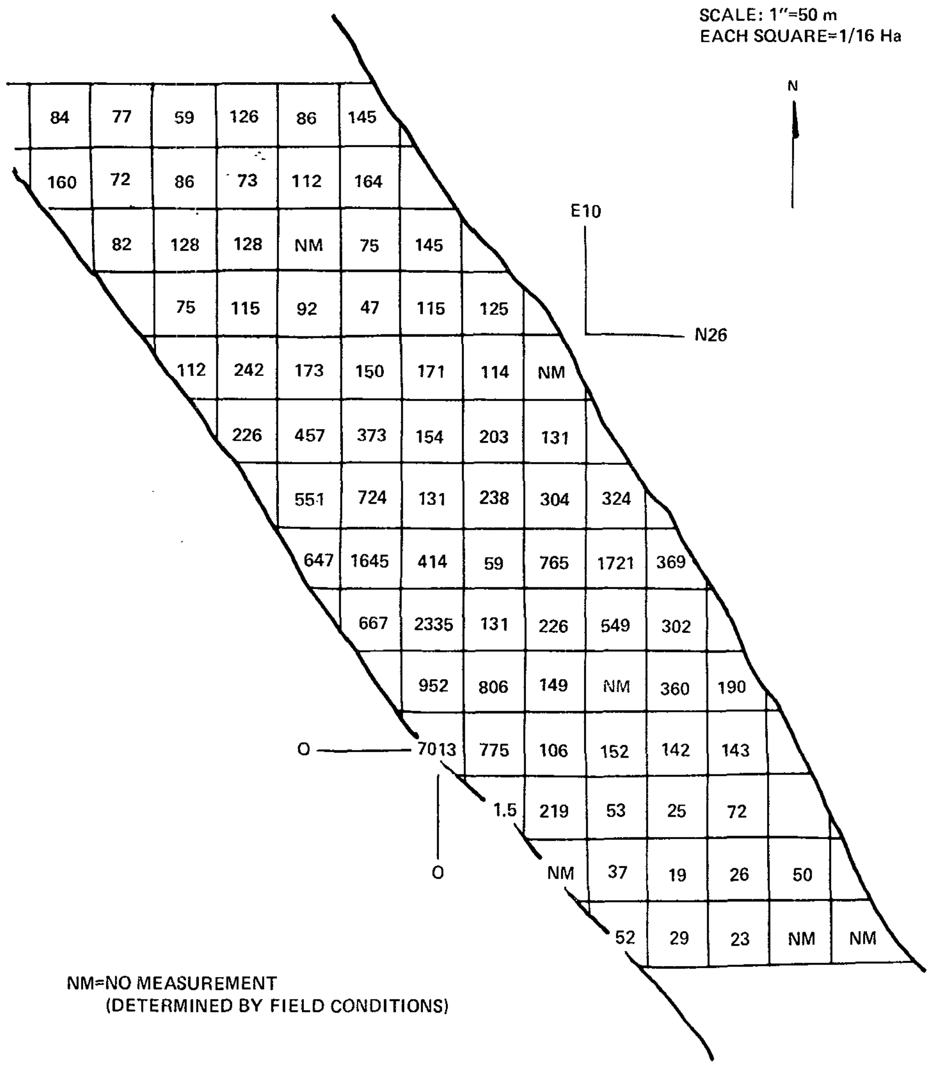

FIGURE 8-37. RUNIT FIG/QUINCE AREA POST 1ST LIFT.

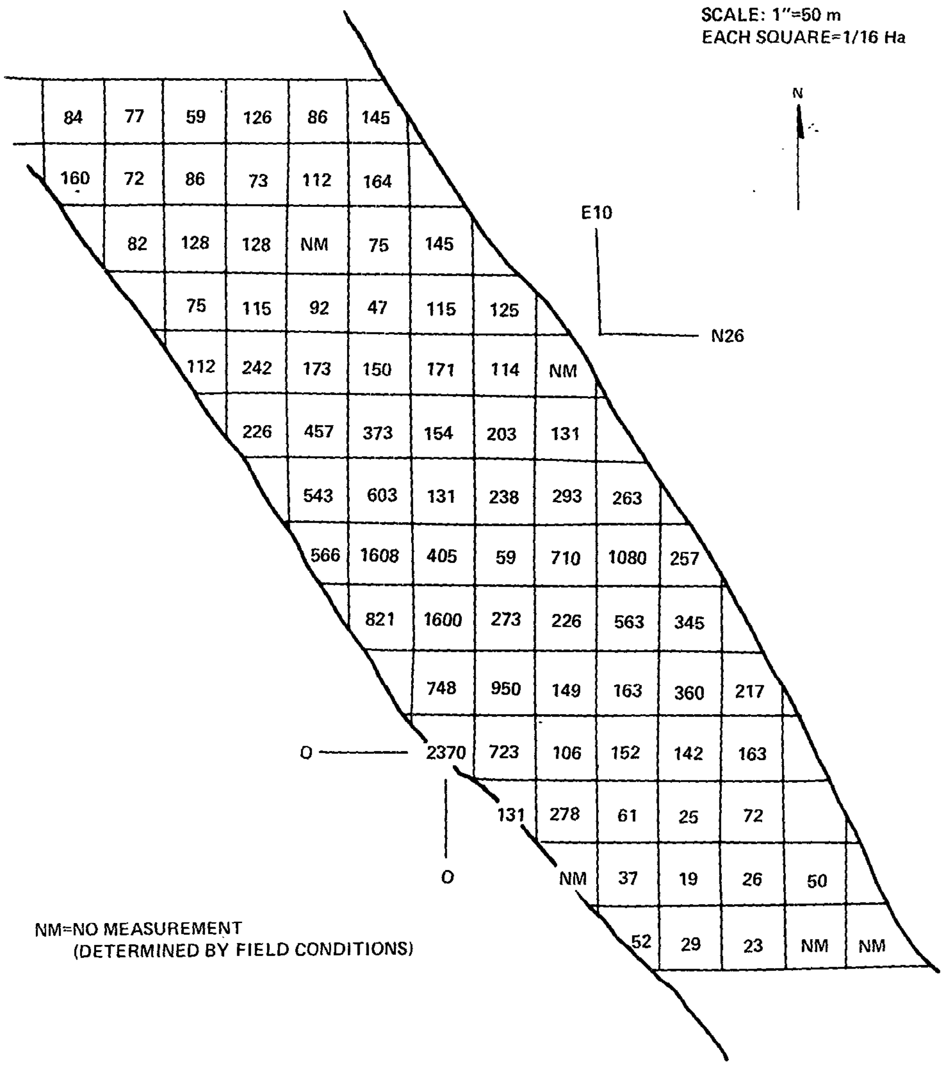

FIGURE 8-38. RUNIT FIG/QUINCE AREA POST 2ND LIFT.

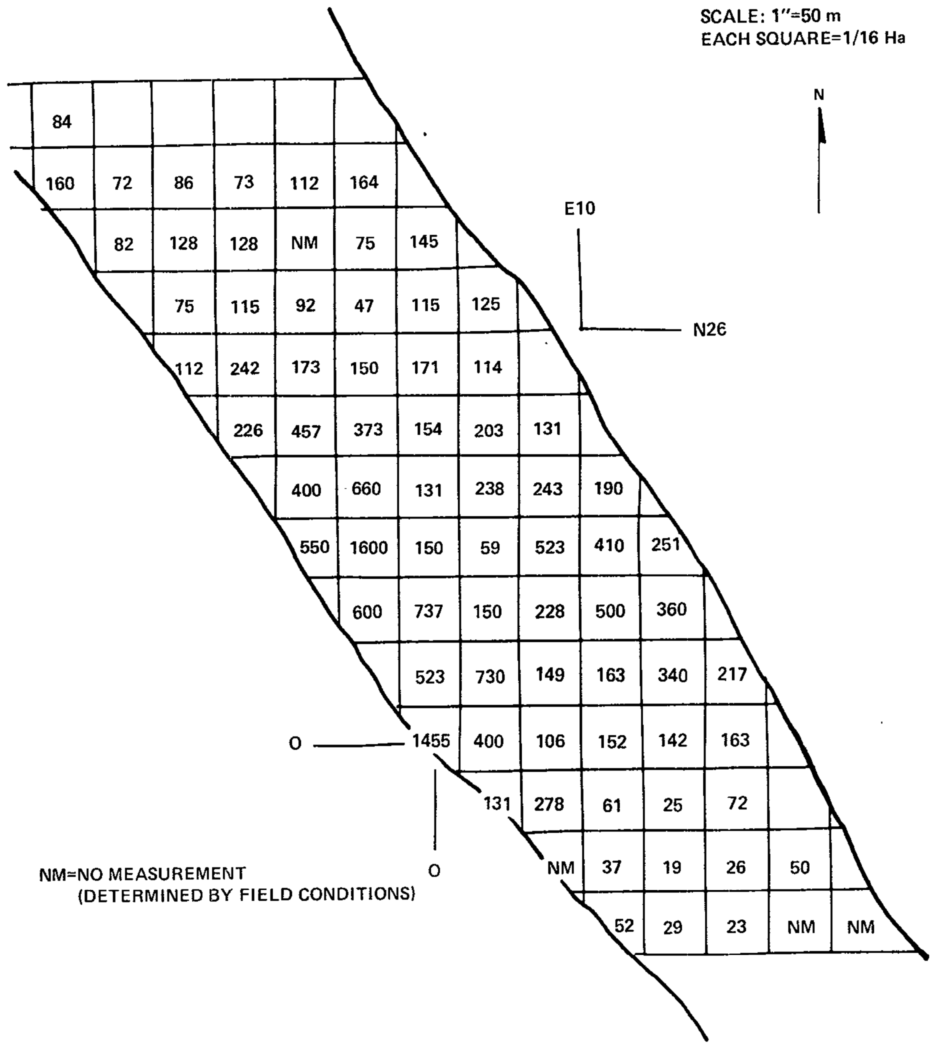

FIGURE 8-39. RUNIT FIG/QUINCE AREA POST 3RD LIFT.

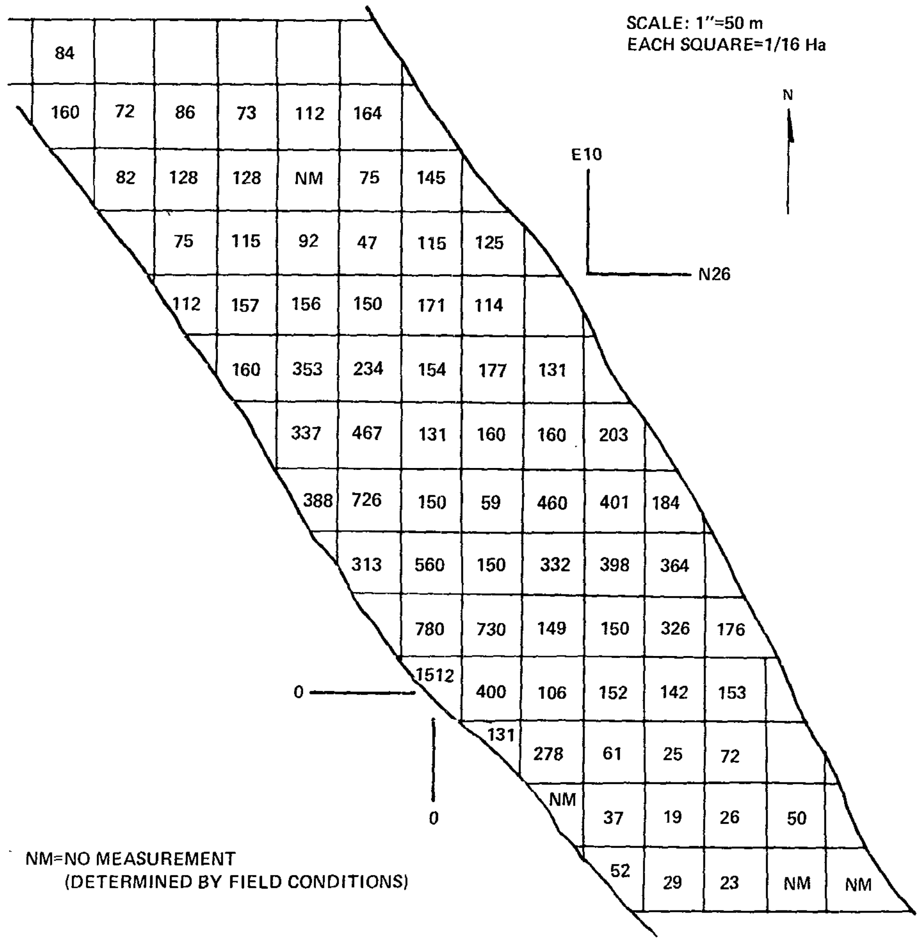

FIGURE 8-40. RUNIT FIG/QUINCE AREA POST 4TH LIFT.

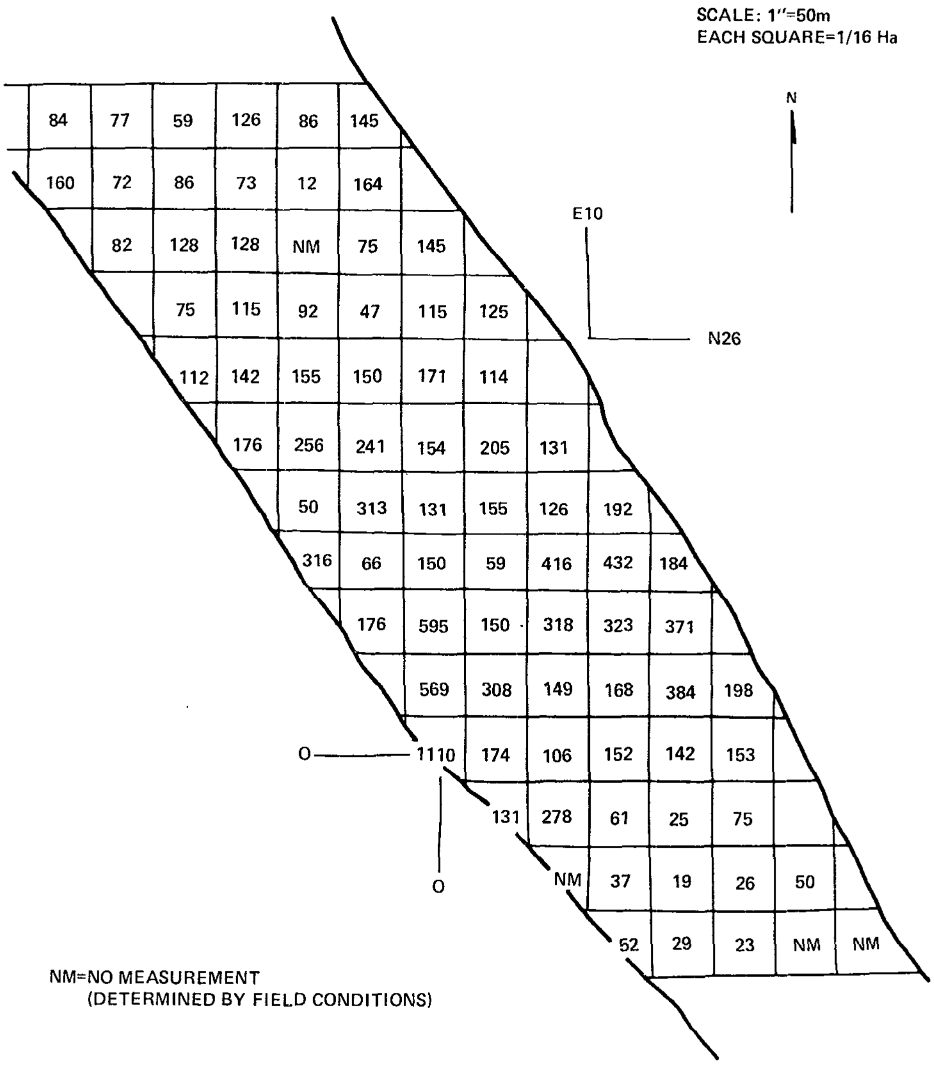

FIGURE 8-41. RUNIT FIG/QUINCE AREA POST 5TH LIFT.

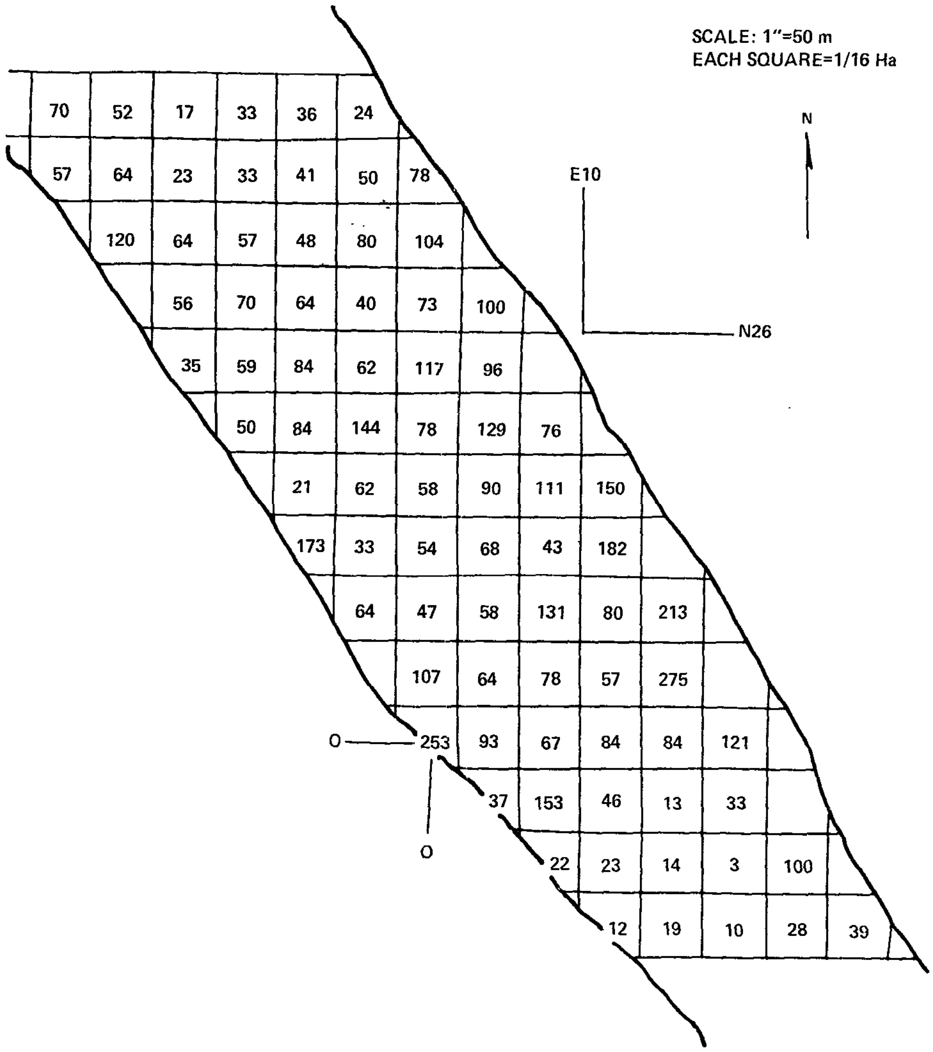

FIGURE 8-42. RUNIT FIG/QUINCE AREA POST BLANKET.

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CAP CONSTRUCTION

The dome cap was designed to protect the mound of contaminated material from natural erosion by wind and water. The POD design prescribed a nonload-bearing surface of 18 inches of concrete with the same strength characteristics as the keywall. Reinforcement was not prescribed because the concrete was to be produced using salt water, which accelerates corrosion of ferrous reinforcing materials. The final design of the cap sections was left to the USAE. In keeping with good engineering practices, it was decided that each cap section should be as close to square as possible to minimize shrinkage cracking. The USAE decided to place approximately 20-by-20-foot sections in the first ring, and continue with that size until the shape of the dome dictated a reduction in size to keep the square shape of the individual sections. Each cap section was keyed to adjacent sections using forming techniques. The POD design required expansion joint material only where the first ring joined the keywall (Figure 8-43). The rings were designated by the letters "A" through "K," beginning at the keywall and extending up to the top of the dome.

The first sections of the "A" ring were placed in May 1979, before the Donut Hole was filled and before final soil-cement operations were completed (Figure 8-44). The initial 20-by-20-foot forms were fabricated on site by the USAE using heavy lumber. The forms were positioned by survey and anchored with pins driven into the soil-cement surface. Full forms were used on alternating cap sections. Intermediate sections required an end form only. The forms were 18 inches deep and contained a 4-by-4-inch tapered key (constructed using two 2-by-4-inch pieces of lumber) located from 7 to 11 inches from the bottom of the side form (Figure 8-45).

As the capping operation progressed, the use of 18-inch steel forms was recommended. These were purchased by Field Command and used through the remainder of the project. The key on the steel forms was approximately the same size as on the wooden forms, but was centered on the bottom third of the form. End forms of heavy lumber still were used in conjunction with the steel forms.

Once the forms were installed, the area within the form was brought to grade. The surface was then raked smooth and covered with polyethylene sheets to prevent absorption of water from the concrete. The forms were then lubricated to preclude their sticking to the concrete.

Concrete was placed directly from the transit-mix trucks (Figure 8-46). For rings "A" through "E," the transit-mix truck was held in place using the winch cable from a dozer. This was necessary because of the relatively steep slope of the lower dome and the deteriorating braking systems on the trucks. Spreading and consolidation of the concrete was accomplished

FIGURE 8-43. KEYWALL EXPANSION JOINT.

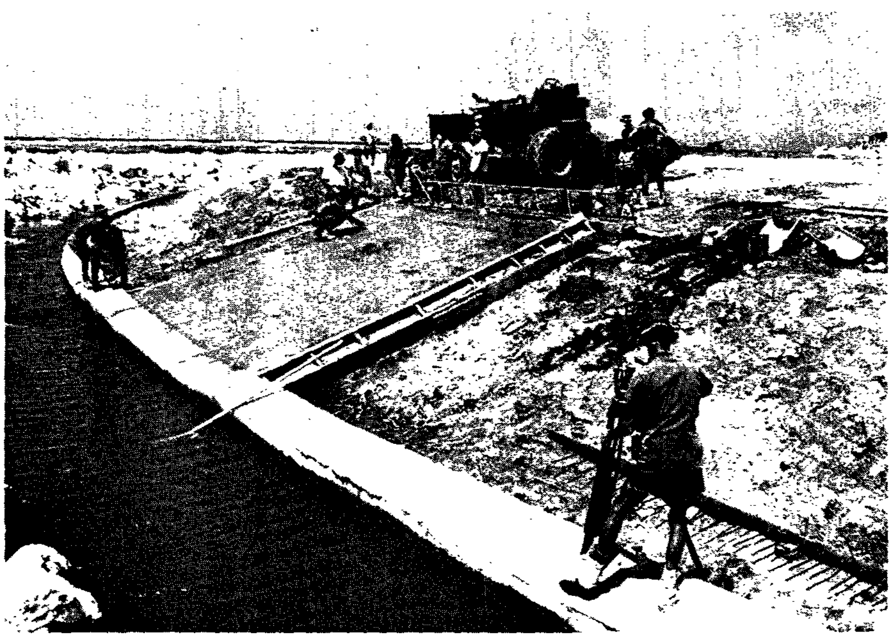

FIGURE 8-44. SIDE VIEW OF FORMS.

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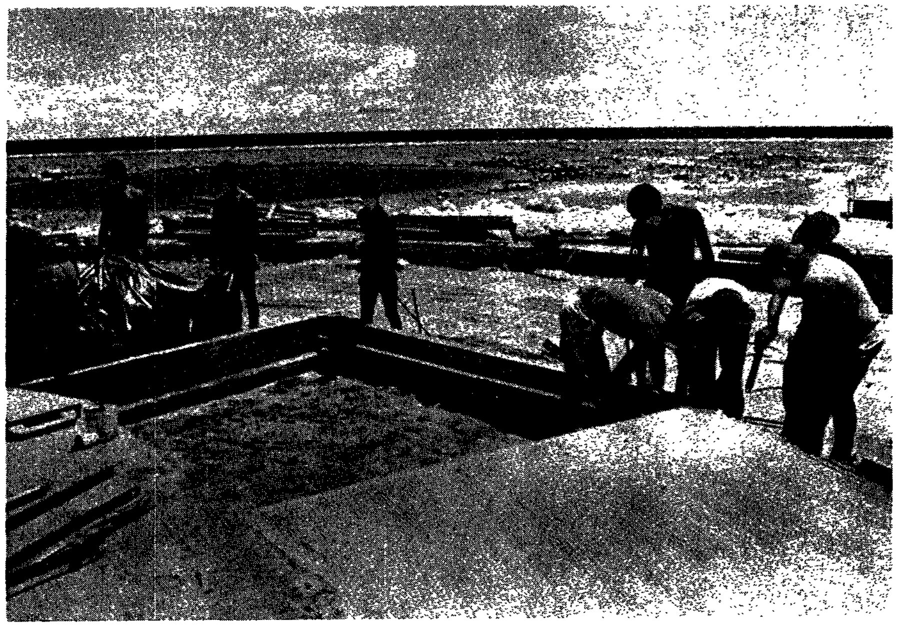

FIGURE 8-45. WOODEN CAP FORMS WITH TAPERED KEY.

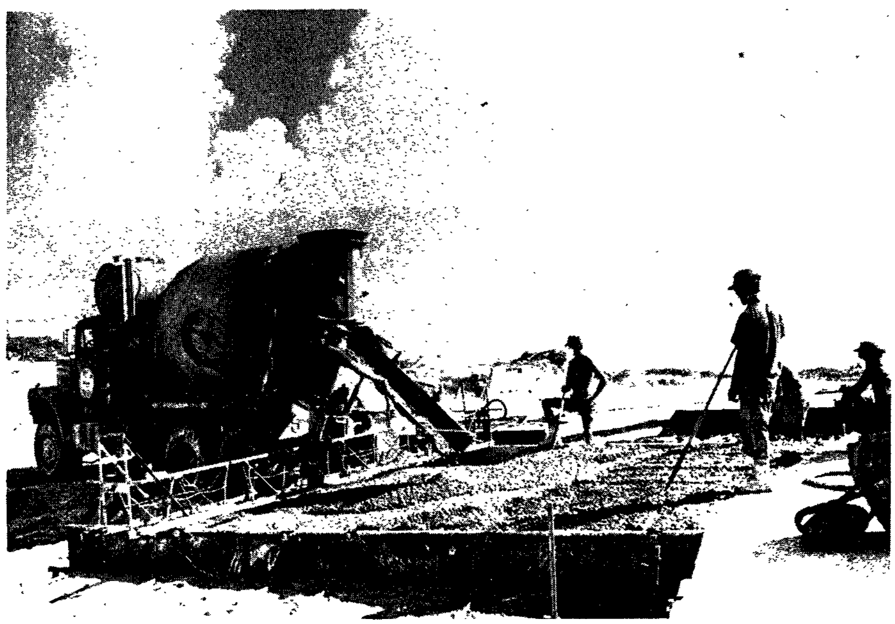

FIGURE 8-46. PLACING CEMENT IN CAP FORM.

using a standard column vibrator and vibratory power screed to dislodge entrapped air and prevent honeycombing. The power screed also provided a rough finished surface (Figure 8-47). Finishing was accomplished using a wooden screed followed by the working of the surface with a bull float. The final finish was applied using coarse brooms to provide a wearing surface (Figure 8-48). Edging trowels were used to finish the joints between adjacent sections. After the cap section was finished, curing compound was applied evenly over the entire surface.

Although soil-cement operations were finished 26 days later than scheduled, the time was made up during capping by utilizing additional manpower and equipment. The cap was finished on 6 September 1979, 9 days ahead of schedule. Over 6,000 cubic yards of concrete were used in construction of the cap itself (Figure 8-49).

Several problems arose during cap construction. While the first section was being placed, the concrete became extremely stiff and difficult to work. This was caused by the very high temperatures, which caused the concrete to hydrate much faster than normal. In order to slow down the rate of hydration, the USAE painted transit-mix truck drums white to reflect as much of the sun's radiation as possible and sprayed the aggregate and sand with water prior to mixing them with cement. The accompanying evaporation produced cooling and increased the workability of the concrete.

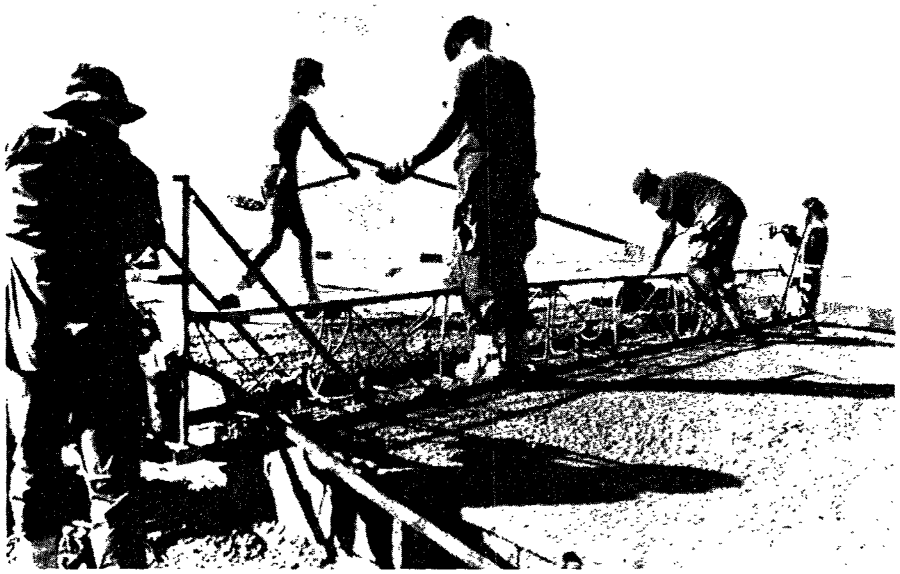

FIGURE 8-47. POWER SCREED.

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FIGURE 8-48. BROOM-FINISHING A CAP SECTION.

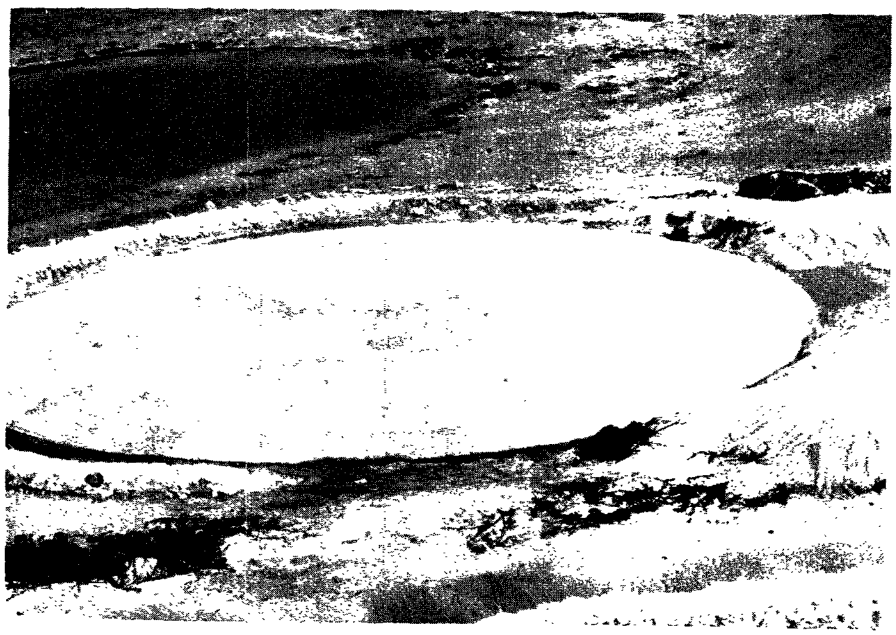

FIGURE 8-49. COMPLETED DOME CAP.

To assure that cap sections were 18 inches thick, a gauge was fabricated. It had the appearance of a huge comb with teeth 18 inches long. Projections on either end were placed atop the side forms before a section was poured and moved from one end of the section to the other. This moved the teeth across the surface to be capped so that any depressions or protrusions could be detected and corrected. After several sections had been placed, it appeared that some cap sections were turning out to be over 20 inches thick, and considerably more concrete was being used than was believed necessary. This appeared to be a result of the compaction of the disturbed soil under the tons of heavy wet concrete poured in each section which, in turn, would require more concrete to fill the form. To compensate for this effect, the teeth on the gauge were cut to 16-1/2 inches.[128] However, despite these procedures and findings, subsequent core sampling found that some sections varied, both thicker and thinner, from the specified thickness.[129]

ADDITIONAL DEBRIS CONTAINMENT

Failure to accomplish Runit debris cleanup earlier in the project began to adversely impact capping operations in August 1979. The USAE had been conducting what they believed to be the final sweeps to remove the last of the debris from the ocean reef of Runit near the Lacrosse Crater. Though this debris had been examined several months previously and found to be "yellow" (disposable by lagoon dumping), after it was removed from the water and allowed to dry, FRST screening disclosed that some of the debris was actually "red" (contaminated, requiring crater containment). It was the consensus of the USAE and the JTG that this small quantity of debris could be accommodated in the dome, despite the fact that capping operations were proceeding rapidly. Depressions were to be made in the surface of the mound to serve as dikes in which debris was to be placed and surrounded with concrete.[130] Properly executed, this would comply with the POD design. In some cases, however, debris was placed inside the cap section forms in such a manner as to extend above the surrounding soil level. Then, the concrete was placed in the cap section. Consequently, several cap sections contain pieces of contaminated metallic debris embedded in the concrete, with the result that less than 18 inches of concrete cover the debris. Inasmuch as the debris was placed in the bottom of the cap sections, it was concluded that spalling would be highly improbable. Also, since the dome was designed to contain the material and prevent erosion rather than act as a radiation shield, completely surrounding and encapsulating the material in concrete appeared to be in conformance with the intent and integrity of the structure. These

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conclusions were later validated by an on-site inspection by representatives of the Army Chief of Engineers, who concluded that the placement of metallic debris in some cap sections was "not detrimental to the adequacy of the concrete dome cap to provide the erosion protection intended."[131] Approximately 30-40 cubic yards of debris were contained in this manner, in and under the cap sections.

As the USAE mobilized more of its forces to complete policing of the debris on the ocean reef, the seasonal recession of the beaches revealed more and more debris, much of it proving to be red when monitored by the FRST. It was concluded from aerial and surface reconnaissance that far more red debris was being found than could be accommodated in the dome.[132,133] It was at this point that Field Command and HQ DNA first heard that red debris was actually going into the cap sections. The CJTG was directed to cease all such debris encapsulation in the cap sections. He was advised that further guidance would be provided on the method to be used for disposal.

POD was consulted and sent a representative to the atoll to study the problem. After on-site conferences with the JTG and USAE, a proposal was made to add a small extension to the containment facility on the island side (Figure 8-50).[134] This antechamber was to be constructed adjacent to the keywall with the same design specifications as the existing facility. The contaminated debris would be placed in the antechamber and choked with clean concrete slurry. An 18-inch cap would be placed on the chamber as in the dome cap construction.

The 7 September 1979 Field Command proposal to DNA was approved for execution on 17 September 1979, and the JTG tasked the USAE to construct the antechamber. Work began on 19 September on a 20-by-60-foot addition at the keywall (Figure 8-51). Aside from problems related to the water table, the work was completed without mishap. Complete sweeps of Runit and its reefs yielded approximately 120 cubic yards of contaminated debris, which were disposed of in the extension before it was sealed and capped.[135]

As the winter equinox approached, the beaches continued to recede. Two months after all capping operations were completed, more debris was exposed which, based on percentages in the previous Runit discoveries, could be expected to contain a substantial amount of contaminated material. The first indications were passed to Field Command by the JTG on 17 November 1979 in a report on seven pieces of red debris.[136] The CJTG recommended several alternative methods of disposal and requested disposition instructions. While awaiting disposition instructions, the stockpile of red debris continued to grow. By 1 December, about 4 cubic yards had accumulated. After considering proposals to seal the debris in drums and ship them to Johnston Island, leave them in place, or place

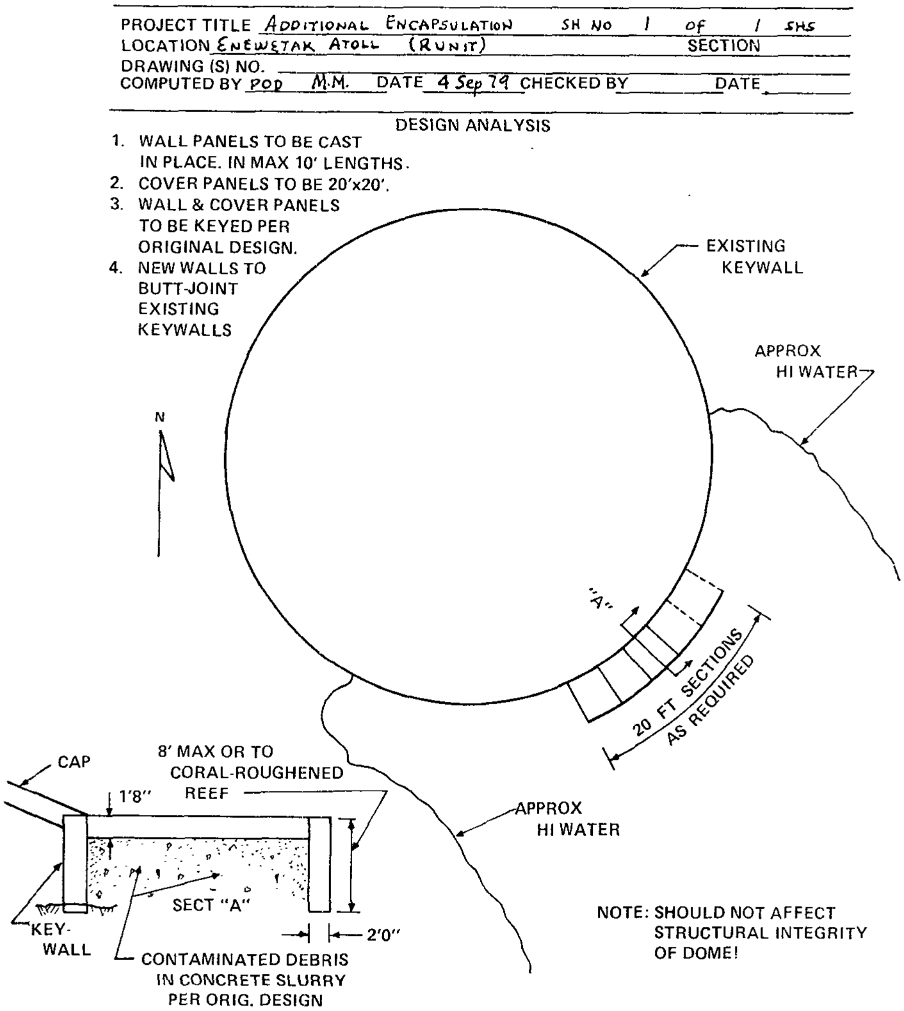

FIGURE 8-50. DESIGN FOR ANTECHAMBER.

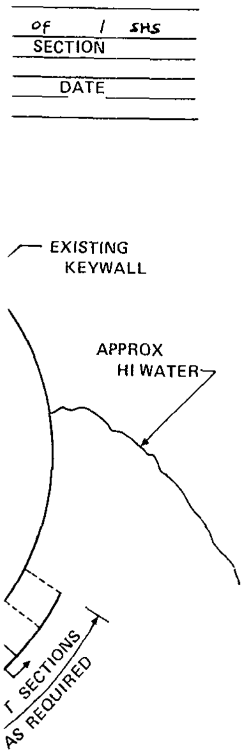

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FIGURE 8-51. CACTUS CRATER EXTENSION.

them in concrete bunkers,[137] Field Command established a disposal policy for any additional red debris on 17 December 1979.[138] Red debris was to be encapsulated in another section to be added to the lagoon side of the Cactus Crater extension. The new section would be designed to hold all red debris on hand and any additional debris that might appear through March 1980, and would be capped with an 18-inch concrete cover. Red debris would be collected and stockpiled until mid-February, at which time the USAE would construct the container and encapsulate the debris on hand. Space would be left unfilled to allow for encapsulation of any debris discovered after military forces were drawn down in February. At the end of March, just prior to project completion, the base support contractor would encapsulate any debris on hand and cap the new annex, conforming with the design and aesthetics of the previous extension. The second extension was constructed in February 1980 and consisted of approximately 13 cubic yards of space. Approximately 4 cubic yards of red debris were enclosed and slurried in place. On 31 March 1980, H&N returned to Runit, encapsulated an additional cubic yard of debris which had been collected in the interim, and capped the facility (Figure 8-52).

FIGURE 8-52. SECOND EXTENSION, CACTUS CRATER STRUCTURE.

EXCESS ATTAPULGITE DISPOSAL

As the container cap was being completed, another disposal problem became critical. Only 38 percent of the attapulgite anticipated in the design was used. This resulted in the need to dispose of over 14,000 bags which remained on the atoll. After several months of seeking local solutions, the JTG reported the excess in June 1979.[139]

Attempts were made to find other government agencies with a requirement for the attapulgite. One was located in Louisiana; however, it was determined that the cost of repackaging the bags, which had deteriorated badly at Enewetak, and shipping them to New Orleans would exceed the cost of new attapulgite. Other disposal methods, such as lagoon dumping or spreading it on the Fig-Quince area of Runit, were rejected on environmental grounds. On 13 September 1979, the JTG was authorized to seal the excess attapulgite in existing concrete bunkers on Runit. The bunkers were marked to identify permanently the material they contained.[140]

QUALITY CONTROL AND RESULTS

If there was an evident shortcoming in the construction portion of the project, it was in the quality control standards and procedures for the Cactus Crater container. Some areas of quality control were well executed. For example, directions and procedures for insuring that compression tests for concrete used in the keywall and dome were adequate, and the tests were documented. A total of 576 concrete cylinders were tested. The tests averaged 5,354 pounds psi with a high of 8,401 psi and a low of 3,298 psi, indicating a quality of concrete far exceeding the 3,000 psi design requirement. Penetrometer tests of the soil-cement reflected a bearing strength consistently in excess of the required 300 psi. On the other hand, no single individual was tasked with overall responsibility for assuring total compliance with the design specifications and adherence to the construction schedule or sequence, or for providing continuity, guidance, and supervision throughout the keywall and dome construction. DNA was designated, as the DOD Project Manager, to be the design and construction agent to supervise the execution of the project,[141] a task which normally would have fallen to the Corps of Engineers on a military construction project. In delegating responsibilities to Field Command, DNA was specific in the guidance for coordinating the preparations of plans and conducting the cleanup and assuring timely and adequate logistical support services.[142] However, there was no clear-cut delegation of the responsibility for providing professional civil engineer continuity, guidance, and expertise. Some at Field Command believed that DNA had retained this overseer responsibility. Others felt that it would be exercised through the establishment of the JTG, with its engineering section, and the designation of an engineer officer to be the JTG commander. Consequently, formal procedures for exercising this technical civil engineering responsibility were not institutionalized. When specialized technical expertise was required, the JTG generally would request assistance from POD.

As tremie operations were being completed in February 1979, HQ DNA tasked Field Command to establish a quality control program for concrete and soil-cement in order to assure the durability of the containment structure for a long period of time.[143] The CJTG reported that a concrete quality control program had been implemented in October 1978, and that concrete cylinders were being tested.[144]

In the concrete quality control program, the need to establish a system of controls during the tremie phase was not adequately highlighted. As related earlier, some oversize material and debris were pushed by bulldozer into the edge of the crater. Diver checks could not insure that these materials were fully encapsulated in slurry or that a monolithic mass resulted. Later, during soil-cement operations, contaminated soil and debris were placed in the Donut Hole without being recorded in daily inspection logs. Consequently, while indications are that the materials were encapsulated in slurry, there are no records that the procedures were checked or that managers were assured that the integrity of the containment process was being maintained.

An investigation by the Army Chief of Engineers after the dome was completed indicated that there were some deviations from the POD design and some construction deficiencies. However, according to the investigation conclusions, they did not affect the adequacy, durability, or use of the facility, and the structure was sufficiently stable to achieve the design intent.[145]

A subsequent, more thorough investigation by the National Academy of Sciences (NAS) was requested by the Director, DNA. Specifically, the NAS was asked to assess the effectiveness of the Cactus Crater structure in preventing harmful amounts of radioactivity from becoming available for internal or external human exposure and to recommend whether the assessment should be reviewed at intervals in the future.[146] Included within this assessment was an evaluation of the permanence of the structure and an assessment of the concentration of radioactive materials contained therein. In March 1980, a team from the NAS visited the atoll to conduct a series of tests to develop information with which to provide their assessment. These tests included the taking of core samples of the dome and keywall and coring in depth through the soil-cement and tremie fill of the crater and dome. Preliminary review of the core samples indicated that, while the concrete was of high quality, there were some keywall and tremie deficiencies which could affect the durability of the crater portion of the structure. On the other hand, there were no indications that the dome would not fulfill its intended purpose, and there was little reason to be concerned over the leakage of radiological materials which might result in internal or external human exposure.

FINAL QUARANTINE

Upon completion of the Runit cleanup, it was the consensus of all concerned (DNA, DOE, DOI and the Enewetak people) that Runit should remain quarantined indefinitely. There were no overt hazards, radiological or otherwise, that were known on the island or its adjoining reef, and there were no other cleanup actions that could be recommended responsibly. However, the possibility would always exist that high levels of plutonium-contaminated subsurface soil could be exposed by wave or storm action. The legal counsel for the Enewetak people, Mr. Ted

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Mitchell, stated it best on several occasions—that foregoing future use of Runit Island was the people's contribution to the cleanup. In the Enewetak Return Ceremony, described in Chapter 9, Iroij Johannes Peter stated that, henceforth, the people would consider the island of Runit to be "OFF-LIMITS." Thus, although it appears that the material in the storage container does not constitute a potential hazard and that surface levels of plutonium concentrations have been reduced to prescribed standards, plutonium concentrations exceeding DOE guidelines still exist at subsurface levels, and Runit should remain quarantined.