UNITED STATES COURT OF APPEALS FOR VETERANS CLAIMS

VICTOR B. SKAAR, *Appellant*,	)	
v.	)	No. 17-2574
ROBERT L. WILKIE, Acting Secretary of Veterans Affairs, *Appellee*.	)	

BRIEF OF *AMICUS CURIAE* FRIENDS OF THE EARTH IN SUPPORT OF APPELLANT, VICTOR B. SKAAR

Respectfully submitted,

DATED: April 13, 2018

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*Motions to appear under Rule 46(b)(1)(F) granted on 4/11/18.

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Identity and Interest of *Amicus Curiae*

Friends of the Earth (FoE) is a non-profit environmental organization that has worked since its formation in 1969 to educate the public about, and take actions to reduce, the environmental and public health threats posed by nuclear energy and nuclear weapons. FoE does so by providing expert testimony to federal and state legislatures and regulatory bodies regarding the licensing and operation of nuclear power plants and nuclear weapons facilities, and by pursuing legal actions on radiation-related issues before federal courts and agencies. On the basis of its scientific expertise and decades of advocacy, FoE files this brief[1] in support of Appellant Skaar in order to contextualize for the Court the rules and practices currently applied by the Department of Veterans Affairs (VA) to the claims of veterans who were exposed to ionizing radiation during cleanup incidents. FoE believes that the VA's approach is inadequate because it both results in injustice for veterans and contributes to a misunderstanding and underestimation of the health risks associated with radiation exposure and nuclear activities.

Argument

The VA arbitrarily treats veterans who cleaned up sites like Palomares worse than other veterans and civilians who were exposed to less radiation, even according to the VA's own dose estimates. Worse, those dose estimates are themselves arbitrary. They are the product of the VA repeatedly pre-determining a conclusion that will lead to claim denials, and then cherry-picking the data, twisting its analyses, and misrepresenting the

[1] FoE's Motion for Leave to File is being submitted concurrently with this brief.

truth in order to ensure the pre-ordained result. It is improper for claims to be adjudicated in this manner. Due to the VA's consistent mistreatment of veterans in this and similar cases, the VA deserves no deference here.

I. The VA's refusal to recognize Palomares and similar cleanups as "radiation-risk activities" under § 3.309 is arbitrary, capricious, and irrational.

A. The Palomares radiation doses recognized by the Air Force exceed the doses from other recognized "radiation-risk activities."

Since December 2013, the Air Force has based its responses to dose inquiries for Palomares responders on a two-part methodology. For the so-called "High 26" (including Appellant Skaar), it applies the intake estimates provided in the 2001 Labat-Anderson Report (L-A Report[2]), which range from 34,000 to 570,000 picocuries (pCi). R. 1581 According to the L-A Report (at p. 25), this range of intake estimates translates to committed effective dose (CED) equivalents ranging from 10 to 170 rem.[3] For responders outside the "High 26," the Air Force is instead setting an intake uncertainty range of 1,100 to 34,000 pCi, which it says corresponds to a CED range of 0.31 to 10.5 rem.[4] For the reasons discussed in Section II below, these numbers are unreliable and artificially suppressed. Even so, they are also markedly higher than the radiation doses received by other classes of veterans whose services are recognized as "radiation-risk activities."

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[2] The L-A Report was provided in Appellant Skaar's Brief as Skaar Attach. A (pp. A-003–140). Citations to L-A in this brief are to the pages of the L-A Report itself.
[3] These were the results of one of the two models used by L-A. The other resulted in estimates with larger upper bounds: 19,000–2,600,000 pCi and 1.3–180 rem (p. 25). The Air Force has not explained why it has selected one set of L-A results over the other.
[4] *See* R. 1581; AFMSA/SG3PB Memo (Jan. 27, 2014), p. 1 (Skaar Attach. E, p. A-168).

In May 2015, the Defense Threat Reduction Agency (DTRA) stated that, of the veterans who participated in the post-WWII occupation of Hiroshima and Nagasaki or were prisoners of war in those areas, "over 95 percent of them received radiation doses below 0.1 rem." Of personnel who participated in U.S. atmospheric nuclear tests between 1945–1962: "Over 99 percent of these participants received radiation doses that were below the current federal occupational whole body dose limit (5 rem per year); the average whole body dose was less than 0.6 rem." [5] All of these services are considered "radiation-risk activities" under §§ 3.309(d)(3)(ii)(A–C), such that military personnel who served during these operations enjoy the presumption of service connection.

Appellant Skaar's brief provides three examples of particular tests that are presumptively covered under §§ 3.309(d)(3)(v)(C, E, F). Operation Buster-Jangle was a series of tests conducted in Nevada in 1951; Operations Sandstone and Greenhouse were test events in the Enewetak Atoll, which occurred in 1948 and 1951, respectively.[6]

The following table summarizes the dose estimates for all the foregoing service activities. It demonstrates that Palomares veterans had significantly higher doses than others who have been found to have participated in a radiation-risk activity. The unjustified discrepancy between the VA's treatment of these "atomic veterans" and the Palomares veterans is arbitrary, capricious, and irrational.

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[5] DTRA, "Fact Sheet: Radiation Exposure in U.S. Atmospheric Nuclear Weapons Testing" (May 2015), p. 1 (Skaar Attach. C, p. A-146).
[6] Buster-Jangle Analysis (Dec. 1987), p. 98 (Skaar Attach. H, p. A-467); Sandstone Analysis (Aug. 1983), pp. 3, 39–40 (Skaar Attach. F, pp. A-180, A-216–17); Greenhouse Analysis (Jul. 1982), pp. 7, 113 (Skaar Attach. G, pp. A-237, A-343; *see also* p. A-230).

Activity	**Dose**	**"Radiation-Risk Activity"?**
Post-WWII occupation of Hiroshima and Nagasaki or POWs in those areas	Over 95% below 0.1 rem	Yes, § 3.309(d)(3)(ii)(B–C)
Onsite participation in U.S. atmospheric nuclear tests	Over 99% below 5 rem On average below 0.6 rem	Yes, § 3.309(d)(3)(ii)(A)
• Operation Buster-Jangle	• Upper bound: near 3 rem	• Yes, § 3.309(d)(3)(v)(F)
• Operation Sandstone	• Upper bound: 0.13 rem	• Yes, § 3.309(d)(3)(v)(C)
• Operation Greenhouse	• Upper bound: 3.10 rem	• Yes, § 3.309(d)(3)(v)(E)
Palomares responders • "High 26" • Non-"High 26"	 • 10–170 rem • Upper bound: 10.5 rem	**No**

It also bears noting that, although the veterans who were onsite during Operations Sandstone and Greenhouse enjoy the presumption of service connection, those who were sent to clean up the Enewetak Atoll from 1977–80 have, like the Palomares veterans, been refused the benefit of that presumption. *See* 67 Fed. Reg. 3612 (Jan. 25, 2002).

B. <u>The VA's refusal to recognize Palomares and similar cleanups as "radiation-risk activities" is inconsistent with its stated intention to "ensure equity" between veterans and similarly situated civilians.</u>

In 2002, the Secretary exercised his authority to expand the category of "radiation-risk activities" to include veterans who worked at certain gaseous diffusion plants or on Amchitka Island, Alaska during certain underground nuclear tests. § 3.309(d)(3)(ii)(D). This was done "to ensure equity between veterans who may have been exposed to radiation during military service and civilians exposed to ionizing radiation under comparable Federal statutes," in particular the Energy Employees Occupational Illness Compensation Program Act of 2000 (EEOICPA), and to ensure that such veterans "do not have a higher burden of proof" than similarly situated civilians. 67 Fed. Reg. 3612 (Jan. 25, 2002). EEOICPA creates a "Special Exposure Cohort" of Department of Energy (DOE) employees for whom dose reconstruction is not required because it is infeasible, and which shifts the burden of proof to the Government. In 2004, the VA further expanded the category of recognized "radiation-risk activities" to include "[s]ervice in a capacity which, if performed as an employee of the [DOE], would qualify for inclusion as a member of [EEOICPA's] Special Exposure Cohort." 38 C.F.R. § 3.309(d)(3)(ii)(E).

In 2012, DOE employees who worked at the Savannah River Site in Aiken, South Carolina, were added to the Special Exposure Cohort. 77 Fed. Reg. 9250 (Feb. 16, 2012). This includes the DOE personnel who buried the 4,827 55-gallon drums of contaminated soil and vegetation removed from Palomares.[7] Thus, the DOE personnel who dealt with storing the barrels of plutonium-laden debris from Palomares once they reached the U.S. enjoy the presumptions of the Special Exposure Cohort, while the military personnel who shoveled and breathed it in without meaningful protection[8] do not. This result fails to "ensure equity" between veterans and similarly situated DOE employees. It saddles Palomares veterans with "a higher burden of proof" than the civilians who came into contact with the same contaminated material but suffered less exposure. Such disparate treatment is arbitrary, capricious, and irrational.

II. <u>The VA's methodology for handling Palomares claims under § 3.311 is arbitrary and unscientific, and it fails to properly account for uncertainty.</u>

As noted above, in 2013, the Air Force adopted a dose estimate methodology for Palomares that is at least partially built on the intake estimates L-A prepared from urine

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[7] Report on Savannah River Plant (Jun. 1976), pp. 24–27 (pp. FoE-30–33). They also disposed of 555 containers of plutonium-contaminated debris removed from the Thule crash site in Greenland, *id.*, whereas the veterans who cleaned it up are denied coverage.
[8] *See*, *e.g.*, von Hippel, pp. 1–3, 15 (Skaar Attach. M, pp. A-518–520, A-15).

samples collected in 1966–68. In particular, members of the so-called "High 26" would have their "established intake estimates" from the L-A Report applied, and the other 1,586 responders who provided samples would be assigned an uncertainty range capped at "the intake calculated for the least exposed member of the High 26 group" (*i.e.*, 34,000 pCi). R. 1580–81. There are at least three problems with this approach.

A. L-A repeatedly cautioned that its dose estimates based on bioassay data were preliminary and not reliable, credible, or meaningful.

L-A repeatedly stressed that "substantial numbers of samples lacked one or more important pieces of data" (p. 9; *see also* p. E-7). In particular, L-A's report highlights that its estimates were made with "limited information about the specific activities and times that the individuals were on the site," which relate to some of the "primary parameters for estimating the intake" (pp. 27, 29–30). The results of L-A's modeling "emphasize the sensitivity of estimated intake to the exposure date range," but much of the data on both Exposure Dates and Sampling Dates was "missing or incorrect," creating "substantial uncertainty" regarding these parameters and "hinder[ing L-A's ability to provide] a reasonable estimate of intake and radiation dose" (pp. D-30, E-4, B-15, D-27).[9]

Given the "numerous technical difficulties," L-A voiced "serious concerns about the reliability of estimates [derived] from the urinary bioassay data" (pp. E-2, 28). L-A ultimately concluded that the "quality of the data set limited the preparation of reasonable estimates" even for the so-called "High 26," and "cast doubt about whether reasonable

[9] Although most assignments were two weeks and some personnel "stayed much longer," L-A assumed a "single acute exposure" (p. E-13), which is not sensible.

estimates could be developed for all individuals" (pp. 24, E-9). Thus, even with regard to its dose estimates for the "High 26," L-A cautioned that, "[w]ithout further details and possible confirmation, permanent assignment of these intakes and doses to the individuals may be premature," and that "credible estimates of intake and dose will depend on an expensive, multi-phased approach" to collect additional information (pp. 28, 30). Regarding the 1,063 sampled veterans outside the "High 26" for whom no measurements were taken in late 1966 or 1967, L-A repeatedly stressed that "confirmation of possible exposures" through additional study was "very important" (p. 30).

Overall, L-A characterized its bioassay results as just "preliminary estimates of intake and dose" which are "useful only to indicate that many individual cases represent significant to very serious situations when compared to accepted guidelines for management of radiation exposures" (p. 28). It said the urine results were "inadequate by themselves to support meaningful intake and dose evaluations without confirmatory studies, such as analysis of urine samples now using very sensitive instrumentation, detailed review of participant medical records, participant interviews, and comprehensive assessment based on sound environmental measurements" (pp. ES-2–3; *also* pp. 27–28).

In this context, the Air Force decision in December 2013 to adopt and apply L-A's preliminary dose estimates for the "High 26" and to claim that these were "established" or "scientifically-based" was clearly incorrect. *See* R. 1580–81. The Air Force ignored the unreliable nature of these estimates, arbitrarily relying on L-A's estimates while ignoring L-A's caveats regarding their reliability. The Air Force also told Congress that it did not intend to undertake any of the follow-up work that L-A had stressed would be necessary to reach "meaningful intake and dose evaluations" (p. ES-2) because that further work, "though technically feasible, is not expected to confirm a correlation between health outcome and exposure *due to the low exposure levels*."[10] This is the definition of a circular argument. The key question is whether exposure levels were, in fact, as low as L-A's preliminary and unreliable estimates indicated. The Air Force also told Congress that it "believe[s] existing biomonitoring information is sufficient to reconstruct doses and establish an acceptable upper bound on possible exposures" and that "[t]his information can and should be used to provide the conservative (worst case) estimate of exposure for responders."[11] These claims flatly contradict L-A's warnings.

B. <u>The L-A Report is not "sound scientific evidence" that would withstand peer review as required under § 3.311, and its estimates do not establish the credible "upper bound" the Air Force claims.</u>

There are numerous problems with the L-A Report, many of which are explained in the critique prepared by Dr. von Hippel.[12] For present purposes, the most important methodological flaw in the L-A Report is its downward manipulation of the data set, which had the predictable effect of reducing "several fold"[13] L-A's estimated exposures as compared to the true "upper-bound" and uncertainty indicated by the full data set. L-A skewed the data in two ways to reach the "High 26" estimates the Air Force now applies.

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[10] HQ USAF/SG Memo (Dec. 6, 2013) (Skaar Attach. O, p. A-584) (emphasis added).
[11] Report with HQ USAF/SG Memo (Dec. 6, 2013), p. 2 (Skaar Attach. O, p. A-586).
[12] Palomares Report by F. von Hippel (Dec. 7, 2017) (Skaar Attach. M, p. A-517–533).
[13] von Hippel, p. 14 (Skaar Attach. M, p. A-531).

First, L-A excluded *all* the "gross alpha" results (nearly 20% of the available samples), which were from the early samples collected on site (pp. 25, E-14, E-22). The basis for this exclusion was that "[g]ross alpha results from samples collected on site produced intake estimates and doses that seemed unreasonably high" compared to the results of environmental monitoring "around Palomares for over 15 years following the accident" (pp. 9, 27). L-A does not even try to justify its conclusion that air quality measurements collected 0.5–1 km away from the bomb impact sites in 1967, a year after cleanup operations were already over, reflect the exposures sustained by the U.S. military personnel who L-A concedes (p. E-13) were exposed to radiation at the time of the cleanup. The entire purpose of the response effort was to address the "dust and debris contaminated with plutonium" (p. 1). Later air quality monitoring would necessarily be less representative of the exposures faced by Palomares veterans than the contemporaneous gross alpha results from samples taken on site before the cleanup lowered ambient concentrations.[14]

Second, L-A also excluded from its "High 26" analysis the remaining "data from the on-site samples" (including so-called "alpha spectrometry" samples collected on site) and attributed more significance to samples collected at later dates" (p. E-11). This was done because, otherwise, "the results [did] not correspond to the expected pattern very

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[14] Even the Board of Veterans' Appeals (BVA) recognizes that L-A's "environmental" estimates were "inaccurate." *See* R.10. But the VA applied these inaccurate estimates derived from irrelevant environmental data from 2001 until Dec. 2013. This approach was certainly arbitrary and may have been a willful attempt to mislead.

well at all," raising "serious concerns about estimates of intake that would be derived from the data" (pp E-20, E-10). The biological model used by L-A thus "failed its only available test," which should have raised concerns about the model's validity.[15] L-A acknowledges that one response to this problem would have been to try "other, or better, models," but it instead assumed that the earlier (inconveniently higher) samples were less reliable because the technology was new and developing (p. E-10).

These and other choices[16] significantly reduced the resulting dose estimates. They reflect a clear bias toward lower doses, apparently based on the arbitrary assumption that samples indicating high levels of exposure must have been contaminated.[17] As L-A notes, the initial phase on site involved "less than ideal conditions," including "strong winds" which "frequently spread [plutonium-laden] dust over the base camp," which "could have contaminated the sample containers and samples themselves" (pp. B-13, E-5). However, this same "blowing dust containing plutonium" (p. B-13) is one of the recognized sources

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[15] von Hippel, pp. 2, 12–13, 15 (Skaar Attach. M, pp. A-519, A-529–30, A-532).

[16] For the 54 veterans in the "Repeat Analysis" group, L-A again excluded "gross alpha" results for samples collected on site, *except* those reported as "NDA" (non-detects) which L-A assigned a value of 0.009 pCi/d (pp. 26, E-26). L-A also excluded "some" alpha spectrometry results when they did not fit the model (p. 26). For 30 of the 313 veterans in the "Contamination Cutoff" group who submitted more than one sample, L-A used only "[t]he lowest results for any individual" (p. E-29).

[17] It is no wonder that the L-A Report confirms the military's conclusions from the 1960s after the military also arbitrarily "threw out about 1,000 samples—67 percent of the results—including all samples from the first days after the blasts when exposure was probably highest," even though the officer in charge now admits that he "had no way of knowing what was from contamination and what was from inhalation." D. Philipps, "Decades Later, Sickness Among Airmen After a Hydrogen Bomb Accident," *N.Y. Times* (Jun. 19, 2016) (Skaar Attach. D, p. A-159).

of possible plutonium exposure faced by Palomares responders (*see* p. 10). It is therefore likely that the "possibly contaminated samples," which L-A excluded from the dose estimates for the "High 26," were in fact samples that correctly reflected high levels of exposure to personnel working in these windy conditions.

It was improper for L-A to exclude large quantities of data reflecting high exposure levels rather than using such data to provide uncertainty ranges. Given the admitted uncertainties regarding both the data and the model used, it is shocking that the L-A Report provides its estimates as individual values rather than uncertainty ranges, which would necessarily have included higher upper bounds than the intake estimates obtained by L-A through the arbitrary exclusion of high measurements. The Air Force now hides behind this façade of scientific exactitude for the "High 26," using their supposedly "established intake estimates" from one of the two models used in the L-A Report. This misleading false precision is a major flaw, particularly since the VA must rely on "sound scientific evidence" and presume "exposure at the highest level of the dose range reported," to the benefit of the veteran. §§ 3.311(c)(2)(ii), 3.11(a)(1).[18]

C. The assumption that *none* of the 1,430 veterans who were not included in the "High 26" were exposed to higher doses than the 26 is unsupported.

Again, the Air Force's current methodology states that any veteran who was not a member of the "High 26" will be assigned an "intake range" of 1,100–34,000 pCi. R.

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[18] Because it is premised on the unjustified assumption that "the radiation dose to which Mr. Skaar was exposed" is certain, rather than artificially reduced and substantially uncertain, the BVA's denial of Mr. Skaar's claim (R. 10–11) is also fatally flawed.

1581. The upper bound of the range is key, as the Air Force must apply it. The problem is that the upper-bound intake of 34,000 pCi actually being applied by the VA is:

- 3 times lower than the highest exposure (110,000 pCi) L-A estimated for the "Contamination Cutoff" group even after the arbitrary inclusion of only the lowest of multiple measures (*see* pp. 27, E-29);
- 38 times lower than the highest exposure (1,300,000 pCi) L-A estimated for the "Report Analysis" group even after all early high measures were improperly excluded (*see* pp. 26, E-26); and
- Between 2 and 600 times lower than *every single one* of L-A's cursory estimates for the 1,063 veterans in the "Remaining Cases" group, which ranged from 75,000 to 20,000,000 pCi (*see* pp. 27, E-33, E-34).

Thus, contrary to the Air Force's repeated claims, "[t]here is nothing conservative about t[he] range" currently being applied to non-"High 26" Palomares personnel.[19]

The Air Force's only justifications for its abandonment of L-A's already-biased estimates for the great majority (over 98%) of the Palomares veterans is that the "High 26" were unquestionably the "highest exposed 26 individuals," such that *none* of the 1,430 veterans who did not receive follow-up monitoring as part of the "High 26" could have received greater doses.[20] The faux certainty implied in these claims is not supported by the L-A Report, which not only calculated higher estimates for many of these responders, but also stressed the need for additional information, follow-up sampling, and reevaluation especially for the many veterans in the "Remaining Cases" group (*see* p. E-

[19] von Hippel, p. 9 n. 30 (Skaar Attach. M, p. A-526).
[20] *See* AFMSA/SG3PB Memo (Jan. 27, 2014), p. 1 (Skaar Attach. E, p. A-168).

34). None of this was done; the Air Force simply determined in 2001 that the collection of additional information "was not necessary,"[21] despite L-A's warnings.

The Air Force's assumptions are a relic of the 1960s, when military personnel labeled those 26 veterans "the 'High 26' although their dose estimates were not, in fact, high compared to dose estimates based on the available data for the other 1,560 veterans."[22] It was the short-lived Plutonium Deposition Registry Board—established in 1966 to oversee exposure assessment and biological monitoring Palomares veterans—that concluded that the "High 26" represented "the highest exposure cohort."[23] However, Col. Odland, who was in charge of the Board and was instrumental in the characterization of the "High 26," has stated that he "never got accurate results from hundreds of men who may have been contaminated," and that he later realized "plutonium lodged in the lungs could not always be detected in veterans' urine," such that "men with clean samples might still be contaminated."[24] In April 1967, he reported that he was "not able to get the support of the Department of Defense to go after [about 50 potentially exposed veterans to collect samples] or set up a real registry because of the Sleeping-dog policy."[25] Col. Odland has since said: "The sleeping dog policy? It was to leave it alone.

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[21] Report with HQ USAF/SG Memo (Dec. 6, 2013), p. 2 (Skaar Attach. O, p. A-586).
[22] von Hippel, p. 13 (Skaar Attach. M, p. A-530). The BVA's finding that the "High 26," including Mr. Skaar, "had the greatest plutonium body burden out of all personnel who submitted samples," R. 6, is clearly erroneous because it ignores most of the samples.
[23] Report with HQ USAF/SG Memo (Dec. 6, 2013) (Skaar Attach. O, p. A-585).
[24] Philipps (2016) (Skaar Attach. D, p. A-159).
[25] Notes on Phone Convo. with Col. Odland (Apr. 5, 1967) (Skaar Attach. L, p. A-516).

Let it lie. I didn't agree. … Everyone decided we should watch these guys, take care of them. And then from somewhere up high they decided it was better to get rid of it."[26]

III. <u>The VA's behavior regarding Palomares and similar nuclear incidents should limit the deference the Court might normally grant to the agency.</u>

In addition to the problems discussed above, Palomares veterans have been mistreated by a system that purposefully did not notify them of their radiation exposure or add testing details to their medical records.[27] The VA continues to claim, incorrectly, that protection and dose monitoring were robust, in what may be an attempt to dissuade veterans from filing claims.[28] Palomares is unfortunately not the only example of a nuclear cleanup operation in which the military has behaved this way.

Regarding the cleanup of a similar crash in Thule, Greenland, in 1968, the Air Force again denies that veterans suffered any harm, based on claims of top-notch protection and another report prepared by L-A in 2001, which assigns them a dose of zero. However, a lawsuit filed by some of these veterans—all of whom have since died of cancer[29]—indicates that protection and monitoring were not as foolproof as the military claims and that, although it learned in the 1980s that Thule responders faced increased risk of certain cancers, the military failed to notify, warn, or test veterans accordingly.[30]

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[26] Philipps (2016) (Skaar Attach. D, p. A-160).
[27] *See* Report on Plutonium Deposition Registry Board's First Annual Meeting (26–28 Oct. 1966), pp. 20–21 (pp. FoE-71–72). Mr. Skaar experienced the results firsthand: he spent two decades trying to obtain his own medical records through FOIA requests after the VA initially told him it had "no record of [his] exposure." *See* R. 18–24.
[28] *See* VA's website entry regarding Palomares (Skaar Attach. B, p. A-142).
[29] Philipps (2016) (Skaar Attach. D, p. A-154).
[30] *See Maas v. United States*, 94 F.3d 291 (7th Cir. 1996).

Veterans who cleaned up the Enewetak Atoll from 1977–80 are also denied benefits based on the military's claims that safety precautions were excellent and reliable measurements of radiation exposure indicate only safe levels. Contemporaneous documents and interviews with veterans again reveal that protection and monitoring were inadequate, exposure data was manipulated and misrepresented, and veterans cannot access their records even through FOIA requests.[31]

In each of these cases, the VA has assumed its preferred "no problem" conclusion and then worked to ensure that any evidence and analyses support this predetermined result. This is not just shoddy science. It is an abdication of the VA's obligation to fairly apply its expertise to these important questions. As a result of this abdication, the VA has forfeited the deference that courts traditionally give to agencies in their areas of expertise.

Conclusion

Col. Odland's position is now: "It's sad, sure, it's sad. But what can you do? You can't take the plutonium out; you can't cure the cancer. All you can do is bow your head and say you are sorry."[32] This, of course, is not true. The VA could also correct its approach going forward by recognizing Palomares as a "radiation-risk activity" akin to those listed in § 3.309, or at least by applying a defensible methodology in adjudicating Palomares claims under § 3.311. For all the reasons discussed above, the VA's failure to do either should be rejected by this Court.

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[31] *See* D. Philipps, "Troops Who Cleaned Up Radioactive Islands Can't Get Medical Care," *N.Y. Times* (Jan. 28, 2017) (FoE-78–85), especially highlighted portions.
[32] Philipps (2016) (Skaar Attach. D, p. A-160).

Appendix

FoE Attachment 1

Horton & Corey, "Storing Solid Radioactive Wastes at the Savannah River Plant" (Jun. 1976), with relevant portions appearing at pp. 24, 26–27

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STORING SOLID RADIOACTIVE WASTES AT THE SAVANNAH RIVER PLANT

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J. H. HORTON
J. C. COREY

SAVANNAH RIVER LABORATORY
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STORING SOLID RADIOACTIVE WASTES AT THE SAVANNAH RIVER PLANT

by

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STORING RADIOACTIVE WASTES AT THE SAVANNAH RIVER PLANT

INTRODUCTION

The Savannah River Plant (SRP) occupies an approximately circular site in South Carolina of about 192,000 acres bounded on the southwest by the Savannah River and centered approximately 25 miles southeast of Augusta, Ga. Solid radioactive waste has been stored at one location at SRP since 1953. This report discusses SRP solid radioactive waste storage site facilities, describes the procedures used to segregate and the methods used to store radioactive waste materials, and summarizes monitoring results obtained from studies of the potential transport of radionuclides from buried wastes at SRP.

FACILITY DESCRIPTION

One centrally located solid radioactive waste storage site (Figure 1) is used to store all solid radioactive waste presently produced on the plant, as well as occasional special ERDA shipments from offsite. The original site of 76 acres, with 8-foot-high woven wire security fencing and lying between Road E and the F-Area railroad, was filled in 1972, and operations have shifted to a 119-acre site across the railroad tracks. The new site is partially enclosed with a similar 8-foot fence, and the remainder is enclosed with a barbed wire fence.

The solid radioactive waste storage site has a paved road to its entrance and has many secondary roads inside the fence for access to burial sites. Three railroad spurs permit trains to bring in heavy process equipment. The equipment and manpower assigned to operate the facility are listed in Table 1.

The solid radioactive waste storage site is principally for the managed storage of solid radioactive wastes in underground trenches or on covered pads on the surface. Examples of the materials handled to date are:

- Contaminated equipment: obsolete or failed tanks, pipes, and other process equipment.

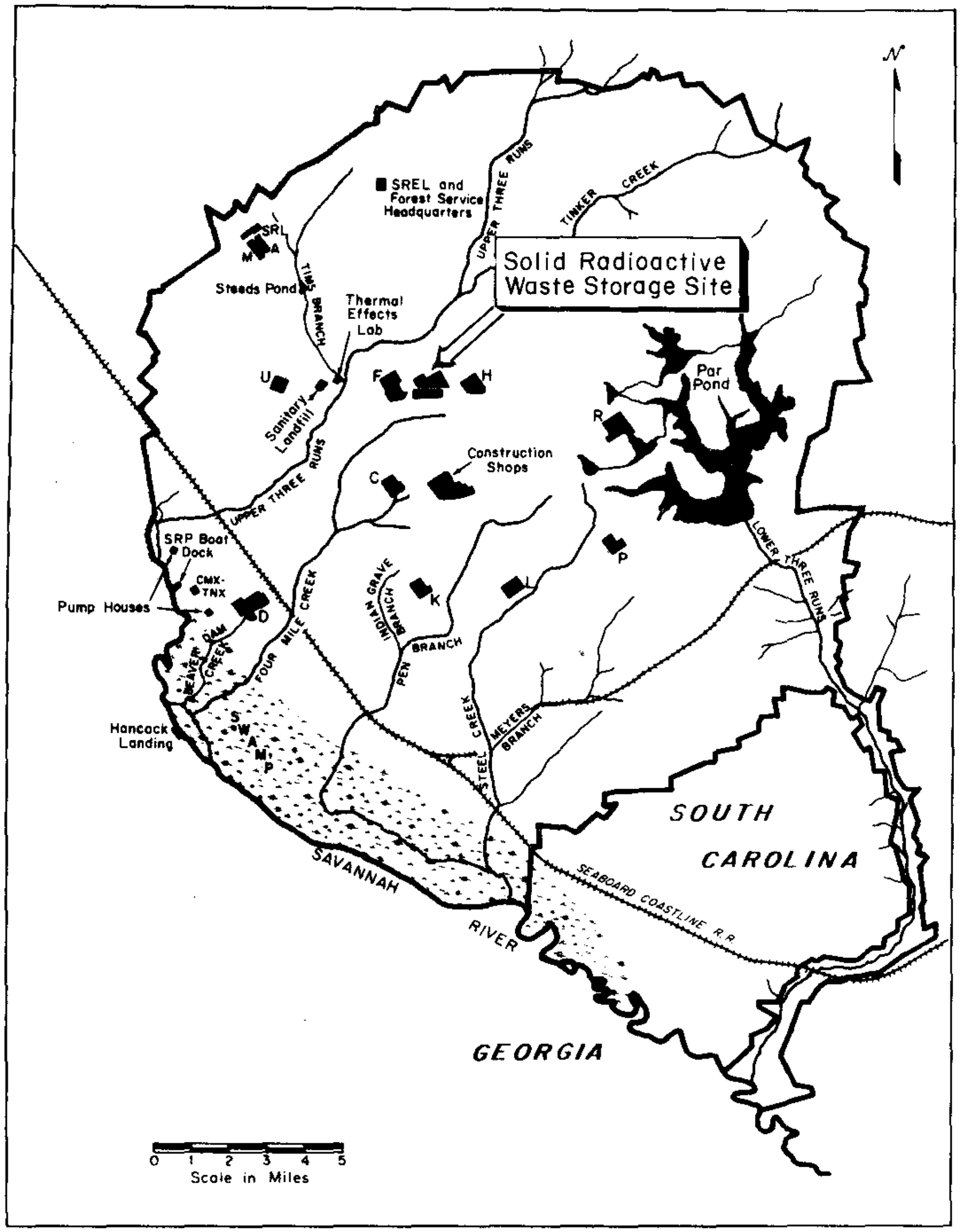


FIGURE 1. Solid Radioactive Waste Storage Site Location on SRP

TABLE 1

Solid Radioactive Waste Storage
Site Personnel and Equipment

Personnel	
1	Supervisor
1	Traffic and Transportation Foreman
1	Health Physics Inspector
1	Laborer
1	Heavy Equipment Operator
1	Crane Operator
2	Riggers
0.5	Dragline Operator

Equipment

Shielded Crawler Crane, with a 100-foot boom and a rating of 25 tons at 35 feet extension

3-ton Mobile Hydrocrane

Dragline

Crawler Crane with Bucket for backfilling transuranium alpha waste trenches

Bulldozer for backfilling trenches

Truck with Water Tank for firefighting and decontaminating recovered equipment

2 Pickup Trucks

1 Carryall Truck

25-ton Fork Lift

- Reactor and fuel hardware: fuel components and housings not containing fuel or products.

- Spent lithium-aluminum targets: the waste target alloy after tritium was extracted by melting the alloy.

- Oil from gas displacement pumps in the tritium facilities: prior to burial, the oil is placed in drums containing an absorbent material.

- Laboratory and operating waste: small equipment, clothes, analytical waste, decontamination residues, plastic sheeting, gloves, etc.

- Special shipments from offsite: tritiated waste from Mound Laboratory; ^{238}Pu process waste from Los Alamos Scientific Laboratory and Mound Laboratory; debris from 2 U.S. airplane accidents in foreign countries.

- Spent deionizer resins: from reactor use.

Several facilities and operations in the area are not directly related to the burial of solid waste. These include above-ground storage of process equipment that is to be returned to service (Figure 2), an organic solvent storage facility (Figure 3), a sandblasting facility for decontaminating equipment (Figure 4), and an equipment repair area (Figure 5). The solid radioactive waste storage site office and clothing change facilities are shown in Figure 6.

The solid radioactive waste storage site is divided into sections for transuranium alpha waste, low-level waste, and high-level waste (Figure 7).

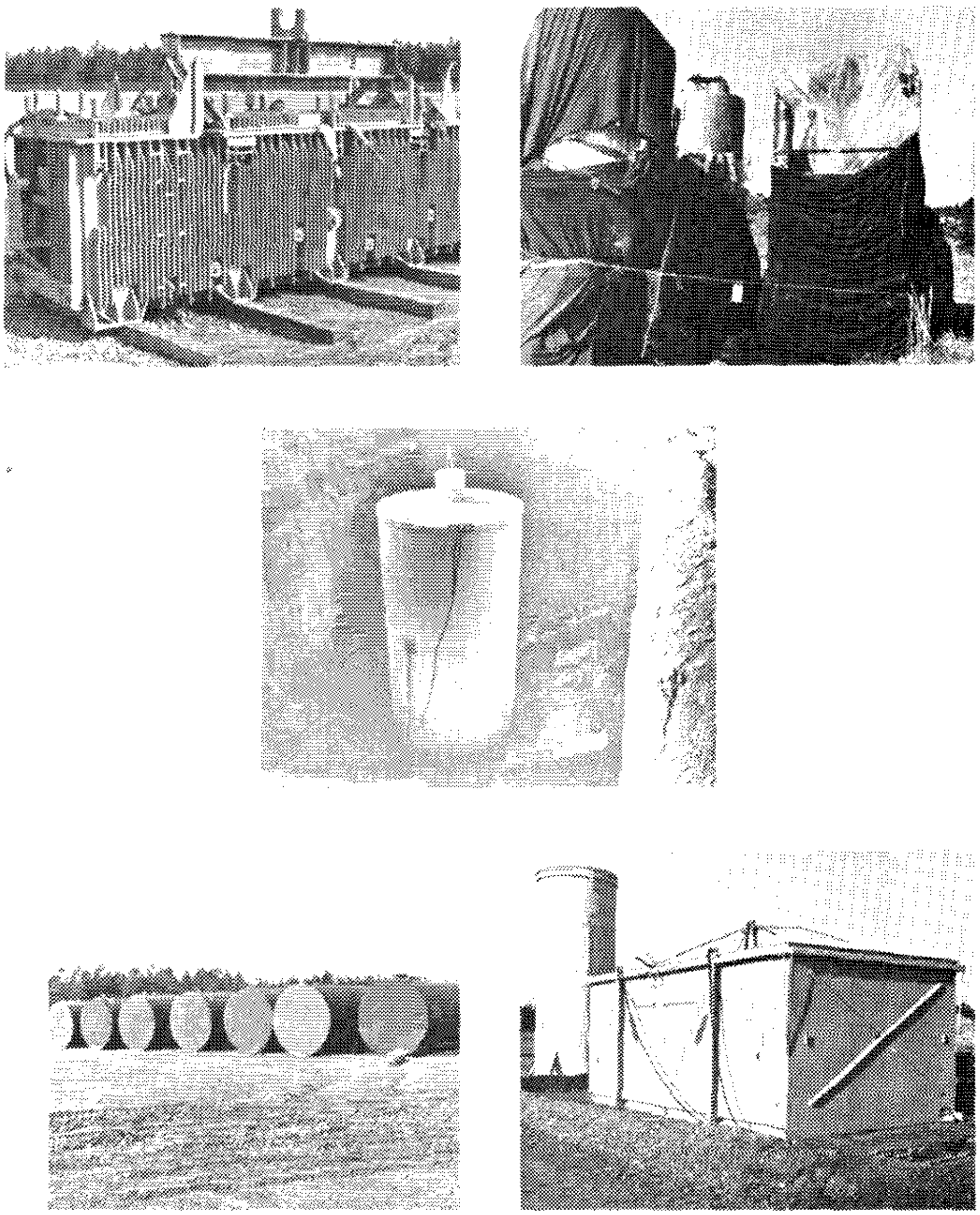
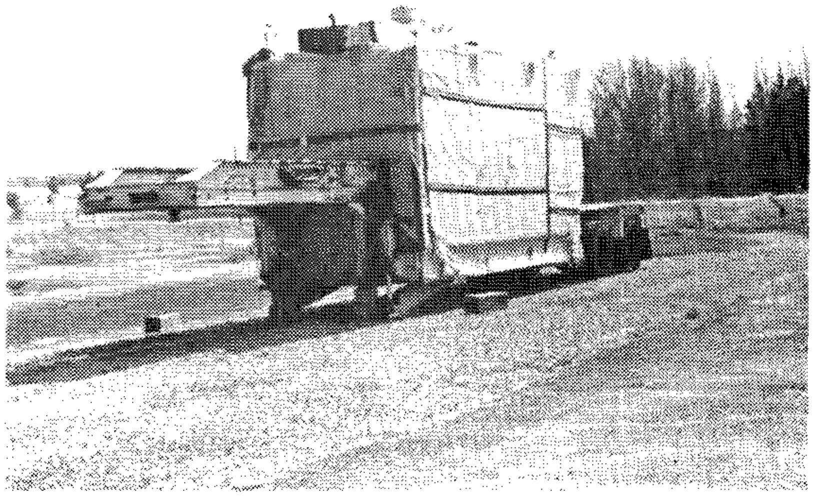
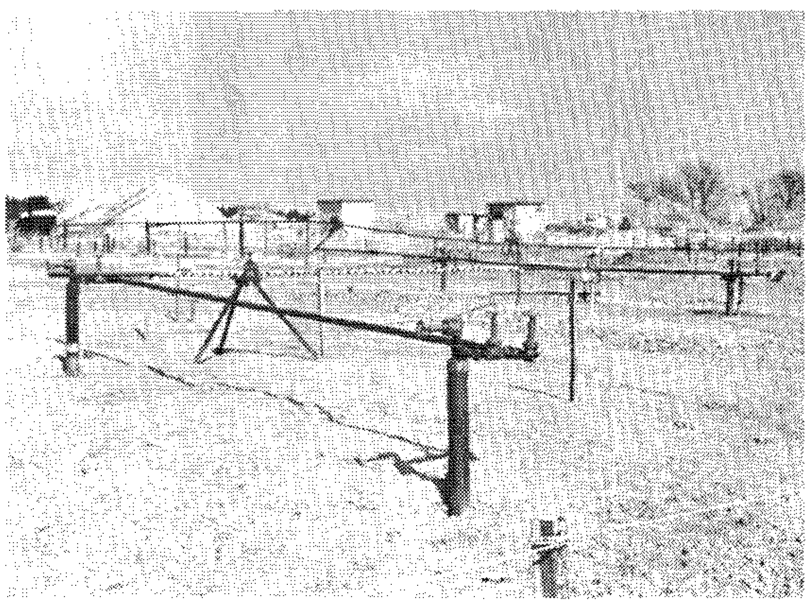


FIGURE 2. Above Ground and Bunker Storage

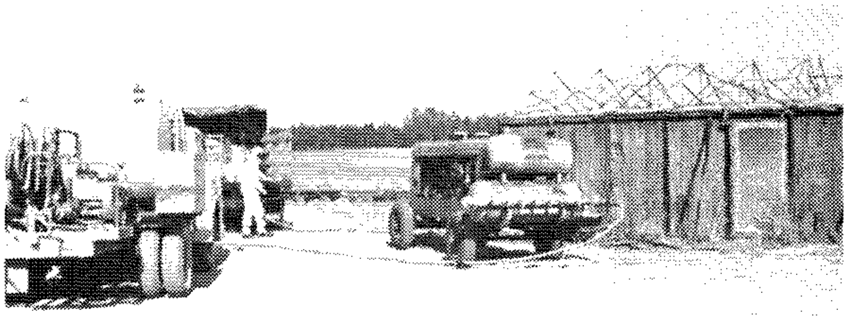


a. Solvent Trailer for Transporting Solvent from Separations Areas to Burial Ground

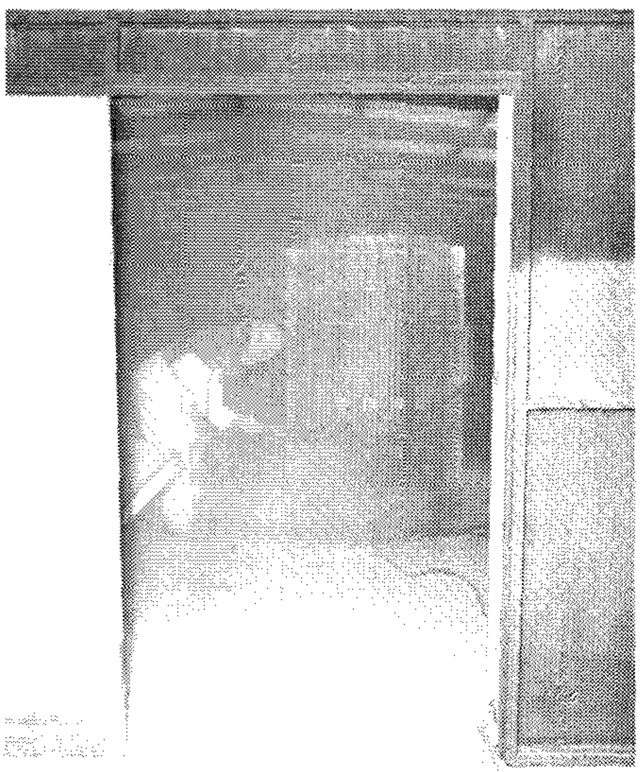


b. Underground Tank Storage Area

FIGURE 3. Solvent Storage Facility



a. Exterior View



b. Interior View

FIGURE 4. Sandblasting Facility

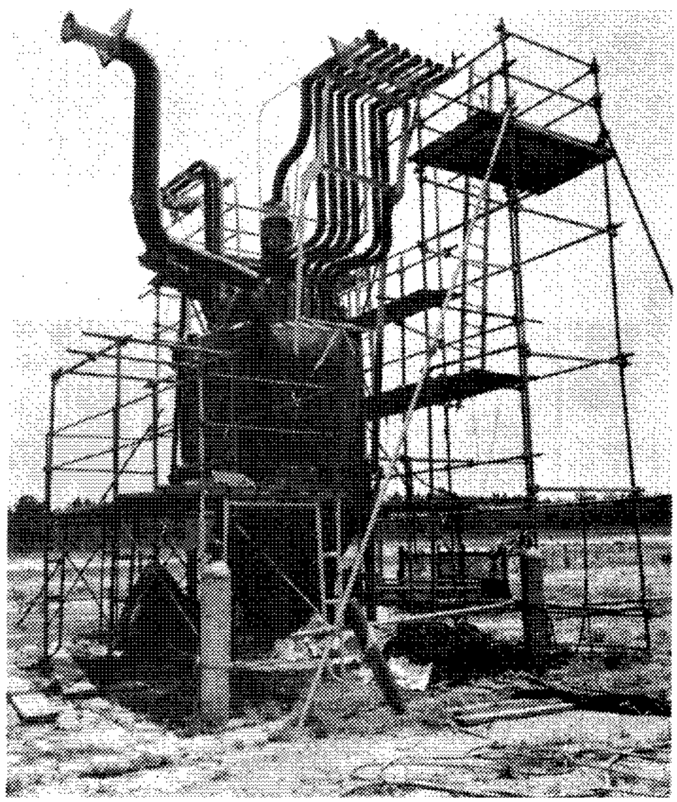


FIGURE 5. Equipment Repair Area

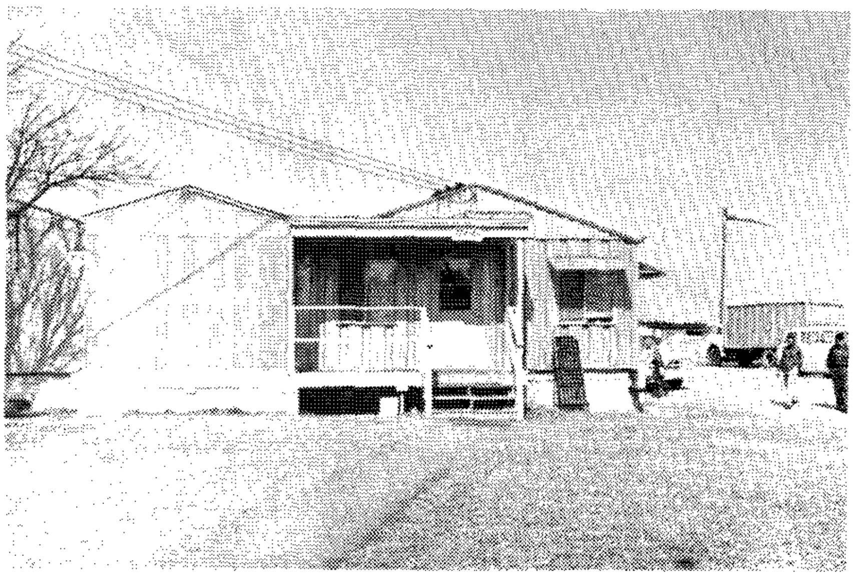


FIGURE 6. Building at Entrance to Solid Radioactive Waste Storage Site Containing Offices and Clothing Change Facilities

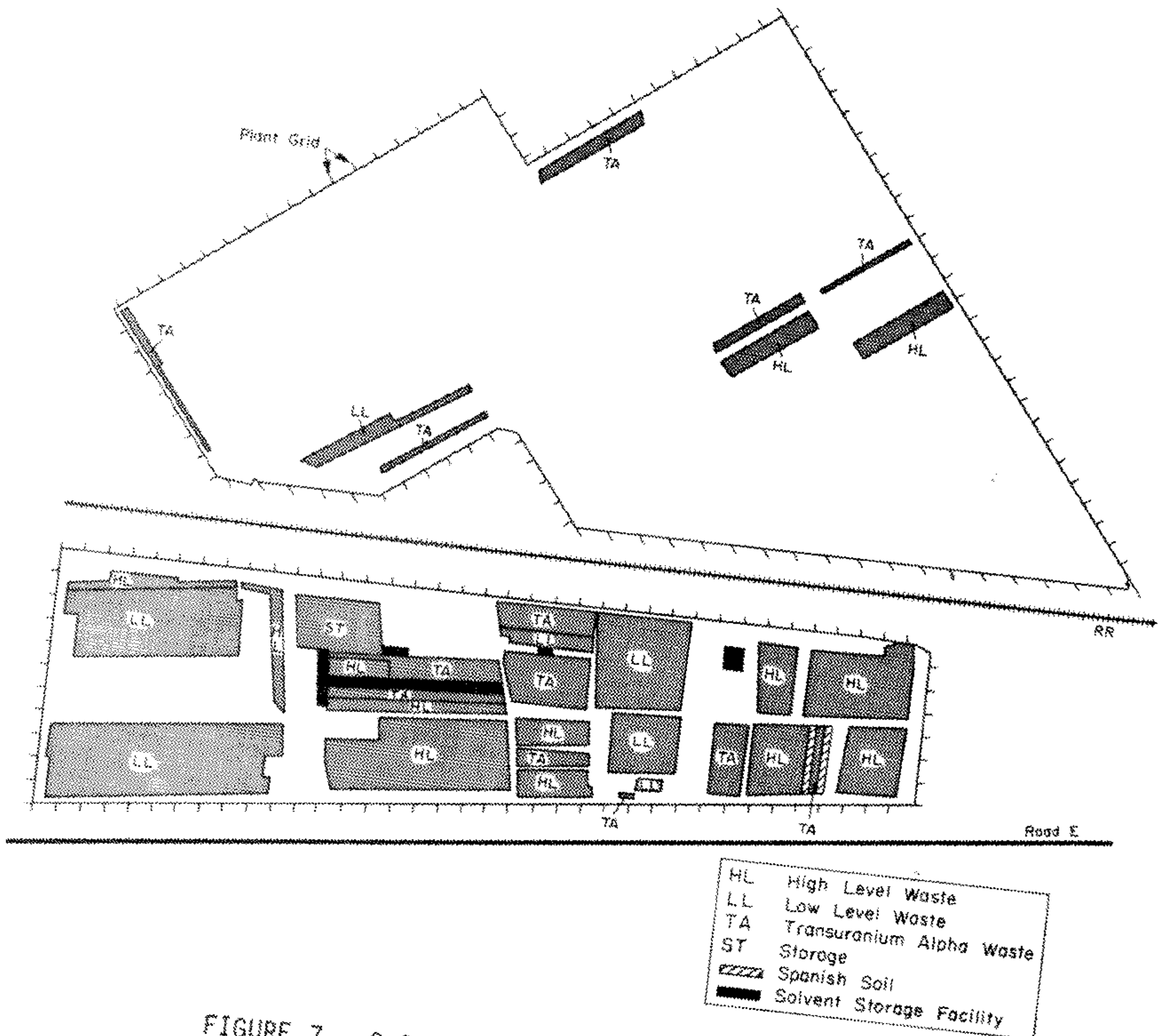


FIGURE 7. Solid Radioactive Waste Storage Site Map Showing Trenches and Grid Spacings

OPERATING PROCEDURES

Procedures and job plans are written prior to initiating storage of waste in order to achieve maximum protection from radiation and contamination to personnel and equipment. Coveralls, rubber shoe covers, gloves, eye protection, and hard hats are required for personnel assisting with waste handling operations (Figure 8). Only essential vehicles are permitted to enter the solid radioactive waste storage site. The vehicles are surveyed for contamination before leaving. A Health Physics inspector observes burial of high-level waste and makes routine surveys to determine ground surface or vegetation contamination.

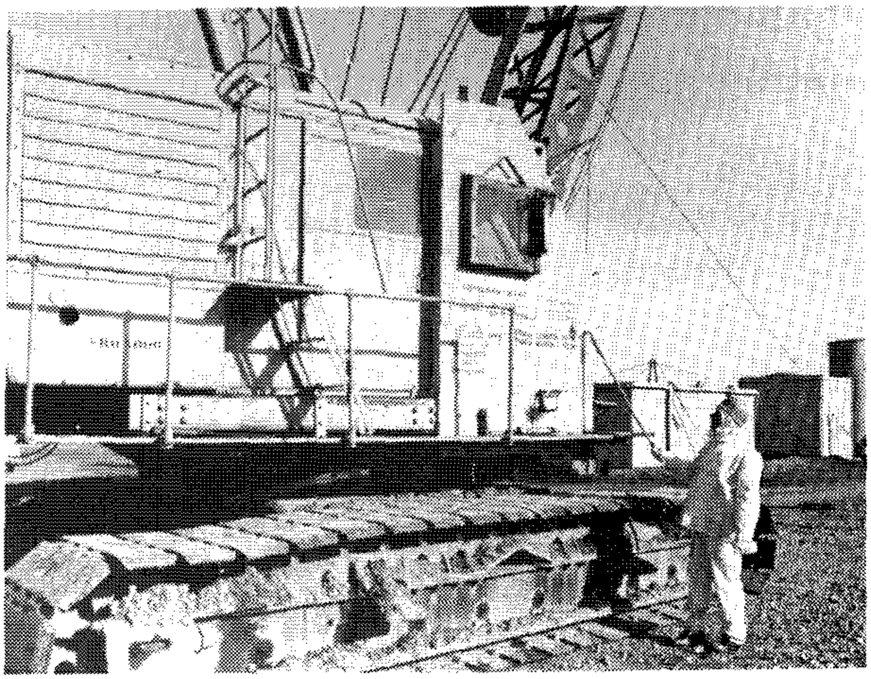
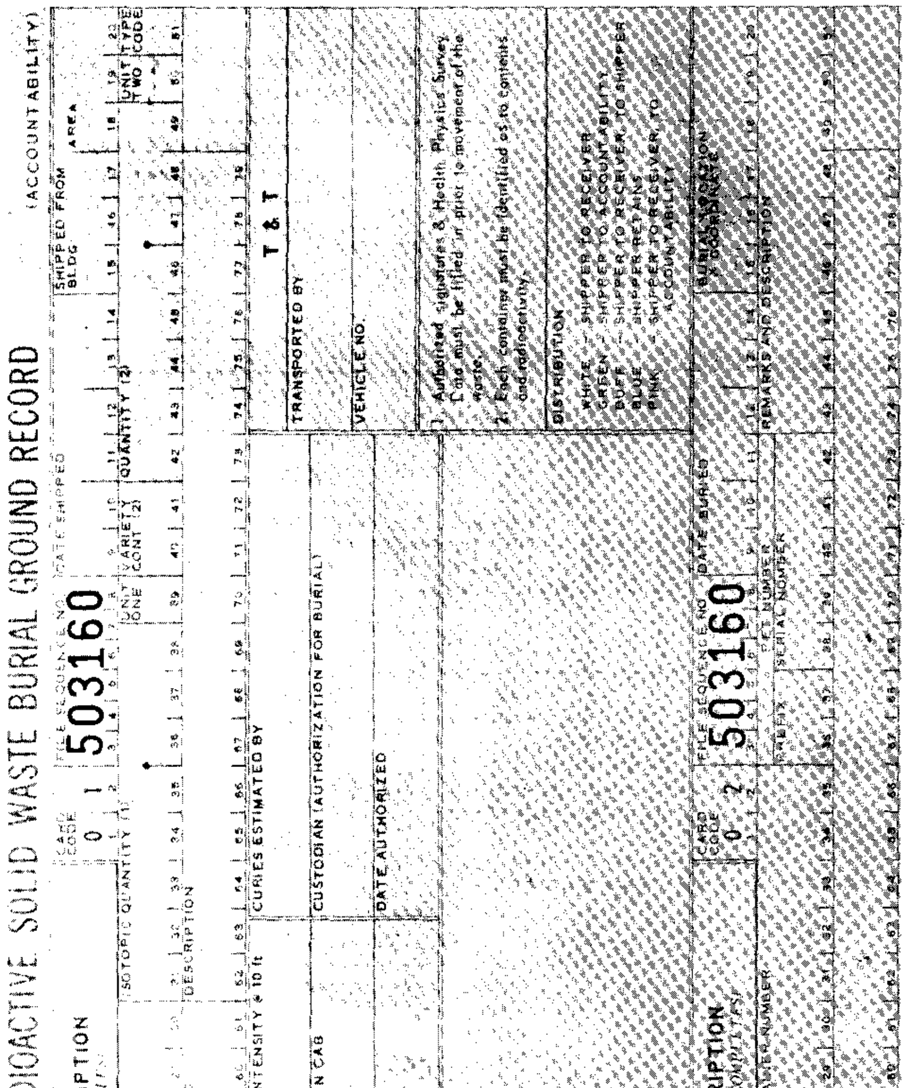


FIGURE 8. A Health Physics Inspector Checks the Shielded Crane for Smearable Radionuclides

The supervisor of the solid radioactive waste storage site keeps accurate records of the contents, radiation level, and burial location of each load received. Shipments are described and recorded on a Radioactive Solid Waste Record (Figure 9), and permanent computerized records are maintained on magnetic tape. The exact location of the trenches is defined by use of a 100-foot grid system laid out in 1960. The 100-foot grids are further divided into twenty-five 20-foot squares. Previous to 1960 the trenches were defined with concrete markers.


RADIOACTIVE SOLID WASTE BURIAL GROUND RECORD (ACCOUNTABILITY)

SOLID WASTE DESCRIPTION (ORIGINATOR COMPLETES)

CARD CODE 0 1 | FILE SEQUENCE NO. 503160 | DATE SHIPPED | SHIPPED FROM BLDG | AREA

VARIETY CONT (1) | TOTAL QUANTITY (1) | ISOTOPIC QUANTITY (1) | UNIT ONE | VARIETY CONT (2) | QUANTITY (2) | UNIT TWO | TYPE CODE

COMB CODE | VOLUME | COMPACTED VOLUME | DESCRIPTION

RADIATION INTENSITY @ 10 ft | CURIES ESTIMATED BY | T & T

HEALTH PHYSICS SURVEY DATA

BODY RATE TO (UN)LOAD | BODY RATE IN CAB | CUSTODIAN (AUTHORIZATION FOR BURIAL) | TRANSPORTED BY

SURVEYED BY | DATE AUTHORIZED | VEHICLE NO.

REMARKS

1. Authorized signatures & Health Physics Survey Data must be filled in prior to movement of the waste.
2. Each container must be identified as to contents and radioactivity.

DISTRIBUTION
WHITE – SHIPPER TO RECEIVER
GREEN – SHIPPER TO ACCOUNTABILITY
BUFF – SHIPPER TO RECEIVER TO SHIPPER
BLUE – SHIPPER RETAINS
PINK – SHIPPER TO RECEIVER TO ACCOUNTABILITY

WASTE BURIAL DESCRIPTION (BURIAL GROUND SUPERVISOR COMPLETES)

CARD CODE 0 2 | FILE SEQUENCE NO. 503160 | DATE BURIED | BURIAL LOCATION X COORDINATE

BURIAL LOCATION Y COORDINATE | BURIAL CONTAINER NUMBER CODE | PREFIX | FFT NUMBER SERIAL NUMBER | REMARKS AND DESCRIPTION

DESCRIPTION CONT'D

a. Obverse Face

FIGURE 9. Radioactive Solid Waste Record

INSTRUCTIONS

01 CARD

SHIPPER'S ADDRESS

Enter 999 in Columns 15-17 for off-plant material received. Blanks and/or dashes should no[t] precede letters or numbers used in Columns 18-20.

VARIETY OF CONTAMINATION – Use symbols as follows:

Columns 21-22, 40-41

10 – Depleted Uranium	70 – Uranium-233	CS – Cesium
20 – Enriched Uranium	81 – Normal Uranium	40 – Plutonium-242
44 – Americium-241	82 – Neptunium-237	SR – Strontium
45 – Americium-243	83 – Plutonium-238	IA – Induced Activity
46 – Curium-244	86 – Deuterium	FP – Fission Products
47 – Berkelium	87 – Tritium	OT – Other
48 – Californium	88 – Thorium	
50 – Plutonium (Weapons Grade)	CO – Cobalt	

RADIOACTIVE WASTE DESCRIPTION CODES

Columns 39 and 50

Unit C – Curies
G – Grams
K – Kilograms
M – Milligrams

Column 51

Type 1 – Job control waste, including housekeeping waste and protective clothing
2 – Oil
3 – Irradiated metal scrap
4 – Naturally radioactive materials
5 – Capital equipment, must be accompanied by a Plant Equipment Transfer (PET)
6 – Resin
7 – Other

Column 52

Combustion N – Noncombustible
C – Combustible

TOTAL ISOTOPIC QUANTITY

Columns 23-38, 40-49

Enter total and isotopic weights for all waste in milligrams, grams, or kilograms. Fissi[on] Products and Induced Activity waste are reported in curies. The isotopic weight of Weapon[s] Grade Plutonium is the sum of the 239 and 241 isotopic weights. The weight of Uranium-2[35] is the isotopic weight for depleted, enriched, and normal uranium.

VOLUME/COMPACTED VOLUME

Columns [illegible]

Enter volume before and after compaction. If waste is not compacted, leave compacted volum[e] field blank.

02 CARD

BURIAL CODE

Column 17

1 – Low Level Beta-Gamma Trench
2 – High Level Beta-Gamma Trench
3 – Low Level Alpha Trench
4 – Burial Containers (Retrievable TRU)
5 – Concrete Pour
6 – Above Ground Storage
7 – Other

AUTHORIZATION FOR SHIPMENT

Requires signature of responsible supervisor who notes Health Physics survey requirement[s]

b. Reverse Face

FIGURE 9. Continued

Burials are made in trenches that are 20 feet deep and 20 feet wide. Low-level waste is unloaded manually or emptied directly into trenches. Where the radiation dose rate is high, the waste is handled remotely. For the highest dose rates, a shielded crane is used. Waste is covered by soil soon after burial to reduce radiation, contamination, and the possibility of fire. The minimum soil cover is 4 feet, but must be sufficient to reduce surface radiation to 6 mR/hr or less.

PAST OPERATING PRACTICES

Routine Burials

Radioactive waste has always been segregated into transuranium alpha, low-level, and high-level waste categories. These are described below:

1. Transuranium Alpha Waste

From 1964 to 1974 this waste was segregated into two divisions:

- *Retrievable*

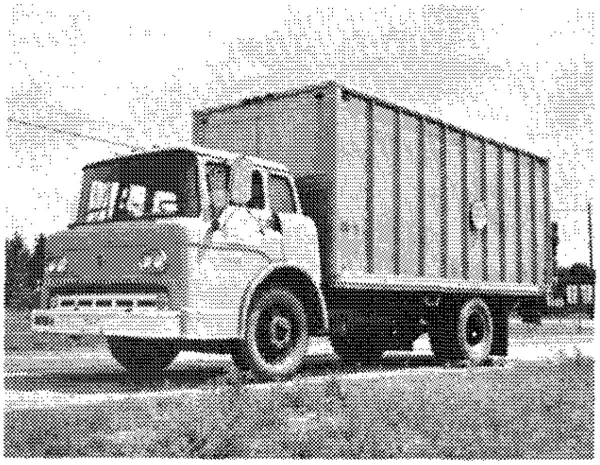
  Waste containing greater than 0.1 curie per package was placed in prefabricated concrete containers and then buried (Figure 10). These containers were 6 feet in diameter by 6.5 feet high. Waste that did not fit into the prefabricated concrete containers was encapsulated in concrete (Figure 11). Transuranium waste from the Savannah River Laboratory (SRL) was buried in square concrete containers (Figure 12). Prior to 1964, this waste was not placed into retrievable containers.

- *Nonretrievable*

  Waste containing less than 0.1 curie per package was buried in a low-level transuranium alpha trench.

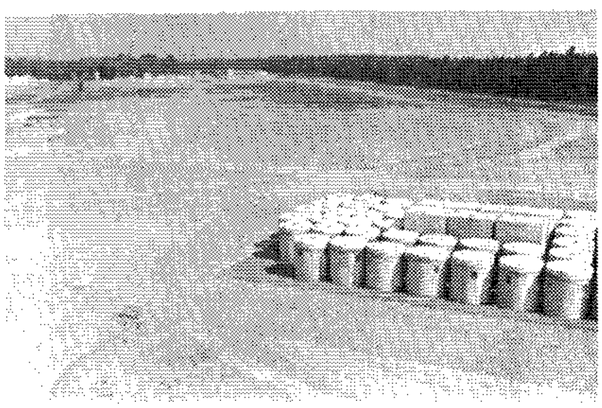
2. Low-Level Waste

Low-level waste (Figure 13) was defined as that measuring less than 50 mR/hr at 3 inches from an unshielded package, less than 50 mR/hr at 10 feet from the truck load, and less than 0.1 Ci of transuranic alpha activity per package. Full shipments of waste, e.g., skip pans or closed container dumpsters with radiation intensities to 50 mR/hr at 10 feet, were disposed of in low-level waste trenches. Scrap uranium from the fuel fabrication operation was also placed in these trenches.



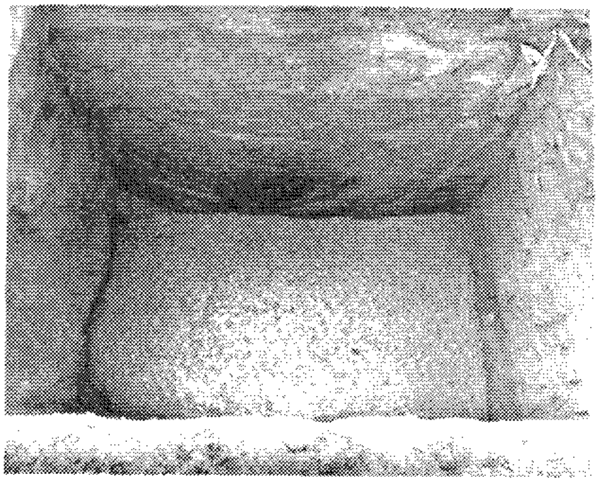
a. Transporting Vehicle

b. Interior View of Container.

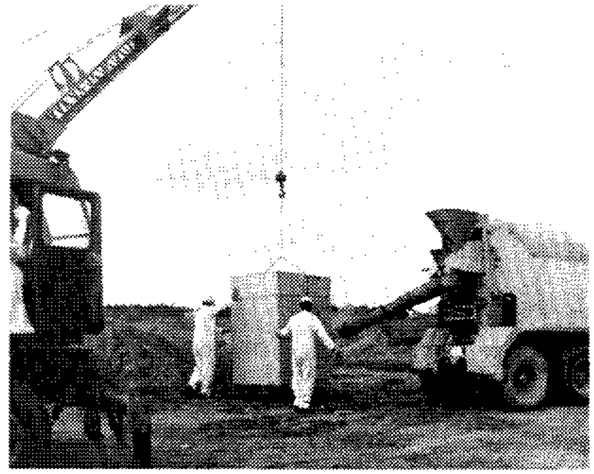


c. Assembled for Mound Burial

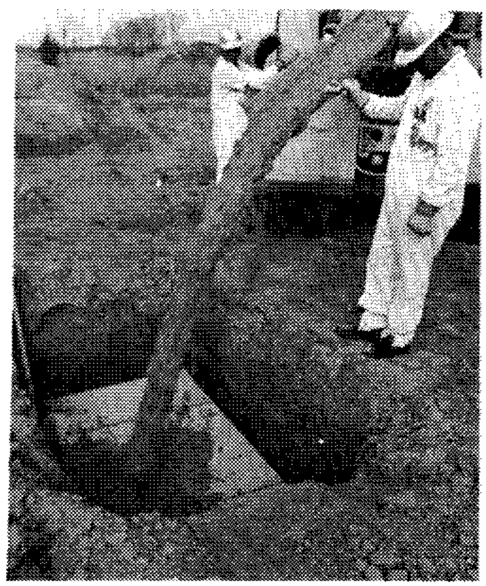
FIGURE 10. Concrete Containers for Transuranic Waste



a. Concrete in Bottom of Hole

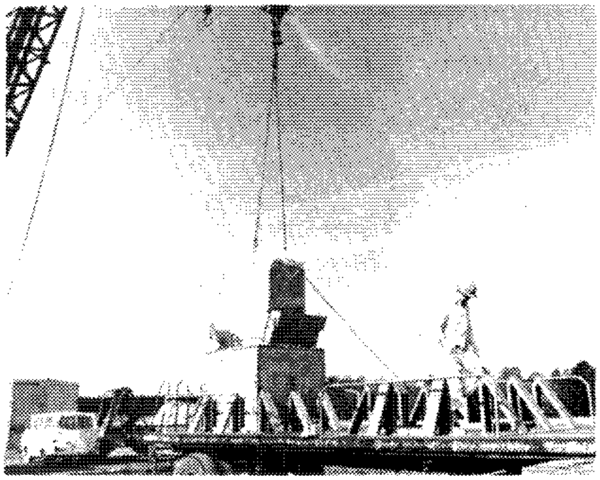


b. Placement of Equipment in Hole

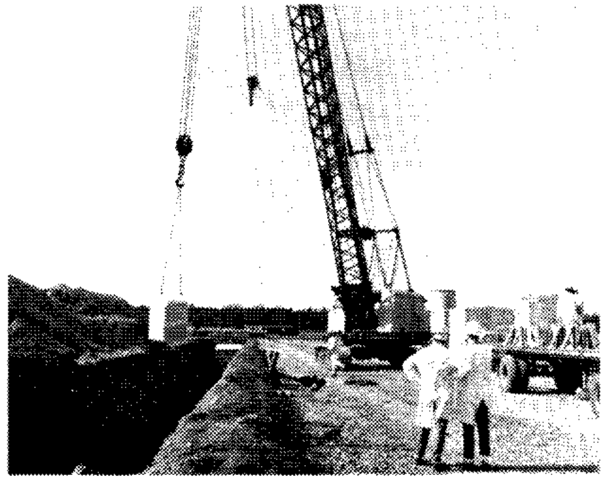


c. Pouring Concrete Around Sides of Box

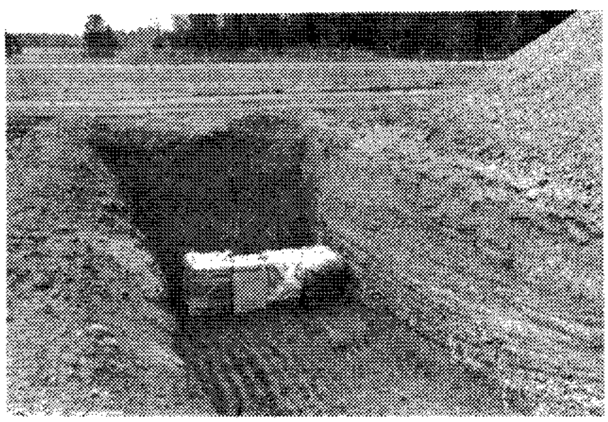
FIGURE 11. Concrete Encapsulation of Equipment too Large for Concrete Containers



a. Transfer Cask on Trailer



b. Concrete Box Being Placed in Trench



c. Waste Trench

FIGURE 12. Transuranic Waste in Concrete Containers Being Placed in Alpha Trench

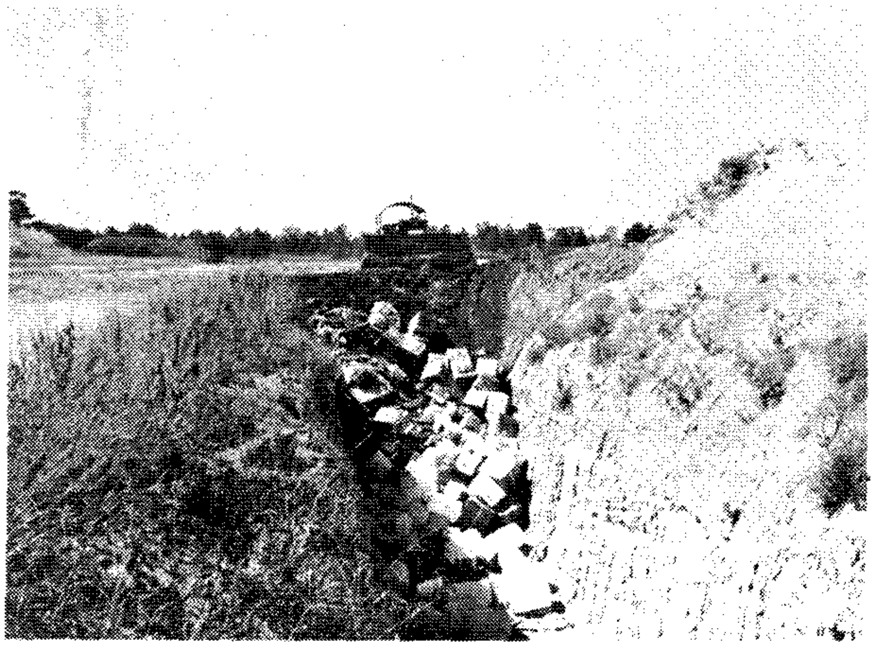


FIGURE 13. Low Level Trench Containing Boxed Paper and Laboratory Waste Being Refilled Using a Bulldozer

3. High-Level Waste

High-level waste was defined as that exceeding 50 mR/hr at 3 inches from an unshielded package. An example of a typical burial operation of high-level waste is shown in Figure 14.

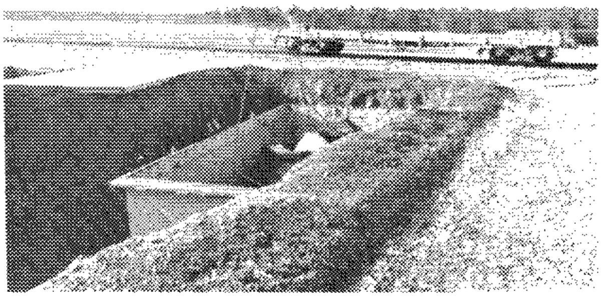
The volume and radioactivity content of waste buried in 1974 are listed in Table 2. The volume and radioactivity of waste buried since startup through 1974 are summarized in Table 3.

Special Burials

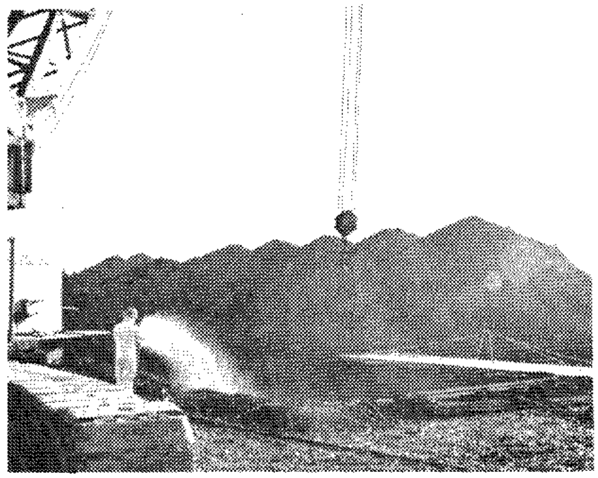
Occasionally shipments of classified wastes are received per ERDA request. Two such shipments occurred following crashes of airplanes.

a. Spanish Soil

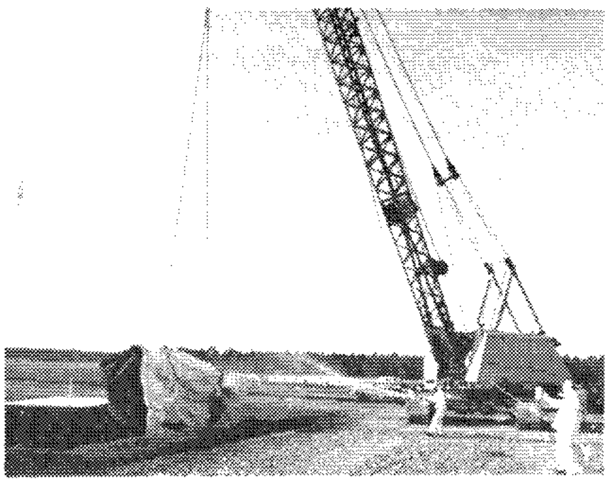
A collision during mid-air refueling on January 17, 1966, between a bomber carrying nuclear weapons and a refueling plane contaminated the ground at Palomares, Spain, with plutonium. Decontamination procedures produced



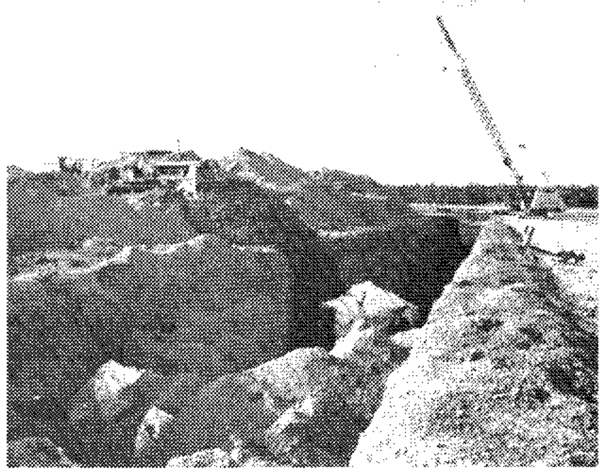
a. Box Containing Process Pipe From Separations Areas in Burial Ground Trench With Lid Removed



b. Spraying Box With Water to Reduce Airborne Contamination During Removal of Process Pipe From Transfer Box



c. Removing Process Pipe From Transfer Box



d. Covering Process Pipe With Earth

FIGURE 14. Process Pipe Burial in High Level Waste Trench

TABLE 2

Radioactive Waste Burials in 1974

Waste Classification	*Radioactivity Content, Ci*	*Volume, ft³*
1. Transuranium Alpha Waste		
Retrievable	5,000	7,000
Nonretrievable	200	74,000
2. Low Level	5,000	280,000
3. High Level	280,000	42,000

TABLE 3

Radioactive Waste Burials From Startup Through 1974

Waste Classification	*Radioactivity Content, Ci*	*Volume, ft³*
1. Transuranium Alpha Waste		
Retrievable	500,000	70,000
Nonretrievable	20,000	1,100,000
2. Low Level	3,200,000	6,700,000
3. High Level	4,100,000	700,000

4,827 55-gallon drums of soil and vegetation. These were placed in two separate trenches in 1966. The drums were buried 10 feet below the ground surface as a precaution against local infestation with plant and soil diseases from Spain (Figure 15).

b. Greenland Ice

On January 21, 1968, a bomber that carried nuclear weapons crashed in Greenland, producing large quantities of contaminated ice and aircraft parts.[1] Recovery activities required 535 containers with a storage

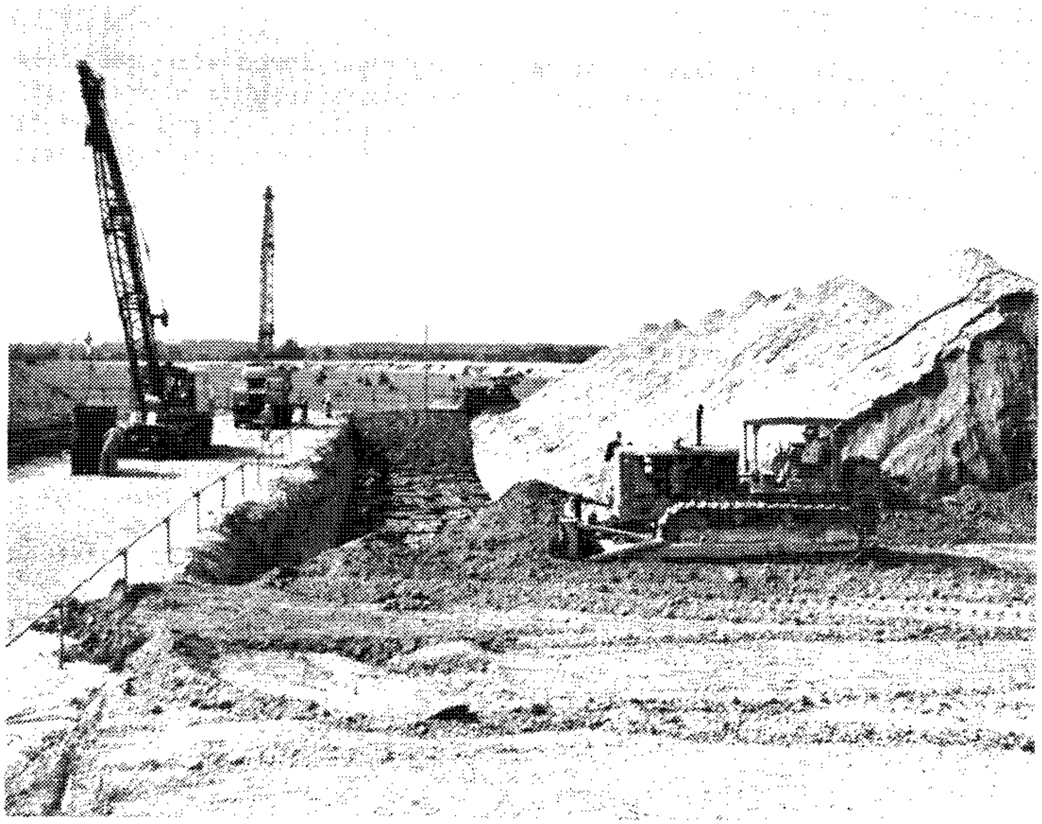


FIGURE 15. Spanish Soil Burial

volume of 120,000 cubic feet for aircraft parts and 680,000 gallons of water potentially contaminated with plutonium. The water was filtered, monitored, and sent to a seepage basin, except for a small fraction that was evaporated and its concentrates stored in the high level waste tanks. Aircraft parts and storage tanks have been buried in three separate trenches.

In addition to these several categories and examples of solid waste, degraded solvent is temporarily stored in the solid radioactive waste storage site in 20 underground tanks (150,000 gal in storage in 1975). The solvent contains residual transuranics and fission products that were not removable by washing procedures. The transuranics in 1975 totaled 45 Ci of alpha radioactivity, primarily ^{238}Pu and ^{239}Pu. Most of the fission product activity in the solvent is short-lived. A facility for incineration of this solvent inventory is being designed.

3. The SRP limits on the quantity of beta-gamma radioactivity emplaced each year at the solid radioactive waste storage site are the following:

^{137}Cs	500 Ci
^{90}Sr	500 Ci
^{60}Co	3×10^5 Ci
^{3}H	4×10^5 Ci
Other nuclides ($T_{1/2} > 10$ y)	1×10^3 Ci
Other nuclides ($T_{1/2} < 10$ y)	5×10^5 Ci

4. A comprehensive surveillance program shall be provided to monitor migration of radionuclides from their storage locations.

TRANSPORT OF RADIOACTIVITY

Stratigraphy of Area

Geological and hydrological characteristics of the SRP site favor the safe burial of radioactive solid wastes. SRP is in the Atlantic Coastal Plain physiographic province. At the solid waste storage site, the stratigraphic section consists of nearly a thousand feet of mostly unconsolidated sands, clayey sands, sandy clays, and clays (Table 4 and Reference 2). Downward flow of ground water into the prolific Tuscaloosa aquifer is prevented by a hydrostatic head reversal in the Congaree formation (Figure 16) that indicates flow is into the Congaree formation both from above and below. Thus, migration of radionuclides is confined to the direction of surface streams.

Water Movement in Soil

The highly favorable ground water hydrology compensates for the high annual rainfall, which averages 47 in./y.[3] Because of surface runoff and evaporation, only about 15 inches flows through the soil to the water table annually;[4] but this is sufficient to outweigh other mechanisms tending to move radionuclides through the soil. Therefore, migration is downward to the water table and then horizontally in the ground water to flowing surface streams. The average depth to the water table at the solid waste storage area is about 45 feet, and in the unsaturated soil above the water table, water flows at a rate of about 7 ft/y.[5,6] In the water saturated zone, water moves between 29 and 47 ft/y.[7] Because the shortest flow path from buried high level waste emplacements to Four Mile Creek is 0.5 mile, the travel time for subsurface water from the solid radioactive waste storage site to this stream is about 70 years.

TABLE 4

Sediments Beneath SRP[a]

System	Series	Formation	Lithology	Thickness, ft	Hydrology	Piezometric Head Below Water Table
Quaternary to Tertiary	Recent to Pliocene	Alluvium	Gravel, sand, silt, clay	0-30	Very little ground water	0
	Miocene	Hawthorn	Multicolored clays, sandy clays, and sands. Many clastic dikes	0-80	Small to moderate amounts of ground water	0
	Eocene	Barnwell	Multicolored fine-coarse sand and sandy clay	0-90	Ground water sufficient for home use	0
Tertiary	Eocene	McBean	Multicolored fine-coarse glauconitic sand and clay. Calcareous zone 0-80 ft thick, composed of limestone, marl, clay, and silicified shells	0-150	Ground water supply moderate to large in sandy portion; small in calcareous zone.	Ranges from 2-33 ft in Separations Areas
	Eocene	Congaree	Green sandy clay, silt, and thin hard sandstone and chert beds near top. Brown and green sandy clay, sand and silicified shells below	0-100	Ground water supply low to moderate	Ranges from 58-102 ft in Separations Areas
Upper Cretaceous		Ellenton	Dark gray to black sandy micaceous clay, sand and gypsum	0-100	Ground water supply moderate	Same as Tuscaloosa
		Tuscaloosa	Tan, buff, red, white cross-bedded coarse micaceous sand, clayey sand, and interbedded with red, brown, purple clay and white Kaolin	0-600	Large supplies of soft ground water. Yields up to 2000 gpm from 8 to 12-inch gravel packed wells.	Ranges from 26-91 ft in Separations Areas

a. Modified from Table 2, p 16 in Siple[2]

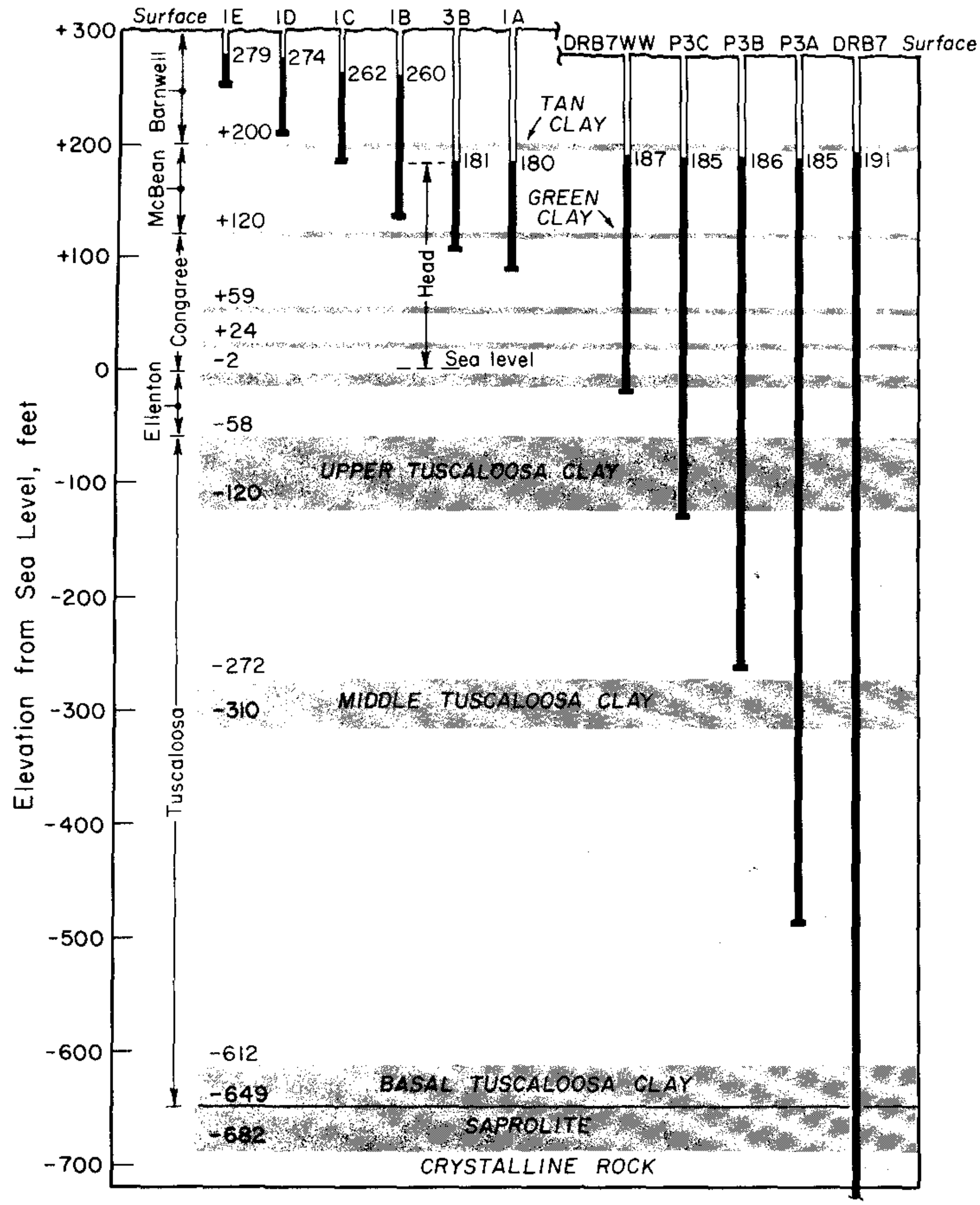


FIGURE 16. Hydrostatic Head in Ground Water Near Solid Radioactive Waste Storage Site

Transport of Nuclides through Soil

Ion exchange will increase the travel time for strontium by a factor of 16 and cesium by a factor of 200.[8] Thus, before emerging into Four Mile Creek, the ^{90}Sr and ^{137}Cs will have decayed to much less than 1 percent of the quantity placed into the ground.

Leaching of radionuclides from buried waste is minimized by the characteristics of water in unsaturated soil. Unless all soil pores are filled with water, the soil is unsaturated and the hydrostatic pressure is less than atmospheric. Under these conditions, water will not flow from water-filled pores to air-filled pores or into cavities in the soil. Many of the radionuclides are in cavities such as the interior of pipes or vessels. In such locations, radionuclides can only be leached if the waste is in perched ground water, i.e., water-saturated soil above the permanent water table. Because of the higher water permeability in backfilled than undisturbed soil, perched water does occur in the bottom of some trenches. Monitoring data from wells installed in backfilled trenches indicate only a small quantity (tens of millicuries) of radioactivity is present in the perched water.

Monitoring Program and Results

Monitoring for radionuclide leaching through the soil in the solid waste storage area began with the installation of 9 wells in 1956 (Figure 17). Two other wells, BG 12 and BG 18, were installed in 1962 after the direction of ground water flow was known to be in a southwesterly direction. Well BG 8 was destroyed in the construction of new waste trenches in 1965, and Well BG 5 was similarly damaged in 1968. The concentrations of alpha and non-volatile beta-emitting radionuclides measured in these 11 wells from 1956 through 1974 were at or near background levels. Tritium concentrations are similar to those found elsewhere in the vicinity of the chemical separations areas and are due to atmospheric releases. The maximum and average concentrations measured in the wells are summarized in Table 5.

To evaluate the extent and effect of perched water in the bottom of backfilled trenches, 24 wells were installed with 6-in.-long screens at the bottom of the trenches in 1969. The locations of the wells are shown in Figure 18. Weekly water-level measurements were made in these from August 1969 through July 1970. Only Wells 6, 7, 17, and 19 had more than a trace of water (Figure 19). Water from these wells has been analyzed for radioactivity every

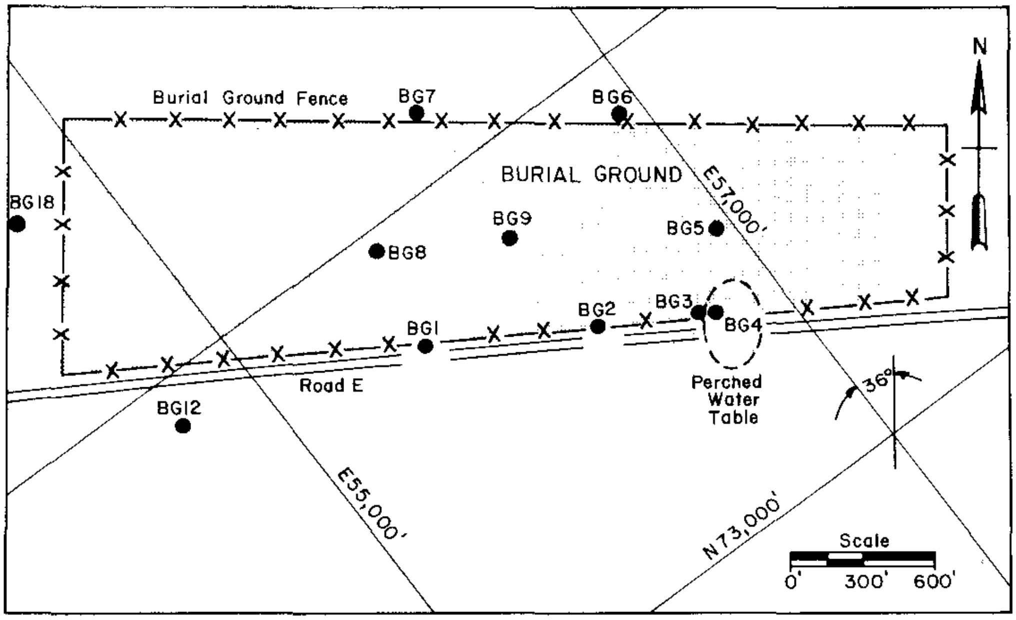


FIGURE 17. Solid Radioactive Waste Storage Site Wells Prior to 1973

TABLE 5

Radionuclide Concentrations in Solid Radioactive Waste Storage Site Monitoring Wells from 1956 Through 1974

	Concentration, pCi/liter					
	Alpha		*Nonvolatile Beta*		*Tritium*	
Well No.	*Max.*[a]	*Avg.*	*Max.*[a]	*Avg.*	*Max.*[a]	*Avg.*
BG 1	0.9	0.5	13	7	62,000	24,000
BG 2	0.7	0.4	11	8	140,000	49,000
BG 3	1.4	0.7	27	12	103,000	58,000
BG 4	1.8	1.0	13	10	860,000	187,000
BG 5[b]	0.7	0.5	13	9	261,000	109,000
BG 6	0.8	0.4	77	13	87,000	46,000
BG 7	0.9	0.5	40	12	62,000	32,000
BG 8[b]	1.1	1.0	15	11	33,000	19,000
BG 9	1.5	0.6	16	9	142,000	42,000
BG 12[b]	2.0	1.3	20	12	84,000	35,000
BG 18[b]	3.6	1.6	44	20	61,000	37,000

a. Maximum yearly average.

b. Well BG 8 was destroyed in 1965, Well BG 5 was destroyed in 1968, and Wells BG 12 and BG 18 were installed in 1962.

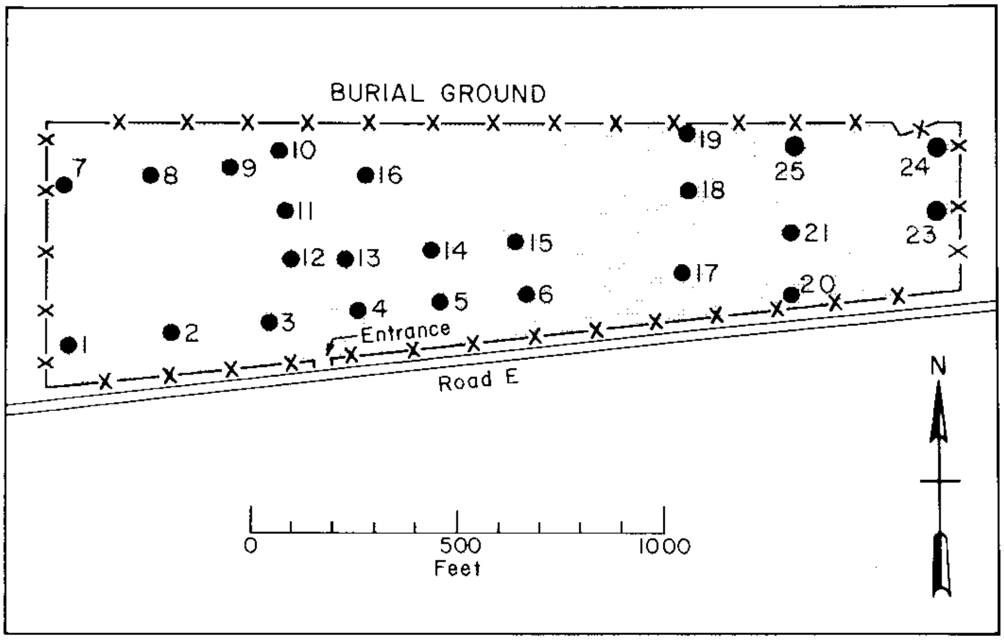


FIGURE 18. Wells Screened at Bottom of Burial Trenches in the SRP Solid Radioactive Waste Storage Site

two weeks since March 1970. The results (Table 6) show that the waters contain levels of nonvolatile beta-emitters above background levels. During April 1974, specific radionuclide analyses showed that ^{90}Sr was the primary component of the nonvolatile beta-emitters, and ^{137}Cs and ^{60}Co were also detectable in Well 9.

When most solid waste storage operations had shifted from the original 76-acre site in 1972, ground water monitoring was increased by installing monitoring wells in a grid pattern on 200-foot centers (Figure 20). The predominant radioactive isotope in the monitoring data (Table 7) is tritium from the burial of spent lithium-aluminum target melts. Approximately one-third of the wells contain tritium levels significantly above concentations recorded for rain in the vicinity of the solid waste storage site. Eight of the wells contain tritium concentrations above the radioactivity concentration guide (RCG) for uncontrolled areas (3000 pCi/ml). The average concentration in these eight wells is approximately 100 times the RCG, and the concentration in the maximum well is 800 times the RCG. The total inventory of tritium in the ground water underlying the old 76-acre sector of the storage site is ∿50,000 Ci. About 1000 Ci have migrated (via ground water movement) into an area of about 17 acres beyond the boundary fence southwest of the storage site. Because of the slow rate of travel of the ground water, most of the tritium will decay before outcropping in Four Mile Creek. When this tritium

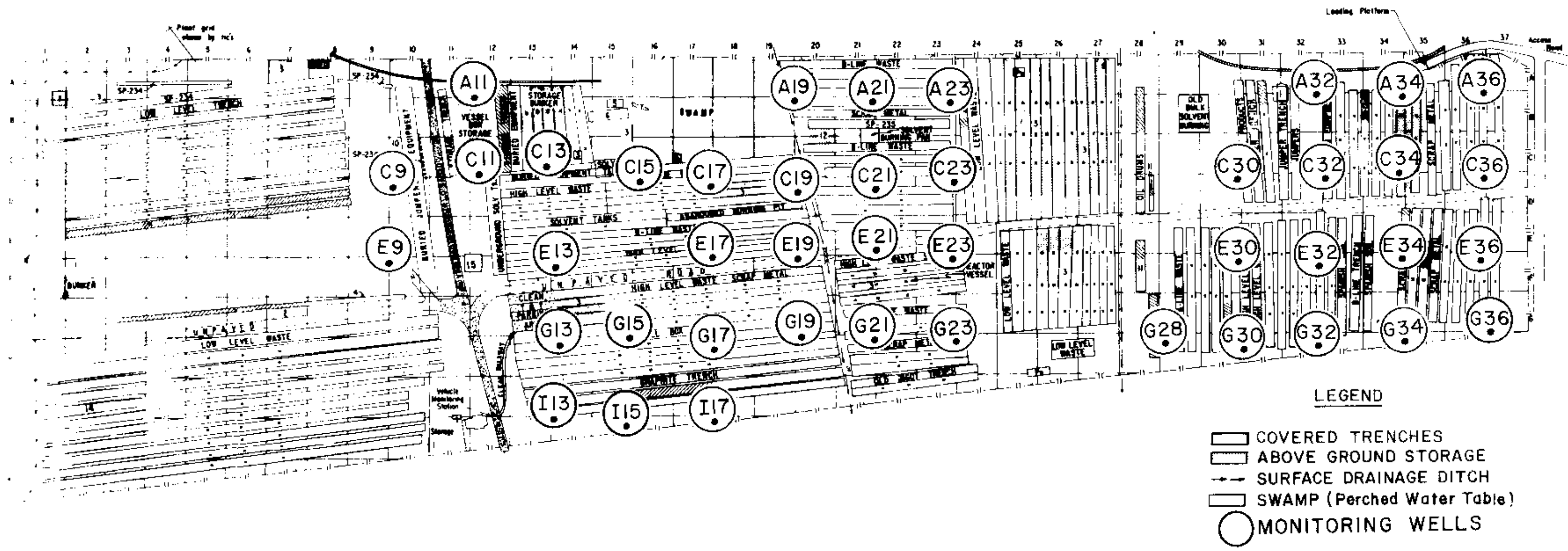


FIGURE 20. Monitoring Well Locations in Solid Radioactive Waste Storage Site in 1974

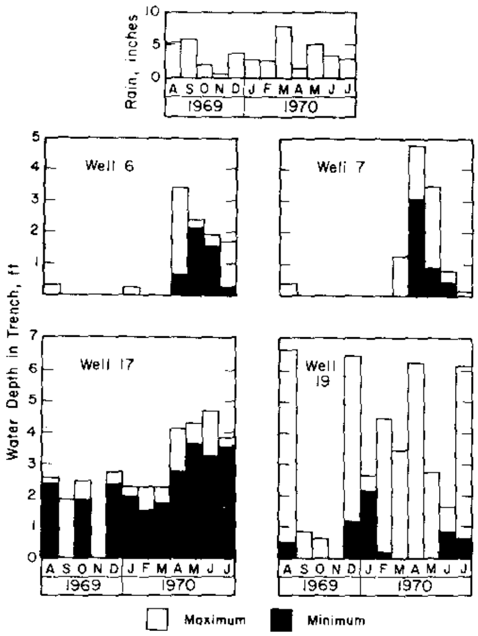


FIGURE 19. Water Levels in Backfilled Trenches

TABLE 6

Radionuclide Concentrations in Perched Water in the Bottom of Backfilled Trenches

Alpha Emitters, pCi/liter

Year	*Well 6*		*Well 7*		*Well 9*		*Well 17*		*Well 19*		*Well 23*	
	Max	*Avg*	*Max*	*Avg*	*Max*	*Avg*	*Max*	*Avg*	*Max*	*Avg*	*Max*	*Avg*
1970	0.8	0.6	0.5	0.5		*a*	1.7	0.6	1.5	1.0		*a*
1971	1.3	0.4	2.3	0.5		*a*	1.8	0.6	2.1	0.7		*a*
1972	0.6	0.3	1.1	0.3		*a*	2.3	0.7	1.6	0.8		*a*
1973	1.7	0.5	2.0	0.6	4.1	1.7	4.0	1.1	2.4	1.2	1.8	0.9
1974	5.4	1.5	1.0	0.4	7.4	2.4	11.0	5.0	4.0	2.2		*a*
1975	4.0	1.9	2.7	0.8	5.4	2.9	2.7	0.7	5.0	2.8		*a*

Nonvolatile Beta Emitters, pCi/liter

Year	*Well 6*		*Well 7*		*Well 9*		*Well 17*		*Well 19*		*Well 23*	
	Max	*Avg*	*Max*	*Avg*	*Max*	*Avg*	*Max*	*Avg*	*Max*	*Avg*	*Max*	*Avg*
1970	83	60	140	105		*a*	170	120	510	380		*a*
1971	1250	330	1600	730		*a*	620	190	740	340		*a*
1972	490	355	1260	950		*a*	390	150	930	290		*a*
1973	530	260	1560	910	3240	1280	450	150	840	350	1670	930
1974	1400	520	2000	1220	5960	2770	210	110	570	310		*a*
1975	80	180	1010	770	3580	2400	160	130	820	400		*a*

a. Well dry.

TABLE 7

Radionuclide Concentrations in Monitoring Wells (1975 data)

	Alpha Emitters, pCi/l		*Beta-Gamma Emitters, pCi/l*		*Tritium, pCi/ml*	
Well	*Max*	*Avg*	*Max*	*Avg*	*Max*	*Avg*
A-11	3	1	17	13	<50	<50
A-19	3	1	9	2	<50	<50
A-21	4	1	26	11	80	50
A-23	2	1	32	11	110	90
A-32	6	2	37	16	210	100
A-34	3	1	12	4	80	60
A-36	2	1	5	2	290	200
C-09	1	0	3	1	8000	6900
C-11	1	1	26	7	50	40
C-13	4	2	56	15	<50	<50
C-15	3	1	31	15	<50	<50
C-17	72	33	68	26	60	50
C-19	2	1	8	2	50	40
C-21	2	1	31	8	160	70
C-23	1	0	25	6	2000	1100
C-30	1	0	32	6	430	360
C-32	2	2	53	19	1600	1000
C-34	5	2	48	21	350	220
C-36	2	1	11	6	2800	1400
E-09	1	1	2	1	50	50
E-13	1	0	11	4	<50	<50
E-17	6	3	84	48	<50	<50
E-19	1	0	46	17	8400	6900
E-21	3	1	4	2	40	30
E-23	3	1	0	0	100	60
E-30	1	1	9	3	390	280
E-32	3	1	18	7	110	80
E-34	2	1	200	100	1000	480
E-36	3	1	27	11	260	130
G-13	19	5	44	14	57,000	40,000
G-15	2	1	6	2	12,000	9000
G-17	2	1	15	7	54,000	30,000
G-19	9	3	18	8	170	150
G-21	36	16	340	220	3,900,000	2,400,000
G-23	1	0	7	2	18,000	12,000
G-28	3	1	0	0	80	75
G-30	1	0	18	10	70	60
G-32	1	1	28	13	110,000	51,000
G-34	1	0	16	4	1100	470
G-36	1	0	7	2	1800	730
I-13	32	18	280	180	90	80
I-15	6	3	87	30	80	70
I-17	9	5	20	5	80	40

reaches Four Mile Creek, the maximum total dose-to-man will be 0.02 man-rem per year to a population of 70,000 people consuming Savannah River water.[9]

Small concentrations of alpha and nonvolatile beta-gamma radioactivities were detected in seven of the wells (C-17, E-17, E-34, G-13, G-21, I-13, and I-17). The alpha and nonvolatile beta-gamma radioactivities in two of these, Wells I-13 and I-17, are natural uranium and its decay products. The alpha and beta-gamma activities in four others (Wells C-17, E-17, G-13, and G-21) are not attributable to migration from solid waste storage, but appear to be residual low-level contamination from spills of spent solvent from storage and burning operations during the period 1955 to 1968. The spills are estimated to have contained approximately 8 mCi of plutonium and ~150 mCi of beta-gamma activity in about 600 gallons of solvent. The nonvolatile beta-gamma activity is primarily ^{60}Co in Well E-34.

UPTAKE OF RADIONUCLIDES BY VEGETATION

General Principles

Radioactivity on buried waste can be translocated to the ground surface by growing plants.[10] Radiostrontium is the radionuclide most readily absorbed when plants are grown on soil contaminated with long-lived mixed fission products. Cesium-137 is relatively unavailable for plant uptake because of its strong fixation by the soil. Romney, et al.[11] found that radiostrontium accounted for 50 to 80% of the beta activity transferred to above-ground plant parts from soil mixed with solutions of mixed fission products. Less than 10% was attributable to ^{106}Ru, ^{137}Cs, and ^{144}Ce. Similar results were found by Anderson.[12]

Plutonium is only slightly available to plants.[13,14] Cline[13] found that the plutonium activity per gram of oven-dried tissue divided by the plutonium activity per gram of oven-dried soil was 0.0002 for ^{239}Pu when barley was growing on Cinebar soil under greenhouse conditions. Studies at SRL of plants grown under field conditions, where both uptake by plant roots of plutonium from the soil and deposition on the plant of plutonium associated with re-suspended soil particles were potentially operable, gave values of 0.01 to 0.1 for the above activity ratio.

The depth at which the radionuclide is buried influences its uptake by vegetation.[15,16] In general, the greater the depth of burial, the smaller the uptake by plants. The maximum depth that roots of native vegetation reach is not known, and considerable efforts to determine this have been unsuccessful, but root depth of some native vegetation is thought to be several times greater than the depth that waste is buried.

SRP Experience

SRP experience has shown that vegetation can absorb significant amounts of radionuclides from buried radioactive waste. Vegetation radiating 2100 mrad/hr at 2 inches was detected growing over backfilled burial trenches during the summer of 1965. The radioactivity was due entirely to ^{90}Sr uptake from a buried evaporator vessel (77 µCi ^{90}Sr/g of soil) that was 2.2 feet beneath the soil surface. At another location in the same trench, radiation levels from vegetation were 210 mrad/hr, and the region of greatest soil contamination (76 µCi ^{90}Sr/g of soil) was at a depth of 4.5 feet. In both cases, the contaminated vegetation was removed and additional backfill added over the trench.

Additional radioactive vegetation was found in the waste storage site during June 1968 (Table 8). The maximum ^{90}Sr reported was only 0.01% of that in 1965 and was found in the same area of the trench as in 1965. Gamma activity in several of the samples was slightly higher than that found routinely on vegetation at the burial ground fence. Alpha activity was within the same range as vegetation exposed only to fallout (1 pCi/g max.).

Controlling Vegetation Uptake

Dispersal of radionuclides through vegetation uptake will negate the purpose of the radioactive waste storage site to contain radionuclides. Thus, deep-rooted vegetation should not be permitted to grow over the waste trenches. Continuing studies are evaluating both shallow-rooted grasses and several nonvegetative soil covers (Table 9 and Figure 21). Other alternatives include chemical and mechanical means of vegetation control.

TABLE 8

Radioactivity in 1968 Vegetation

	Concentration, pCi/g					
	Solid Radioactive Waste Storage Site				*General, F and H Areas*	
	Within Site		*At Fence*			
Isotope	*Avg*	*Max*	*Avg*	*Max*	*Avg*	*Max*
^{144}Ce	17	75	6.0	10.1	5.4	6.4
^{137}Cs	12	140	2.0	3.1	1.5	1.8
^{106}Ru	16	84	9.8	32.0	3.5	4.2
^{95}Zr-^{95}Nb	3	17	1.9	2.6	1.6	2.3
^{90}Sr	120	790	4.6	7.9	*a*	*a*
^{54}Mn	25	260	0.6	0.6	0.6	0.6

a. No analysis

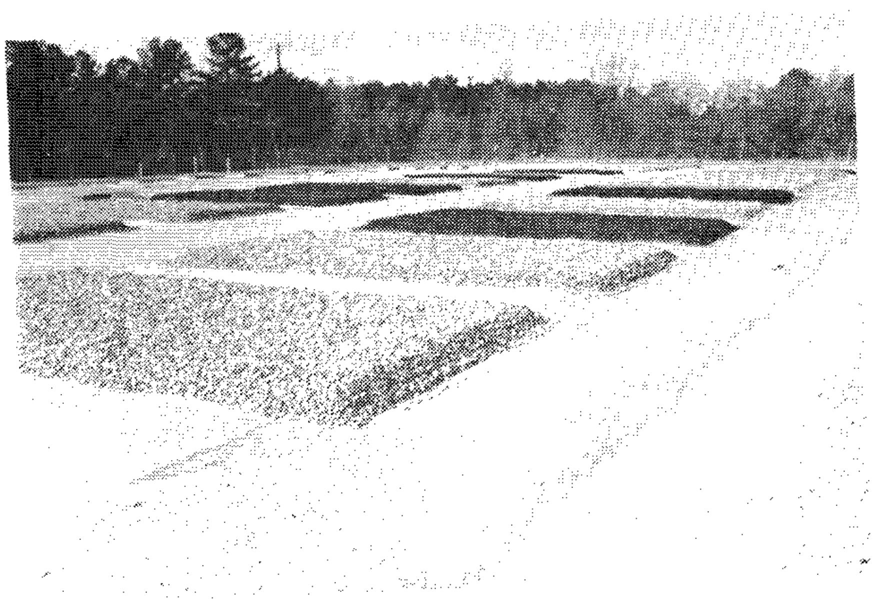
TABLE 9

Surface Covers Currently being Evaluated

1. Herbicide, *Hypalon*[a] sheet, asphalt, crushed stone
2. Herbicide, crushed stone
3. Herbicide, polyethylene sheet, asphalt, crushed stone
4. Herbicide, soil cement
5. Herbicide, polyethylene sheet, crushed stone, asphalt
6. Herbicide, *Tedlar*[a] sheet, crushed stone
7. Herbicide, *Hypalon*[a] sheet, crushed stone, asphalt
8. Herbicide, *Hypalon*[a] sheet, crushed stone, asphalt
9. Herbicide, polyethylene sheet, crushed stone
10. Herbicide, asphalt, crushed stone
11. Crushed stone

a. Trademarks, E. I. du Pont de Nemours and Co., Wilmington, Delaware.

a. Vegetative



b. Nonvegetative

FIGURE 21. Test Plots for Evaluating Soil Covers for Burial Trenches

CONCLUSIONS

Radioactive waste management policies in the United States are undergoing continual revision. These changes necessitate a solid waste management program that not only meets present standards, but is also adaptable to future requirements. The SRP waste management procedures satisfy these criteria.

With the attention currently given to monitoring and control of migration, the solid wastes can remain safely in their present location for as long as is necessary for a national policy to be established for their eventual disposal. Leaching of fission product, activation product, and transuranium nuclides has been negligible. However, tritium is leaching from buried wastes. Because of the low movement rate of ground water, the dose-to-man projection from tritium leaching from the inventory in the burial trenches is estimated to be less than 0.02 man-rem per year. Uptake of radionuclides by vegetation growing over buried waste has shown that deep-rooted vegetation should not be permitted to grow over the waste. Thus, long-term (100 to 200 years) managment will primarily require vegetation and erosion control.

SRP waste management procedures for transuranium wastes are compatible with recovery and removal of buried solid wastes if national policy should so dictate. Segregation of waste according to source and radiation levels permits minimum management for much of the area and permits recovery of any one type of waste. Transuranium alpha emitters buried in concrete can be recovered without including soil. Detailed records of waste burial locations will facilitate recovery of wastes.

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FoE Attachment 2

Report on the Plutonium Deposition Registry Board's First Annual Meeting (Oct. 1966)

Taschner

338917

DEPARTMENT OF THE AIR FORCE
AIR FORCE LOGISTICS COMMAND
WRIGHT-PATTERSON AFB, OHIO

PLUTONIUM DEPOSITION REGISTRY BOARD

PROCEEDINGS
First Annual Meeting
26 - 28 October 1966

USAF RADIOLOGICAL HEALTH LABORATORY

Prepared by:
L. T. Odland, LtCol, USAF, MC

AFLC—WPAFB—DEC 66 30

PROCEEDINGS

First Annual Meeting

PLUTONIUM DEPOSITION REGISTRY BOARD

PURPOSE: To review results of bio-assay data collected in support of Palomares Broken Arrow operation, and related matters.

PLACE: Room B-98, USAF Hospital Wright-Patterson, Air Force Logistics Command, Wright-Patterson AFB, Ohio.

TIME: 0830 hours.

DATE: 27 Oct 1966.

ATTENDEES:

Guest Speaker

BrigGen John M. Talbot, USAF, MC, Special Assistant to The Surgeon General for Medical Research
Hq USAF, Wash DC

Registry Board Members

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Command Surgeon, Hq AFLC
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Battelle-Northwest
Pacific Northwest Laboratory, Richland Wash

W. E. Lotz, Ph.D.
Medical Branch, Division of Biology & Medicine
Hq USAEC, Wash DC

Capt R. G. Conrad, USAF, BSC
Chief, Special Activities Branch
USAF Radl Health Lab, Wright-Patterson AFB Ohio

FORMAL PRESENTATIONS:

Opening Address - Brig Gen J. M. Talbot, USAF, MC

On behalf of the Surgeon General and the United States Air Force Medical Service, I want to add my welcome to the participants in this first meeting of the USAF Plutonium Deposition Registry Board. The Air Force is particularly grateful to those of you from our sister military services, the Atomic Energy Commission, the Veterans Administration, and the civilian scientific community who have consented to serve as members or as consultants to this board.

The large number of observers at this meeting is also gratifying to us. It indicates the continuing interest in Plutonium-239 inhalation and internal deposition, and further reinforces our belief that establishing and maintaining this permanent registry and its associated board, are, indeed, essential. For those of you who are visiting Wright-Patterson Air Force Base for the first time, I would urge you to visit the USAF Radiological Health Laboratory, if your time permits. This laboratory is unique in being the only military laboratory within the free world exclusively devoted to handling all laboratory aspects of occupational radiological health. In addition, the Radioisotope Clinic here in the hospital, the Nuclear Engineering Test Facility reactor on the other side of the base, and the various component laboratories of the USAF Aerospace Medical Research Laboratories are also worth visiting. In terms of personnel, the Air Force has concentrated a pool of its finest talent in health physics, applied radiobiology, reactor technology, and nuclear medicine here at Wright-Patterson, in support of these various laboratories and their headquarters.

Little needs to be said about the more dramatic aspects of the Broken Arrow of last January 17. In the nine months which have elapsed since that tragic day, "Palomares" has become virtually a household word, at least, within the military. Television news coverage and special programs in the first three months following the accident were widely viewed. Reams of articles concerning this Broken Arrow have poured from the popular press, and as recently as last month The Reader's Digest magazine published an excellent 35-page special feature on this subject, in lieu of its usual best-seller condensation. A Broadway play on Palomares and the missing bomb is (or was) scheduled to go into production this coming winter. (Who, one wonders, will be cast in the role of Dr. Wright Langham?)

We, here today, are concerned with less dramatic but equally-significant sequelae to the Palomares Broken Arrow. Shortly after the accident it became evident that the plutonium contamination problem in Palomares was going to be far more extensive than initially supposed--and that, despite protective measures, a large number of military personnel involved in the clean-up operation were receiving or would receive, at least, a fraction of a body burden of Plutonium-239. Concerned individuals in the USAF Medical Service were aware that there was little information in the literature on which to predict medical disability or complications which may arise subsequent to the inhalation and deposition of Plutonium-239 in the lungs and other organ systems of man. They were further aware that many medical authorities are of the opinion that small amounts of Plutonium-239 detectable in the urine; i.e., amounts less than acceptable body burden, are of biological significance, since permissible burdens as assayed by urinalysis may only vaguely indicate the amount of the isotope which may be deposited in the lungs. They knew that the present acceptable body burden of Plutonium-239 is based on extrapolations from experience with radium-dial painters and small animals. Until the present, we have not had a group of human exposures of statistically-significant size which we could study, in an attempt to better define the medical hazards subsequent to inhalation of Plutonium-239, and such reports as do appear in the literature for the most part describe chronic occupational exposures. Since Plutonium-239 was not discovered until 25 years ago, no cases have been followed for longer periods of time. While it seemed highly unlikely that any individual involved in the clean-up operation in Palomares had, or would receive, sufficient internal deposition of Plutonium-239 to warrant consideration of clinical treatment, it was felt that the Air Force Medical Service could be in a precarious position were the question of treatment to arise following any future Broken Arrow. No physician in the Air Force has, to date, ever treated an individual for plutonium deposition. Further, although techniques of treatment are available, there is no unanimity of opinion, even in the civilian scientific community, as to when treatment should be initiated and as to the duration of treatment.

The medicolegal aspects involved in a large number of military personnel with internal deposition of Plutonium-239, even though at levels below one body burden, also concerned us. As most of you are well aware, instances of disease or injury due to alleged ionizing radiation exposures during prior military service are increasing in frequency. True, many such claims are absurd, but all of them require at least minimal investigation in order to forestall further unnecessary, time-consuming, and expensive action over non-valid claims. Some such claims are total frauds, perpetrated for individual publicity, financial gain or other factors. As often as not, however, the claims are submitted by well-meaning individuals, who are grasping at straws to explain the origin of their disease. The latest such case in which my staff became involved concerned a schizophrenic beatnik in San Francisco, who was a sometime in-patient at a California State Mental Hospital. During his more lucid intervals, when he would be released on out-patient status, he proved to be an inveterate letter-writer, particularly after he decided that his schizophrenia had been induced by ionizing radiation exposure received during a 4-year tour of duty with the Air Force between 1954-1958. Where and when had he been exposed to this ionizing radiation? In his own words, he had flown over a portion of the State of Nevada en route from Oxnard Air Force Base, near Ventura, California, to a brief TDY at Nellis Air Force Base in Las Vegas, during Operation Plumbob. Review of his records revealed that he had no connection with weapons testing in Operation Plumbob or any other nuclear test. His service medical record was negative for everything except mumps and athlete's foot, both incurred while in service. I might add that this chap wrote letters to the Atomic Energy Commission, the Veterans Administration, and DASA, before settling on the Air Force as the agency responsible for his recent schizophrenia.

With all of the above factors in mind, a small group of USAF Medical Service officers concerned with nuclear weapon accidents met in Omaha, Nebraska, during a spring blizzard late last March, to review the medical aspects of the Palomares Broken Arrow. It was unanimously decided that the USAF Medical Service needed to develop a detailed and long-range program to provide adequate follow-up and treatment, when and if required, for military personnel with internal plutonium deposition resulting from the Palomares Broken Arrow, as well as from any future weapons or laboratory accidents involving internal deposition of plutonium. The concept of a Plutonium Deposition Registry and Registry Board was felt to be the best approach to conducting this program. The program would have three primary purposes:

(1) It would provide adequate follow-up of personnel with internal deposition of plutonium, in order that any possible biological injury would be detected at the earliest possible date, and it would provide, when required, the best possible treatment to reduce body burdens of Plutonium-239.

(2) It would provide the government with complete factual data upon which to evaluate claims for compensation which might subsequently arise.

(3) It would provide the medical profession with additional urgently-needed data with which to manage medical problems resulting in future Broken Arrow or laboratory accidents of a similar nature.

1966

Since that meeting in Omaha last March, the Plutonium Deposition Registry and Board have become a reality. As originally conceived, the Board was to be tri-service in nature, with non-voting liaison members from the Atomic Energy Commission, the Veterans Administration, and Defense Atomic Support Agency. However, to expedite establishment of the Registry and the Registry Board, they were created within the Air Force, and the selection of the USAF Radiological Health Laboratory as the permanent location for the Registry was, of course, an obvious choice since almost all of the plutonium bio-assays following the Palomares Broken Arrow were performed here. Further, the USAF Hospital Wright-Patterson is the single USAF Hospital designated as a specialty center in the treatment of occupational disease. Finally, we have a unique, and, for the purposes of this Registry and its Board, a highly-desirable management situation in the Office of the Surgeon, Air Force Logistics Command here at Wright-Patterson Air Force Base, to which both the USAF Radiological Health Laboratory and this hospital report directly. Colonel Arnoldi and his highly-competent staff are deeply involved and personally interested in all aspects of occupational medicine. Thanks to their cooperation and administrative support, establishment of this Registry and its Board entailed no financial complications whatsoever.

The function of this Registry is, of course, to maintain permanent records of Plutonium-239 bio-assay and other pertinent laboratory and medical data on all military personnel who have received or who will receive internal deposition of Plutonium-239 above such limit as may be established by the Registry Board. Because it was essential to establish some limit within which the USAF Radiological Health Laboratory might operate in the months prior to formal establishment of this Registry and the initial meeting of the Board, the Air Force Medical Service unilaterally selected a cut-off of 9% of one body burden of Plutonium-239 as the level above which personnel would be included in this Registry. This figure is not irrevocably fixed, and it may be raised or lowered at the discretion of the Registry Board. The Registry will have to maintain permanent contact with individuals included in the Registry, and will, at the request of the Board, schedule and perform follow-up laboratory procedures on these individuals. The administrative problems involved in such permanent follow-up are self-evident in view of the increasing mobility of the civilian population in the United States. In the past few months the mobility of military personnel has also proven to be a large problem for the Board. Many of the personnel who received internal deposition of Plutonium-239 in the Palomares clean-up operation have already completed military tours and returned to civilian life. Further, because of the emergency nature of the clean-up operation, large numbers of military personnel were sent to provide assistance in Palomares on emergency temporary duty orders, some of which did not become formalized on paper until a later date. This has entailed administrative problems for the Registry in establishing with certainty the home base of certain personnel on whom urine specimens were forwarded to the laboratory for bio-assay. The current military action in Southeast Asia, the current military withdrawal from France, and the recent withdrawal of the Air Force's Strategic Air Command from Spain, have increased the numbers of personnel transfers, and have further compounded the problem of follow-up of personnel involved in the Palomares Broken Arrow. Thus, long-term follow-up of large numbers of personnel cannot be assumed to be an easy task.

The Registry Board will be responsible for determining who shall be included in the Registry, and what shall be the nature of routine long-term follow-up. The Board will determine when treatment for Plutonium-239 internal deposition is required, will determine the type of treatment indicated, and will supervise treatment, as required. In the event that an individual on the Registry develops a pathologic process related or potentially related to Plutonium-239 internal deposition, the Board will, insofar as possible, insure that complete postmortem studies are performed, the exact nature of these studies to be determined by the Board in cooperation with the Radiation Pathology Register of the Armed Forces Institute of Pathology.

This Board will be required to make some difficult and far-reaching decisions. Fortunately, for the three military services, the Board includes two of the world's most knowledgable scientists in the area of internal deposition of plutonium--Dr. Langham and Dr. Norwood. I want to extend special appreciation to these two gentlemen for consenting to serve on the Board, in view of their already heavy schedules in their own laboratories and elsewhere in the scientific community. I hope that the data available to them through this Registry will prove of value in the programs and studies underway in their own laboratories. Since this Registry and Board are envisioned as completely "non-partisan", we welcome participation by, and free exchange of, information with all interested governmental and quasigovernmental agencies.

Wright-Patterson AFB as a Nuclear Center

Col L. B. Arnoldi, USAF, MC

Col Arnoldi urged the Board and consultants to consider adopting a common format for the recording of radiation exposure (internal and external) data, and that a central repository be set up to maintain this information and retrieve it as desired. Within limits imposed by operating policies, Col Arnoldi placed at the disposal of the Board, the computer and ancillary facilities of Hq Air Force Logistics Command for whatever use they might suggest. Because of the unique resources in the nuclear energy field available at Wright-Patterson AFB, he urged that this base be considered as a nuclear medicine research and operational center.

The USAF Hospital, Wright-Patterson, the Nuclear Engineering Test Facility, and the USAF Radiological Health Laboratory were singled out as the keystones upon which such a center could be built.

Field Operations

Capt J. S. Pizzuto, USAF, BSC

On 17 Jan 66 a B-52 bomber and KC-135 tanker aircraft collided in flight over or near Spanish territory. The resulting impact permitted the uncontrolled dispersion of four nuclear weapons, three of which fell on Spanish soil and one in the Mediterranean Sea.

Immediate search operations located the three devices on the ground and verified that the integrity of two was destroyed. High winds permitted dispersal of 239-plutonium over a wide area.

Because the whereabouts of the fourth weapon remained a matter for speculation, a large-scale search operation continued on land and sea until 26 Mar 66, when it was removed from the sea. Nearly 2000 American personnel participated in the search, and many Spanish Nationals were also involved. During this period the 239-plutonium constituted an inhalation hazard, even though precautions were taken to prevent gross exposure.

Before completion of the task, several tons of topsoil were collected, sealed in barrels, and removed to a national nuclear burial ground in the United States.

Sample Control System

1Lt Harold R. Kaufman, USAF

The sample control system permitted the laboratory to keep accurate records on all samples received for analysis. In addition, it provided a simple, fast, method of recalling data for report generation and statistical analysis.

The combined resources of the punch-card equipment and the Mathatron desk calculator located in the laboratory, and the IBM 7094 DCS located at Aeronautical Systems Division, gives this laboratory a formidable data-processing capability that should be able to meet any requirement placed on it by the Plutonium Deposition Registry Board.

Analytical Chemistry Methods Used in Processing Samples

Maj J. C. Taschner, USAF, BSC

Initial urine samples from personnel involved in the Palomares search and recovery operation were processed, using a gross alpha screening procedure. The steps in this procedure were:

(1) wet ashing of an aliquot of the urine sample with concentrated nitric acid and hydrogen-peroxide to a white ash;

(2) Solubilizing the white ash and coprecipitation of plutonium with bismuth salts;

(3) dissolution with hydrochloric acid followed by the addition of lanthanum carrier before hydrofluoric acid precipitation;

(4) direct mounting of the precipitate on a 2" steel planchet; and,

(5) counting for 120 minutes in an internal proportional counter.

Plutonium-239 spiked pooled urine samples were processed in a like manner to obtain quality control data. Plutonium recoveries of 75.6 ± 19.6 percent (68% confidence) were obtained.

Because of field contamination of initial samples, a resampling program was initiated 2-3 months after the personnel returned to their home base. A procedure which is specific for plutonium was adopted for the resample urines. One-half of the total urine sample was adjusted to pH 2 with concentrated nitric acid. A plutonium-236 internal tracer was added to each sample for quality control. The sample was then heated to boiling to break any metabolic complex-binding plutonium. The plutonium was coprecipitated with the alkaline earth phosphates by adjusting the urine sample to pH 10 with concentrated ammonium-hydroxide. The salts were dissolved in nitric acid and coprecipitated with radio-chemically-pure cerium by adjusting to pH 4.5. This precipitate was dissolved in hydrochloric acid and passed through an anion-exchange column which adsorbs the plutonium. Interfering anions adsorbed on the column were removed by washing with hydrochloric acid. Hydriodic acid was used to elute the plutonium from the ion-exchange column. The plutonium was changed to the sulfate salt by heating the evaporated column residue in sulfuric acid. The solution was adjusted to approximately pH 3 and electroplated on a one-half inch steel planchet. A solid state alpha spectrometer was used to measure the plutonium alpha activity present. Plutonium recoveries of 75.6 ± 16.2 percent (68% confidence) were obtained.

Counting Procedures for 239-Plutonium in Urine

Capt R. G. Thomas, USAF, BSC

I. Counting procedures used for initial samples:

Samples were counted, using Nuclear Measurement Corporation PC-3A, windowless, gas-flow proportional counters. Daily checks were made on instrument performance by counting reference standards of 239-Pu, to insure constancy of counting efficiency. Samples were counted for 120 minutes and backgrounds were counted daily, normally for 960 minutes. The daily background counts also served as checks on contamination; the counting chambers were decontaminated when background became greater than 0.1 count per minute. Normal backgrounds ranged from 0.02-0.06 count per minute.

Sample activity was calculated from the following expression:

pCi/sample =

$$\frac{(\text{gross counts/gross ctg time}) - (\text{bkg counts/bkg ctg time})}{(\text{counting efficiency})(2.22)\ (\text{procedural yield})}$$

II. Counting procedures used for resamples:

The detectors were solid-state surface-barrier types mounted in a vacuum chamber. Charge sensitive preamplifiers, designed and built by Mr. Robert L. Farr of the laboratory staff, were used to amplify signals from the detector. Output from the preamplifiers was fed to a Nuclear Data 130 AT multichannel analyzer. Readout from the analyzer was in the form of typewriter printout.

Using an electroplated source containing known activities of 239-Pu and 236-Pu, instrument performance was checked each morning before beginning counting, and normally, an additional time each afternoon. The performance check consisted of observing the peak channels for 239-Pu and 236-Pu, and adjusting the gain of the amplifier system, if necessary, to correct for any gain shifts. Additionally, the counting efficiency of the system was checked at the same time, to insure constancy.

Background counts were made each night for 800 minutes' duration, with a blank planchet in the counting chamber. The daily background count also served as a check for any possible contamination in the counting chamber. Samples were routinely counted for 100 minutes.

The data was collected in an analyzer memory of 255 storage positions. Total counts in two bands, centered on the peak channels of 239-Pu and 236-Pu, and each containing 11 storage locations, were totaled and used for the sample activity calculations. The same bands were used for both sample and background determinations. Sample activity was calculated from the following expression:

$$\text{pCi/sample} = \frac{(\text{net cpm in 239-Pu band}) \times (\text{dpm 236-Pu added})}{(\text{net cpm in 236-Pu band} \times (2.22)}$$

where

$$\text{net cpm in 239-Pu band} = \left[\frac{\text{gross cts 239-Pu band}}{\text{gross ctg time}} - \frac{\text{bkg cts in 239-Pu band}}{\text{bkg ctg time}} \right]$$

$$\text{net cpm in 236-Pu band} = \left[\frac{\text{gross cts 236-Pu band}}{\text{gross ctg time}} - \frac{\text{bkg cts 236-Pu band}}{\text{bkg ctg time}} \right]$$

dpm 236-Pu added = activity of 236-Pu spike added to sample corrected for decay to date of count.

RESULTS

Initial Urine Samples--Alpha Activity

LtCol L. T. Odland, USAF, MC

	Air Force	Army	Navy	Other	Total
Number analyzed	1389	107	37	38	1571
BB* greater 100%**	19(0)	1(0)	0	0	20
BB 0.99 to 0.09	361	33	5	8	407
BB 0.09 to 0.009	487	23	20	7	537
BB less than 0.009	522	50	12	23	607

* Systemic body burden (bone, critical organ)--calculated on the basis of urinary excretion according to expression

$$D = 435\ U\ t^{0.76}$$

where D = systemic body burden

U = 239-Pu activity in 24-hour sample

t = time in days from exposure to sampling

** Value of 0.044 μCi 239-Pu for D represents one body burden or 100%.

RESULTS

Miscellaneous Samples

LtCol L. T. Odland, USAF, MC

WATER

Samples analyzed	40
No detectable activity	7
Range of 0.1 to 633 pCi/liter	33
Median value of 1.64 pCi/liter	

VEGETATION SWIPES

Total swipes counted	78
No detectable activity	63
Range of 0.1 to 4.3 pCi	13

NASAL SWIPES

Total swipes counted	120
No detectable activity	70
Range of 1.0 to 337 dpm	50
Mean 24.4, S.D. 48.0, median 13 dpm	

RESULTS--Miscellaneous Samples

SOIL

Total samples -- gamma scan	23

Peaks at 60, 27, 16, 110, 185 Kev

VEGETATION

Samples too active for processing

RESULTS

Resampling Program
(As of 1 Nov 1966)

LtCol L. T. Odland, USAF, MC

	Air Force	Army	Navy	Other	Total
BB* greater 10%	6	0	0	0	6
BB 1 to 10%	162	10	5	0	177
BB less 1%	36	11	1	1	49
BB zero	124	9	2	6	141
	328	30	8	7	373
Number requested	(363)	(33)	(5)	(8)	(409)

*BB defined as systemic body burden (bone, critical organ).

Analysis of BB Greater 1% Group

(183 Samples)

	Mean	SD	Median	Range
239-Pu (curies x 10^{-15})	93	63	77	26-390
236-Pu spike (% recovery)	76	13	75	43-109
Sample volume (liters)	1.3	0.5	1.2	.29-3.1
Elapsed time (days)	147	25	140	110-237
BB (%)	4	3	3	1-16

SUMMARY OF DISCUSSIONS:

Use of the term "body burden. Dr. Norwood expressed objection to the use of the term "body burden" in presenting results. He stated the term is misleading since it could be interpreted to include the entire body when, in reality, it refers only to that portion of 239-Pu distributed by systemic circulation, and, in no way, reflects that which may be fixed in thoracic viscera. Dr. Norwood further stated that correction values have been suggested to permit estimating lung burden from system burden. Depending on various factors, a correction of 10-100 could be applied to systemic burden to estimate lung burden.

Dr. Langham stated that the formula he developed for use in estimating body burden was never intended to apply to lung burdens. He related some of the history of his early work and that of colleagues on this problem, and questioned the whole concept of critical organ in relation to inhalation exposures of 239-Pu. Systemically, the bone is considered the critical organ, while in the chest it may be lung or lymph nodes, or both, but in the case of inhalation exposures, the thoracic viscera may be the important tissue with bone receiving only an insignificant dose. In summary, Dr. Langham stated that he did not like the application of corrective factors to body burden to estimate lung burdens, particularly when the corrective factor varies by at least a factor of 10, and the basis upon which this value is derived is somewhat nebulous. Dr. Norwood agreed that it was difficult to assign a corrective factor to body burden in order to arrive at the lung burden. Several other attendees voiced their feelings on this problem, and the consensus was that lung burdens, under conditions of uncontrolled acute inhalation exposures, are impossible to accurately measure at this time.

In an effort to more accurately present analytical results, the term body burden will be modified to reflect its reference to systemic with bone as the critical organ, and, in addition, absolute terms of activity per sample will also be reported along with sample volume, elapsed time, etc.

Reporting of Results. The question was raised whether or not the individual results should be reported back to appropriate units of assignment and entered in medical records. One objection to reporting results was that they may be misinterpreted at the local level, and perhaps set the stage for legal action. Dr. Norwood felt the results should be reported because the doctors involved must be given this information. LtCol Froemming stated that the Army wanted something entered in the medical records, but was not firm on just what form the entry should take. Cmdr Tedford stated the Navy did not want their results entered in medical records, and that the USAF Radiological Health Laboratory should maintain these records as a part of a repository from which the data could readily be retrieved when desired. General Talbot stated that the question, insofar as the Air Force was concerned, should be studied by legal advisors prior to a decision.

It was decided that the USAF Radiological Health Laboratory would send results of bio-assay work to the appropriate Surgeon General for deposition and recording, as he saw fit. Dr. Johnston pointed out that exposures or body burdens of 239-Pu do not have to be given to the individual concerned since this material does not come under the provisions of 10CFR.

GENERAL DISCUSSION:

Item Nr 1 -- Should continued efforts be made to secure initial and/or repeat samples on all personnel who have not been tested but who were in the area?

The board recommended that continued efforts should be made to secure initial samples from individuals who participated in the operation and departed the area without submitting a specimen. In addition, it recommended that continued effort be made to secure a second sample from individuals whose initial sample contained sufficient activity to suggest a systemic body burden in excess of 9%, and who failed to respond to the resampling program. The maximum extent of this effort should consist of two letters soliciting cooperation, and one telephone call. Accurate records will be kept of the communications, since the primary reason for the continued effort is to demonstrate a reasonable effort to screen every individual involved. The board felt that it was extremely unlikely that any individual would display excretion values at significant variance from those obtained to date.

Item Nr 2 -- Does the board recommend resampling of individuals whose initial urine samples showed less than 9% of one body burden?

The board recommended that no further effort be devoted to resampling individuals whose initial urine sample showed activity suggesting a systemic body burden less than 9%.

Item Nr 3 -- At what level of body burden, if any, obtained on resampling does the board recommend continued follow-up? What should be the nature and frequency of such follow-up, if recommended?

Dr. Langham pointed out that the results of the bio-assay program were very good in terms of preventive medicine and risks to individual patients, but insofar as providing a basis for follow-up and long-term study, they provided little reason for enthusiasm. Dr. Norwood concurred in this observation, as did other attendees, all agreeing that the bio-assay data showed levels of activity far below those necessary for a meaningful follow-on program to assess excretion patterns, use of whole-body counting techniques, etc. Capt Skow stated that no follow-up effort should be devoted to any individual whose systemic body burden was less than 50%. Dr. Norwood suggested continued bio-assay studies on all individuals whose systemic body burden was 9% or greater. After more discussion on this point, it was agreed that continued follow-up bio-assay studies at a frequency of once every two months would be done on the highest 10% of the resampling group that showed a systemic body burden of between 1-10%. This number would be about 17, and would include some with systemic body burdens as low as 7%. Considerable discussion centered around the possibility of inciting undue concern in these individuals, perhaps to the point of legal action for compensation. However, this was realized, and a certain probability of risk had to be accepted if any follow-up program was to be pursued. All attendees agreed that whole-body counting techniques are not sufficiently refined to be utilized in any follow-up program on this group, and, certainly, there was no indication for treatment.

Item Nr 4 -- Should whole-body counting techniques be developed by the U. S. Air Force for detection of 239-Pu-241-Am as an additional tool, in the event of future similar incidents? If affirmative, what type of hardware is recommended?

This subject stimulated a lengthy and detailed discussion on the whole problem of in vivo assay of 239-Pu-241-Am using whole-body counting techniques. Dr. Norwood and Mr. Newton discussed the advances that have been made on the problem, and felt that it was just a matter of months before the hardware would be perfected. Dr. Langham related the experience of his group and others in building a device suitable for detection of 239-Pu in vivo and the application of it to the Spanish incident. He further related that detection can be done, but the problem of quantitating what is detected is still formidable. Apparently, levels on the order of nanocuries in the thorax can be detected, either by counting 239-Pu or via extrapolation of 241-Am content. It became obvious, as the discussions continued, that whole-body counting was possible, but that no one is willing to categorically state their limits of detectability, or advertise as being operational and ready to accept candidates. Dr. Dunning expressed a personal opinion that the USAF Radiological Health Laboratory should develop a capability in this area if it is to be more adequately prepared for the next Broken Arrow. Dr. Langham and Mr. Newton advised caution on development of whole-body counting techniques by the USAF because of the developmental effort going forth in other quarters. However, Dr. Langham felt such experience would be valuable for the USAF in that it would place it in a much more ready position for future incidents, but certainly could be of no value in this (Palomares) incident.

LtCol Woodward asked where assistance would be available in the event the Army experienced a Broken Arrow of significant proportions. Specifically, he wanted to know what one group had facilities for whole-body counting, treatment and bio-assay. Dr. Norwood stated his group had capability to handle a small (5-8) number of patients, could do bio-assay tests in large numbers, and would soon have whole-body counting facilities. Col Hennessen stated his hospital census was running over 90%, but he could handle perhaps up to 20 patients at any given time.

No specific recommendations were obtained with respect to the type of hardware that should be used.

Item Nr 5 -- By using ratios of 239-Pu to 241-Am in the weapon, soil, and urine, is it possible to determine the 239-Pu content of the lungs using 241-Am values determined by whole-body counting techniques?

Mr. Newton reviewed data on recent studies of 241-Am and 239-Pu in laboratory animals following inhalation exposures which indicated that americium may move out of the lungs faster than 239-Pu under certain experimental conditions. In these studies the ratio of 239-Pu to 241-Am varied by a factor of 2 from what it was in the inhaled material.

Messrs Sheehan and Wood presented bio-assay (urine) excretion data on five individuals who have appreciable systemic body burdens of 238-Pu as a result of inhalation exposures. The information suggested that at about 150 days after an acute exposure the urinary excretion values parallel quite closely with those predicted by a computer model, and that both follow Langham's equation quite well, subsequent to this time period.

While certainly not applicable to exposures under consideration, it was conceded that if future Broken Arrow incidents resulted in inhalation and retention of nanocuries or more of 239-Pu and the attendant 241-Am, using the ratio of the two in the weapon, and determining a similar relationship in soil and urine, estimates based on whole-body assay of 241-Am by <u>in vivo</u> counting would give an estimate of thoracic burden no farther removed from reality than other methods or extrapolations currently available.

<u>FoE Attachment 3</u>

D. Philipps, "Troops Who Cleaned Up Radioactive Islands Can't Get Medical Care,"
N.Y. Times (Jan. 28, 2017)

The New York Times | https://nyti.ms/2jIkRXf

U.S.

Troops Who Cleaned Up Radioactive Islands Can't Get Medical Care

By DAVE PHILIPPS JAN. 28, 2017

RICHLAND, Wash. — When Tim Snider arrived on Enewetak Atoll in the middle of the Pacific Ocean to clean up the fallout from dozens of nuclear tests on the ring of coral islands, Army officers immediately ordered him to put on a respirator and a bright yellow suit designed to guard against plutonium poisoning.

A military film crew snapped photos and shot movies of Mr. Snider, a 20-year-old Air Force radiation technician, in the crisp new safety gear. Then he was ordered to give all the gear back. He spent the rest of his four-month stint on the islands wearing only cutoff shorts and a floppy sun hat.

"I never saw one of those suits again," Mr. Snider, now 58, said in an interview in his kitchen here as he thumbed a yellowing photo he still has from the 1979 shoot. "It was just propaganda."

Today Mr. Snider has tumors on his ribs, spine and skull — which he thinks resulted from his work on the crew, in the largest nuclear cleanup ever undertaken by the United States military.

FoE-79

Roughly 4,000 troops helped clean up the atoll between 1977 and 1980. Like Mr. Snider, most did not even wear shirts, let alone respirators. Hundreds say they are now plagued by health problems, including brittle bones, cancer and birth defects in their children. Many are already dead. Others are too sick to work.

The military says there is no connection between these illnesses and the cleanup. Radiation exposure during the work fell well below recommended thresholds, it says, and safety precautions were top notch. So the government refuses to pay for the veterans' medical care.

Congress long ago recognized that troops were harmed by radiation on Enewetak during the original atomic tests, which occurred in the 1950s, and should be cared for and compensated. Still, it has failed to do the same for the men who cleaned up the toxic debris 20 years later. The disconnect continues a longstanding pattern in which the government has shrugged off responsibility for its nuclear mistakes.

On one cleanup after another, veterans have been denied care because shoddy or intentionally false radiation monitoring was later used as proof that there was no radiation exposure.

A report by The New York Times last spring found that veterans were exposed to plutonium during the cleanup of a 1966 accident involving American hydrogen bombs in Palomares, Spain. Declassified documents and a recent study by the Air Force said the men might have been poisoned, and needed new testing.

But in the months since the report, nothing has been done to help them.

For two years, the Enewetak veterans have been trying, without success, to win medical benefits from Congress through a proposed Atomic Veterans Healthcare Parity Act. Some lawmakers hope to introduce a bill this year, but its fate is uncertain. Now, as new cases of cancer emerge nearly every month, many of the men wonder how much longer they can wait.

'Plutonium Problems'

The cleanup of Enewetak has long been portrayed as a triumph. During the operation, officials told reporters that they were setting a new standard in safety. One report from the end of the cleanup said safety was so strict that "it would be difficult to identify additional radsafe precautions that could have been taken."

Documents from the time and interviews with dozens of veterans tell a different story.

Most of the documents were declassified and made publicly available in the 1990s, along with millions of pages of other files relating to nuclear testing, and sat unnoticed for years. They show that the government used troops instead of professional nuclear workers to save money. Then it saved even more money by skimping on safety precautions.

Records show that protective equipment was missing or unusable. Troops requesting respirators couldn't get them. Cut-rate safety monitoring systems failed. Officials assured concerned members of Congress by listing safeguards that didn't exist.

And though leaders of the cleanup told troops that the islands emitted no more radiation than a dental X-ray, documents show they privately worried about "plutonium problems" and areas that were "highly radiologically contaminated."

Tying any disease to radiation exposure years earlier is nearly impossible; there has never been a formal study of the health of the Enewetak cleanup crews. The military collected nasal swabs and urine samples during the cleanup to measure how much plutonium troops were absorbing, but in response to a Freedom of Information Act request, it said it could not find the records.

Hundreds of the troops, though, almost all now in their late 50s, have found one another on Facebook and discovered remarkably similar problems involving deteriorating bones and an incidence of cancer that appears to be far above the norm.

A tally of 431 of the veterans by a member of the group shows that of those who stayed on the southernmost island, where radiation was low, only 2 percent reported having cancer. Of those who worked on the most contaminated islands in the north, 20 percent reported cancer. An additional 34 percent from the contaminated islands reported other health problems that could be related to radiation, like failing bones, infertility and thyroid problems.

Budget Cuts and the Cleanup

Between 1948 and 1958, 43 atomic blasts rocked the tiny atoll — part of the Marshall Islands, which sit between Hawaii and the Philippines — obliterating the native groves of breadfruit trees and coconut palms, and leaving an apocalyptic wreckage of twisted test towers, radioactive bunkers and rusting military equipment.

Four islands were entirely vaporized; only deep blue radioactive craters in the ocean remained. The residents had been evacuated. No one thought they would ever return.

In the early 1970s, the Enewetak islanders threatened legal action if they didn't get their home back. In 1972, the United States government agreed to return the atoll and vowed to clean it up first, a project shared by the Atomic Energy Commission, now called the Department of Energy, and the Department of Defense.

The biggest problem, according to Energy Department reports, was Runit Island, a 75-acre spit of sand blitzed by 11 nuclear tests in 1958. The north end was gouged by a 300-foot-wide crater that documents from the time describe as "a special problem" because of "high subsurface contamination."

The island was littered with a fine dust of pulverized plutonium, which if inhaled or otherwise absorbed can cause cancer years or even decades later. A millionth of a gram is potentially harmful, and because the isotopes have a half-life of 24,000 years, the danger effectively never goes away.

The military initially quarantined Runit. Government scientists agreed that other islands might be made habitable, but Runit would most likely forever be too toxic, memos show.

So federal officials decided to collect radioactive debris from the other islands and dump it into the Runit crater, then cap it with a thick concrete dome.

The government intended to use private contractors and estimated the cleanup would cost $40 million, documents show. But Congress balked at the price and approved only half the money. It ordered that "all reasonable economies should be realized" by using troops to do the work.

Safety planners intended to use protective suits, respirators and sprinklers to keep down dust. But without adequate funding, simple precautions were scrapped.

Paul Laird was one of the first service members to arrive for the atoll's cleanup, in 1977. Then a 20-year-old bulldozer driver, he began scraping topsoil that records show contained plutonium. He was given no safety equipment.

"That dust was like baby powder. We were covered in it," said Mr. Laird, now 60, during an interview in rural Maine, where he owns a small auto repair shop. "But we couldn't even get a paper dust mask. I begged for one daily. My lieutenant said the masks were on back order so use a T-shirt."

By the time Mr. Laird left the islands, he was throwing up and had a blisterlike rash. He got out of the Army in 1978 and moved home to Maine. When he turned 52, he found a lump that turned out to be kidney cancer. A scan at the hospital showed he also had bladder cancer. A few years later he developed a different form of bladder cancer.

His private health insurance covered the treatment, but co-payments left him deep in debt. He applied repeatedly for free veterans' health care for radiation but was denied. His medical records from the military all said he had not been exposed.

"When the job was done, they threw my bulldozer in the ocean because it was so hot," Mr. Laird said. "If it got that much radiation, how the hell did it miss me?"

Scant Avenues for Help

As the cleanup continued, federal officials tried to institute safety measures. A shipment of yellow radiation suits arrived on the islands in 1978, but in interviews veterans said that they were too hot to wear in the tropical sun and that the military told them that it was safe to go without them.

The military tried to monitor plutonium inhalation using air samplers. But they soon broke. According to an Energy Department memo, in 1978, only a third of the samplers were working.

All troops were issued a small film badge to measure radiation exposure, but government memos note that humid conditions destroyed the film. Failure rates often reached 100 percent.

Every evening, Air Force technicians scanned workers for plutonium particles before they left Runit. Men said dozens of workers each day had screened positive for dangerous levels of radiation.

"Sometimes we'd get readings that were all the way to the red," said one technician, David Roach, 57, who now lives in Rockland, Me.

None of the high readings were recorded, said Mr. Roach, who has since had several strokes.

Two members of Congress wrote to the secretary of defense in 1978 with concerns, but his office told them not to worry: Suits and respirators ensured the cleanup was conducted in "a manner as to assure that radiation exposure to individuals is limited to the lowest levels practicable."

Even after the cleanup, many of the islands were still too radioactive to inhabit.

In 1988, Congress passed a law providing automatic medical care to any troops involved in the original atomic testing. But the act covers veterans only up to 1958, when atomic testing stopped, excluding the Enewetak cleanup crews.

If civilian contractors had done the cleanup and later discovered declassified documents that show the government failed to follow its own safety plan, they could sue for negligence. Veterans don't have that right. A 1950 Supreme Court ruling bars troops and their families from suing for injuries arising from military service.

The veterans' only avenue for help is to apply individually to the Department of Veterans Affairs for free medical care and disability payments. But the department bases decisions on old military records — including defective air sampling and radiation badge data — that show no one was harmed. It nearly always denies coverage.

"A lot of guys can't survive anymore, financially," said Jeff Dean, 60, who piloted boats loaded with contaminated soil.

Mr. Dean developed cancer at 43, then again two years later. He had to give up his job as a carpenter as the bones in his spine deteriorated. Unpaid medical bills left him $100,000 in debt.

"No one seems to want to admit anything," Mr. Dean said. "I don't know how much longer we can wait, we have guys dying all the time."

Correction: February 5, 2017

An article last Sunday about medical problems among soldiers who cleaned up the fallout from nuclear tests on Enewetak Atoll misstated, in some editions, the type of cancer that one service member, Paul Laird, learned he had after turning 52. It was kidney — not testicular — cancer. An accompanying picture caption also misstated Mr. Laird's age in some editions. As the article correctly noted, he is 60, not 59.

A version of this article appears in print on January 29, 2017, on Page A1 of the New York edition with the headline: Veterans Feel Cost of U.S. Nuclear Tests.

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