Workers in the Cannikin shaft, Amchitka Island, 1971. (U.S. Department of Energy photograph)

NUCLEAR Flashback

PART TWO:
The Threat of the U.S. Nuclear Complex

A report confirming radioactive leakage into the Bering Sea from the world's largest underground nuclear explosion

Authors:
Norm Buske, Nuclear-Weapons-Free America
Pamela K. Miller, Alaska Community Action on Toxics

February 1998

A quarter-century of Greenpeace nuclear criticism culminates in this report. Greenpeace now spins this work off in two directions:

Norm Buske
Nuclear-Weapons-Free America
785 20th Street, #3
Boulder, CO 80302
303.415.1504 phone/fax
search@igc.org

Pamela K. Miller
Alaska Community Action on Toxics
135 Christensen Drive
Anchorage, AK 99501
907.222.7714 phone
907.222.7715 fax
acat@akcf.org

Nuclear-Weapons-Free America aims to end U.S. deployment of weapons of mass destruction with their attendant risks of catastrophic planetary losses.

Alaska Community Action of Toxics seeks to protect environmental and human health by eliminating sources of toxic and radioactive pollution.

Photo courtesy U.S. Department of Energy

The Cannikin nuclear bomb is lowered into the Earth. Amchitka Island, 1971.

The authors wish to thank:
Jay Stange, editing and graphics
Karen Button, cover design
Bev Aleck
Dr. Lorraine Eckstein
Carl Hild
Bill Keller
Jerry Leitch
Flore Lekanof

and

Alaska Technical Advisory Group members
U.S. Department of Energy
Environmental Protection Agency

Table of Contents

Summary: Chronicle of a Department of Energy Cover-Up at Amchitka

This report confirms radioactive leakage into the Bering Sea from the world's largest underground nuclear explosion. Government data show americium-241 leaking from all three nuclear blast sites under Amchitka Island, Alaska. Americium-241 is a radionuclide with a 433-year half-life. It is produced by the decay of plutonium that fueled the bombs. The full extent of the leakage from the Amchitka nuclear blast sites is yet unknown.

The U.S. Department of Energy (DOE) undertook its own study in 1997, under public oversight, to check Greenpeace's 1996 discovery of radioactive leakage. Since then, DOE continues to corrupt the scientific data and has no current completion schedule. Greenpeace scientists provided oversight of the 1997 DOE sampling program and subsequent analytical work.

This report blows the whistle on DOE's cover-up of radioactive leakage from all three underground nuclear explosions detonated on Amchitka Island. 1997 DOE data confirm radioactive springs near the Cannikin and Long Shot blast sites, on the Bering Sea side of Amchitka Island. Clevenger Creek, flowing past the Milrow blast site into the Pacific Ocean, is also contaminated with americium-241. Government data reveal cobalt-60 traces in the radioactive "fingerprint."

The Atomic Energy Commission (DOE's predecessor) claimed that nuclear waste from the three Amchitka detonations would be contained for hundreds, if not thousands, of years. Both the 1996 and 1997 investigations clearly reveal radioactive leakage.

Nuclear Flashback Part 2 chronicles problems encountered by independent scientists when results do not conform with the government's vested interests. Norm Buske analyzed more than 1,600 pages of DOE's own data to trace the government's corruption of sample gathering, data management, violations of laboratory operating procedures, analyses, and subsequent reporting delays. Greenpeace's unique public oversight role in this study provides a first-hand look at methods by which the Department of Energy disavows evidence of radioactive leakage at Amchitka. This is the "Amchitka example" of a system-wide problem at DOE.

The radioactive leakage from Amchitka is a harbinger of a deep and pervasive problem with the safety of the U.S. nuclear weapons arsenal. DOE's technical failures call into question the agency's ability to adequately manage the vast U.S. nuclear complex. Failures of government management of nuclear technology pose a clear and present danger to the American public.

Background: Amchitka Nuclear Blasts and the Public Storm of Protest

The U.S. Department of Defense and Atomic Energy Commission detonated three underground nuclear blasts on the Aleutian island of Amchitka, Alaska between 1965 and 1971. Government officials used Amchitka as a nuclear test site for underground nuclear blasts deemed too large for the Nevada Test Site near Las Vegas.

The 80,000 ton Long Shot explosion was detonated on October 29, 1965 at 2,300 feet below the island's surface. Milrow was the code name for the second nuclear test on Amchitka, a one million-ton "calibration test" of the AEC, detonated at 4,000 feet on October 2, 1969. Milrow was designed to determine whether the island could contain a much larger test of the Spartan anti-ballistic warhead. The 5 million-ton Cannikin test (at 5,875 feet) was the world's largest underground nuclear explosion—equivalent in destructive yield to 5,000,000 tons of TNT.

All three nuclear explosions at Amchitka were detonated below the island's water table and below sea level in apparent violation of the 1963 Limited Test Ban Treaty. AEC asserted that the radioactivity would be contained despite the fact that the tests were detonated within a saturated environment and in a volcanic substrate fraught with cracks and fissures. Long Shot vented radioactive krypton and tritium in the months and years following the blast in 1965. Within two days after the Cannikin test in 1971, the Cannikin shaft collapsed with a mechanical breach, forming a subsidence crater over one mile wide and 60 feet deep. During May of 1972, samples from the Cannikin shaft revealed venting of about 14,000 cubic feet of radioactive krypton-85 gas with concentrations of 200,000 femtocuries per milliliter. This was the first radiological evidence of a containment breach at Cannikin, yet AEC did not reveal the incident publicly.

Cannikin alone produced about 13% of the total radioactive waste from the entire U.S. underground nuclear testing program because the 5 megaton blast constitutes 13% of the total yield of all U.S. underground nuclear explosions. The Cannikin nuclear explosion detonated at 385 times the explosive power of the nuclear bomb that devastated Hiroshima.

Vigorous and sustained protests and legal action from Aleut communities, scientists, physicians, environmental and social justice organizations failed to stop the Cannikin blast. The momentum from the Cannikin grassroots campaign catalyzed an international movement for ecological integrity and peace. Greenpeace was born through the grassroots campaign against the Cannikin test. Motivated by the Quaker tradition of bearing witness, twelve people set sail from Vancouver to stop the nuclear explosion at Amchitka. Although stormy weather and initial postponement of the test prevented the crew from the *F/V Phyllis Cormack* from reaching Amchitka, this first Greenpeace action became a dramatic focal point for an international movement by citizen activists and scientists.

Twenty-five years later, in 1996, Greenpeace was compelled to organize a small, scientific expedition to the island of Amchitka, located 1340 miles southwest of Anchorage, Alaska along the Aleutian archipelago. In October 1996, Greenpeace released "Nuclear Flashback—the Return to Amchitka: Report of a Greenpeace Scientific Expedition to Amchitka Island, Alaska—Site of the Largest Nuclear Test in U.S. History." Greenpeace's 1996 "Nuclear Flashback" report first announced the discovery of radioactive

leakage from Amchitka after 25 years of AEC and DOE denial.

Since the release of the 1996 Nuclear Flashback report, many workers and their families have expressed concern over potential radiation exposures and the prevalence of related cancers and illnesses among the population of Amchitka workers. The unions representing the workers are seeking information concerning sources of radioactive exposure and independent health studies. The Aleutian and Pribilof Islands Association (APIA), representing the subsistence-based Aleut communities along the Aleutian chain, is working to protect the health of Aleut people and insure conduct of independent, comprehensive studies of the environment and subsistence resources in the vicinity of Amchitka. Greenpeace has continued to work in cooperation with the unions, APIA, and others in oversight of the Department of Energy and in the pursuit of the truth concerning the impacts of Amchitka blasts on the environment and human health. Alaska Community Action on Toxics (co-author Pamela Miller, ACAT Project Director) and Nuclear-Weapons-Free America (author and project oversight scientist Norm Buske) now continue the work begun by Greenpeace.

Conclusions from 1997 Sampling Program

- Long-Shot, Milrow, and Cannikin—the three underground nuclear explosion sites on Amchitka Island—are leaking long-lived radioactivity into the open, aquatic environment at several times the background level.

- The 1997 data confirm Greenpeace's 1996 findings of americium-241 leakage at Long Shot and Cannikin. In addition, cobalt-60 is co-leaking. The 1997 data also demonstrate that Milrow is leaking americium-241 into Clevenger Creek.

- Radioactive leakage on Amchitka is a local, but likely increasing environmental problem. The full extent of the problem is difficult for the public to determine in the face of continuing DOE obfuscation.

- DOE has delayed completion of the 1997 Amchitka study and managed serious data corruption.

- The government is not using objective radiological studies nor modern scientific methods to rationally manage the most dangerous technology on earth. Instead, DOE uses its technical resources as public-relations ploys to counter legitimate concerns for the safety of this technological complex which is owned and operated by DOE and the Department of Defense.

- The technical and managerial failures of the U.S. nuclear weapons complex show DOE has fallen far behind mainstream science and technology in management of the U.S. nuclear weapons complex. Substandard DOE management of the vast U.S. nuclear arsenal poses real and present dangers of system-wide, catastrophic, global accidents which threaten America and the world.

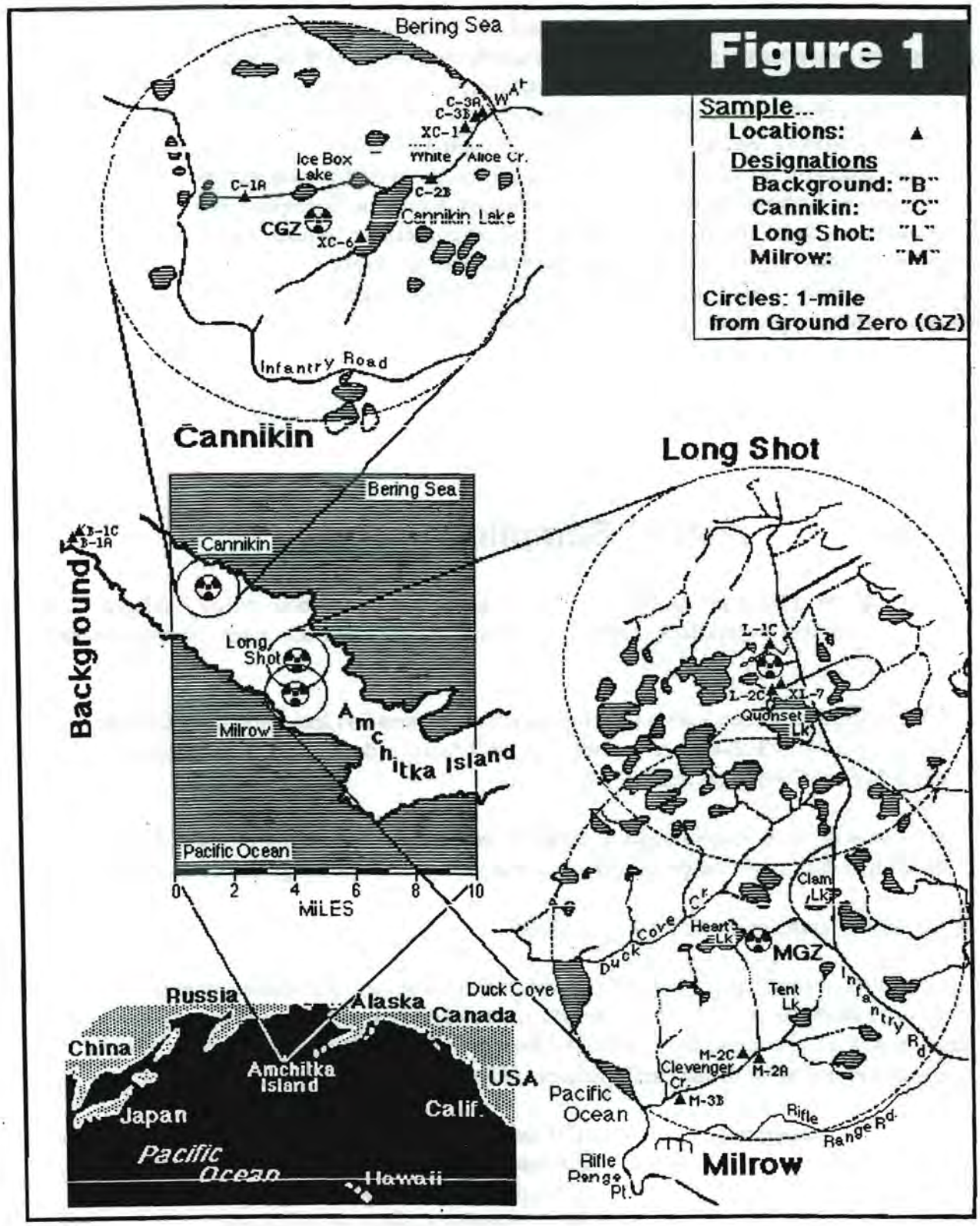


Figure 1
Sample...
Locations: ▲
Designations
Background: "B"
Cannikin: "C"
Long Shot: "L"
Milrow: "M"
Circles: 1-mile from Ground Zero (GZ)
Bering Sea
C-3A
C-3B
XC-1
White
Alice Cr.
Ice Box Lake
C-1A
C-2B
Cannikin Lake
CGZ
XC-6
Infantry Road
Cannikin
Long Shot
Background
Bering Sea
Cannikin
Long Shot
Milrow
Amchitka Island
Pacific Ocean
0 2 4 6 8 10
MILES
L-1C
L-2C
XL-7
Quonset Lk
Clam Lk
Heart Lk
MGZ
Duck Cove
Duck Cove Cr.
Tent Lk
Infantry Rd.
M-2C
M-2A
Clevenger Cr.
M-3B
Rifle Range Rd.
Rifle Range Pt.
Milrow
Pacific Ocean
Russia
Alaska
Canada
China
Amchitka Island
USA
Japan
Calif.
Pacific Ocean
Hawaii

The Truth is Leaking Out : Independent Monitoring of Radiation Leakage at U.S. and French Nuclear Test Sites

During the 1960s and 1970s, citizen activists developed the scientific expertise to challenge government assurances of nuclear arsenal safety. These independent investigations produced a specialized consensus of the underlying technical and managerial failures of the nuclear weapons states.

Rocky Flats

A large fire broke out on 11 May 1969 at the Rocky Flats plutonium processing plant outside Denver. The Atomic Energy Commission assured the public there was no reason for concern. But the Colorado Committee for Environmental Information retained radiochemists who analyzed the extent of plutonium migration, which received national press coverage. A new technological age of activism had begun.

Hanford

By the 1980s, the image of the American nuclear weapons complex as an example of modern technology run by the best and brightest minds in the country began to fail. Citizen groups demanded truth and clean-up at DOE nuclear materials facilities across the country. Greenpeace pioneered joint sampling with states and DOE beginning in 1985.

The first joint sampling program with Greenpeace sampled shoreline seeps from the Hanford Nuclear Reservation into the Columbia River in Washington State. A study of groundwater migration under Hanford in 1986 revealed migration of radioactivity in groundwater from Hanford facilities into the Columbia River in a fraction of the time DOE had estimated in its assurances.[1] After these revelations, DOE abandoned its proposal to site the nation's first high-level radioactive waste repository under Hanford and instead shut down its N-Reactor, which was discharging strontium-90 into trenches next to the Columbia River bank.

Moruroa

The year after the *Phyllis Cormack* crew set sail to protest the Cannikin shot marked another wave of citizen oversight of the world's nuclear weapons complex. David McTaggart, a 39 year-old Canadian industry drop-out, sailed the 11-meter ketch *Vega* from Auckland, New Zealand to put his body and his boat in the way of fallout from French nuclear shots above Moruroa Atoll.[2] The conflict over this site 7,000 miles south of Amchitka escalated until the French mined the Greenpeace vessel Rainbow Warrior in Auckland harbor on 11 July 1985, killing photographer Fernando Pereira.

After the sinking of the *Rainbow Warrior*, Greenpeace began to develop methods for measuring radioactivity leaking out from Moruroa. So the scientific activism underway on the Columbia River at Hanford was broadened. In October 1990, a clone of the gamma spectrometer used in the Hanford work was installed in a specially constructed closet amidships on Greenpeace's new *Rainbow Warrior*, and the problem of bringing a modern laboratory on-line on the high seas commenced.

By the time the boat reached the French nuclear test site close to Tahiti in early December, all the salt-aired, steel-hull-interferenced electronics were tenuously working. With sampling timed to tides, currents, and diurnal migration of plankton, Greenpeace confirmed, on-board, the nuclear activation product cesium-134 (first reported by Jacques Cousteau in 1987) in plankton, in international waters, 12 miles from the Moruroa Atoll.[3] A banner in Greenpeace's Auckland, New Zealand office carried the message: THE TRUTH IS LEAKING OUT. The truths of the French nuclear testing program in the South Pacific spread, and under worldwide protest, France finally closed its South Pacific Nuclear Test Site in 1995.

Puget Sound Naval Shipyard

With an end to the Cold War in the early 1990s, the scientific approach to nuclear activism turned to linking small-but-denied nuclear accidents by the U.S. Navy with dangers of nuclear weaponry. In a project of the Tides Center of San Francisco, Norm Buske sampled estuarine biota and terrestrial mosses in western Washington State in 1993-96 to identify radiological accidents at the Puget Sound Naval Shipyard (PSNS), west of Seattle. Although sampling revealed iodine-131 in shipyard waters and cesium-134 in the terrestrial environs around PSNS, sampling was finally curtailed by Navy legal action.

The 1996 Findings at Amchitka

Meanwhile, the first quarter century after the Cannikin shot was coming to a close, and Greenpeace's founding was thus to be marked. Pam Miller in Greenpeace's Alaska Office undertook to revisit Amchitka to see how public concerns expressed before the blast corresponded to the reality of what had actually happened in the darkness after Cannikin.

In June of 1996, Greenpeace sponsored the expedition to Amchitka Island to conduct an independent, public-interest, scientific investigation to determine whether radioactivity was leaking from the three nuclear test sites. Greenpeace review of more than 1,100 documents from the Department of Energy suggested that sampling efforts sponsored by the government since 1971 were inadequate to detect the presence of long-lived radionuclides in the environment of Amchitka. It was the first opportunity for critics of nuclear weapons to access a major nuclear weapons test site and assess its radiological condition without military intervention.

The technical developments from the work at Hanford, Moruroa and the Puget Sound Naval Shipyard spawned a number of technical models for studying radionuclides at test sites. More specifically, the expertise developed since 1983 provided guidance for the identification of candidate seeps likely contaminated by radioactive leakage and for the selection of appropriate sample media.

Greenpeace's 25th anniversary scientific expedition set out from Dutch Harbor, Alaska in May 1996 on a fishing boat reminiscent of the 25-meter halibut seiner *Phyllis Cormack*. The scientific party of five and the crew of two spent 5 days sampling the old nuclear sites on Amchitka and returned to Dutch Harbor with samples that would vindicate those who had been so concerned a quarter century before. Experience at

Americium-241 reported by Greenpeace in 1996 ... as replicated in 1997.

Source	1997 Replicate and Dry/Ash		1996 fCi/gm-ash*	Comment on 1997 Replicate
Cannikin	XC-1	7.9	60 ±20	aquatic vs. terrestrial moss
Cannikin	XC-8	4.2	30 ±12	White Alice Falls: inadequate analysis
Long Shot	XL-7	14.1	140 ±40	algae vs. moss & algae

* "fCi/gm-ash" = femtocurie/gram of ash. A femtocurie is one nuclear decay every 7-1/2 hours. 1000 fCi = 1 pCi. The unit of radioactivity in the original report was picocuries/gm-ash. So equivalent values are displayed 1000 times larger here than in "Nuclear Flashback".[4]

Moruroa had demonstrated that wet sites leak radioactivity—Amchitka would not prove to be an exception.

In its report, "Nuclear Flashback: The Return to Amchitka," Greenpeace catalogued its discoveries from the 1996 field work and led the state and federal governments to propose the 1997 follow-up study.

Nuclear Flashback II: Follow-Up DOE Study with Public Oversight

Soon after the release of the 1996 Amchitka report, Alaska Governor Tony Knowles asked DOE to perform "an independent analysis of possible radiation leakage" from Amchitka, with "public oversight of monitoring and assessment efforts."[5] DOE announced it would do a follow-up study with the outcome to be reported to the public within a year. The first organizational meeting of the Amchitka Technical Advisory Group (ATAG) occurred in December 1996 in Anchorage. Membership was not formalized, nor did ATAG have a charter or terms of reference. Participants included:

Alaska Department of Environmental Conservation
Aleutian/Pribilof Islands Association
Rural Community Action Program
University of Alaska
U.S. Fish and Wildlife Service
Greenpeace
Arctic Research Commission
Alaska Workers
U.S. Environmental Protection Agency
U.S. Department of Energy[6]

ATAG adopted the following Statement of the Problem for the 1997 study:

> The primary problems to be addressed by the sampling event are whether measured values of man-made radionuclides from suspected groundwater leakage zones near the three shot areas are related to the tests [Cannikin, Milrow, and Long Shot] and can they be distinguished from worldwide fallout.[7]

Greenpeace had three major scientific goals for its participation in ATAG:

- to assure samples were the best examples of leakage to test world fallout levels
- to test the hypothesis that leakage resides in the groundwater and plant biota rather than the atmospheric fallout fractions of the samples
- to identify new leakage pathways, especially at Milrow

And one overview goal:

- to determine how DOE would cooperate with public oversight on a scientific study of this element of the U.S. nuclear weapons complex.

Greenpeace worked with ATAG members to prepare a draft sampling plan for the 1997 joint investiga-

tion. It was prepared by the Environmental Protection Agency (EPA) then revised and approved by ATAG in April. Revisions sufficient to do the field work were approved by EPA and DOE on May 28. This Study Plan was never approved by ATAG. The group chose to move ahead with the study in June 1997. The ATAG-approved Study Plan for this return to Amchitka is the EPA draft and the April ATAG meeting video. Non-conformities with what ATAG had approved in April 1997 were noted at the December 1997 ATAG meeting.

Overview of Study Concepts

As a general matter, most contaminants are filtered from groundwater by sorption processes as moving water passes over chemically active rock and soil surfaces. But underground nuclear explosions produce dozens of radioactive elements. Depending on local hydrology, some of these radionuclides almost certainly migrate. So if radioactive waste is to be contained for long periods of time, nuclear bombs should not be exploded in wet, dynamic environments. This is the reason the U.S. has conducted almost all its underground nuclear tests under the Nevada desert, which is a relatively dry and static location.

The nuclear test sites at Amchitka are wet.

Detailed knowledge of the sorptive properties of geologic features on the island are required to make reliable predictions of radioactive leakage. In the absence of such information, investigators look for gamma emitters to locate leakage. Follow-up alpha and beta spectrometry can then fingerprint what is actually leaking.

If there is radioactive leakage, some radionuclides bio-accumulate in vegetation found in the radioactive seeps or springs. Samples are collected, washed to remove sediment, dried, and then ashed. Drying and ashing concentrates the biological material, improving detection levels. The ratio of dry weight to ash weight is one measure of how much sediment or dirt there is in the sample, with high ratios indicating clean, relatively dirt-free samples.

The basic conceptual model assumed for radioactive leakage revolves around groundwater pathways. These flow past radioactive debris underground and dissolve radionuclides, carrying them away. While such pathways are invisible underground, the terminal ends of those hidden pathways which emerge on the land are springs or seeps.

Since water flows downhill, a candidate spring can only emerge below the level of the watertable at Ground Zero (GZ). The hydraulic head (pressure) difference between the ground zero water table and the elevation of the seep drives groundwater flow.

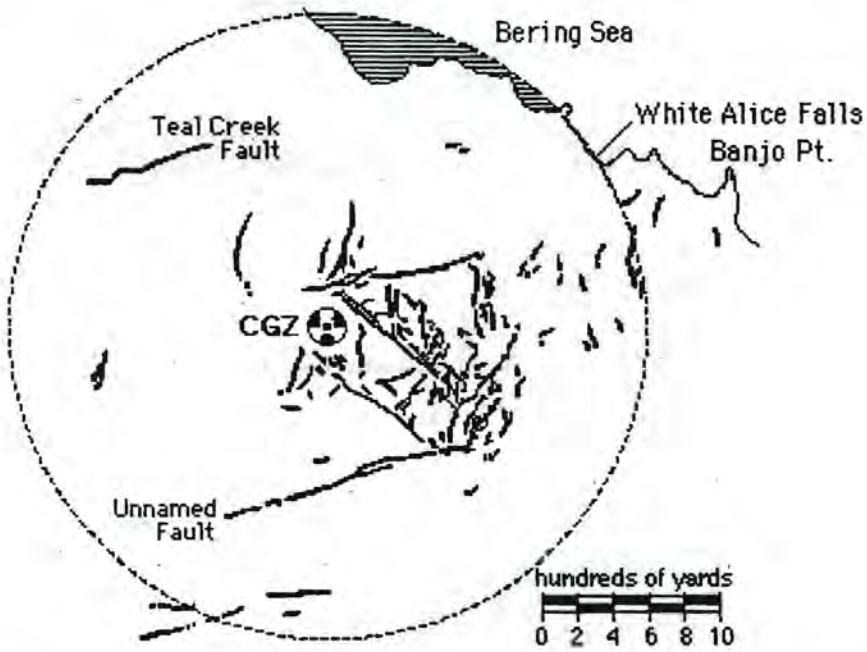
The length of the hypothetical groundwater pathway is another important consideration. With radiation leakage from an underground nuclear explosion, the important pathways are likely along fractures opened by the blast and emanating from the blast cavity. As seen from Fig. 2, the large, blast-opened faults from the 5,000,000-ton Cannikin explosion extend a mile from CGZ. So this is about the likely range of rapid groundwater migration that has passed through the blast cavity.

The 1997 sampling design also focused on potential detection of radioactive leakage in large streams draining the area from the large nuclear blast debris systems of Cannikin and Milrow.

These concepts allowed design of the 1997 monitoring program to detect radioactive leakage, as Greenpeace did in 1996. A site-specific theory was developed by Norm Buske through the melding of detailed conceptual considerations and hydrologic information.[8] This generated testable predictions and guided follow-up work. Figure 3 is a sketch of the model of radioactive groundwater migration from Cannikin debris to XC-1 and White Alice Falls.[9]

Figure 2

Fractures >100 yards long, reported by USGS after Cannikin blast. [NVO-123, from Fig.10]



As this model was developed, scientists applied other historic data. For example, upwardly-decreasing values of both tritium and non-tritium radioactivity after the Cannikin shot indicated upward flow of water from great depth combined with dilution from surface water.[10] See Table 1.

Table 1

Non-Tritium / Tritium in Cannikin Well UA-1-P1.

Depth [yds]	Non-Tritium* [fCi/mL]	Tritium [fCi/mL]	Non/Tritium** [ratio]	Collection Date
79	110	8,400	0.013	10-13-72
886	87	33,000	0.0026	10-13-72
1542	250	8,700,000	0.000029	5-3-73
1363	2,900	2,400,000,000	0.0000012	7-17-72

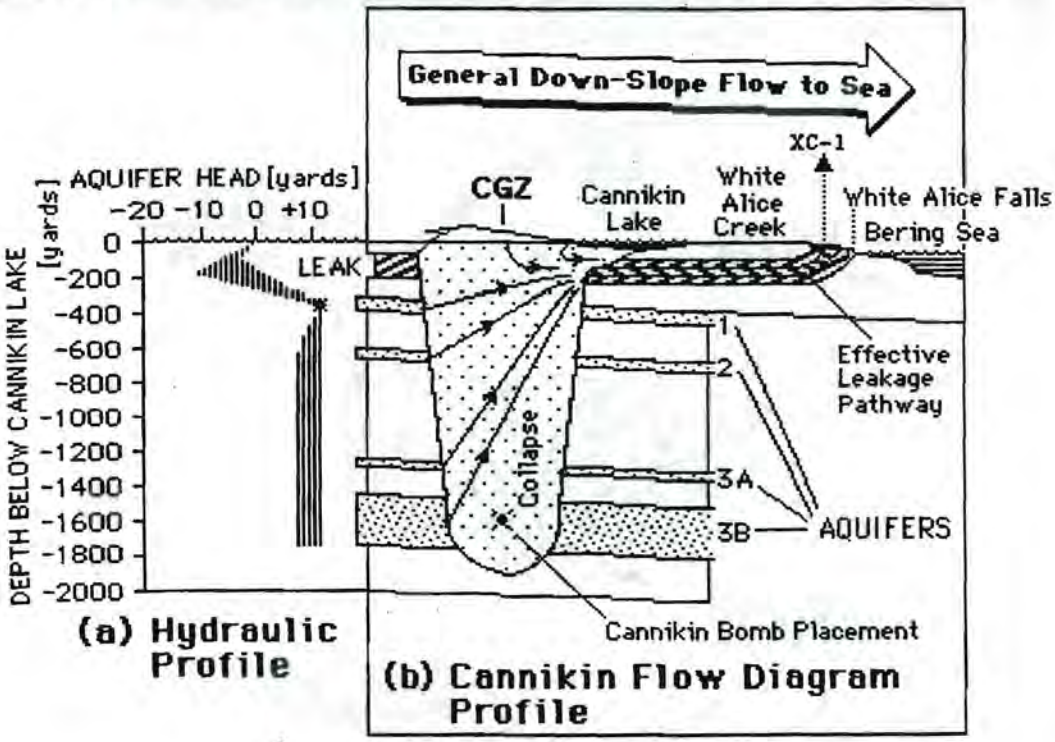
* "Non-Tritium" is "Gross beta,gamma" analysis of dissolved fraction of water sample. "mL" = milliliter.

** "Non/Tritium" is "Non-Tritium" divided by "Tritium" in previous two columns.

The upward increase of the Non-Tritium/Tritium ratio is particularly interesting. This suggests that dissolved radionuclides such as cesium-137 and complexed americium-241 may be better indicators of radioactive leakage than tritium, which is completely incorporated into water molecules.[11] In this way, an adequate picture of radioactive leakage from a complex triple site like Amchitka can be developed in two or three years of intensive investigation.

Figure 3

Cannikin leakage model. This graphical model combines data from measured hydraulic profiles (a) with diagrams of aquifers and flows that would result (b) from the hydraulic profiles.



Return to Ground Zero: The 1997 ATAG Field Work

Before the June 1997 field work even began, DOE issued a press release which foreshadowed communication difficulties to come. Greenpeace had submitted the 1996 Greenpeace samples for plutonium isotopic analyses at the DOE's Los Alamos National Laboratory. The Laboratory concluded that the plutonium in the 1996 Greenpeace samples originated from atmospheric fallout, not test site leakage.[12] DOE conducted an isotopic fingerprinting study to characterize the plutonium ratios discussed in "Nuclear Flashback" as fallout. They only analyzed plutonium isotopes despite Greenpeace's notice beforehand that americium, not plutonium, was the relevant isotope. DOE's press release dismissed the Greenpeace 1996 findings. The DOE press release was issued, without notifying Greenpeace, the day the lab work was completed: a breach of trust felt by the independent scientists. DOE's scientific claims were false, as Greenpeace later demonstrated.

Selection of 1997 Samples

The breach of trust created by the DOE press release was then amplified by a destructive action at the site of the field work. A DOE contractor walked ahead of the sampling party and over an important flagged section of stream bed which was chosen as a sample candidate for leakage. The contractor so disrupted the ideal moss substrate that it could not be sampled.

Nevertheless, 44 samples of aquatic and marine vegetation were finally collected from Amchitka Island for radiological analysis by the EPA. Additional samples were collected for isotopic ratio analyses by DOE's Los Alamos National Laboratory.

The 44 samples were of four general types:

- Replicates of the 1996 Greenpeace candidates for radioactive leakage
- Background samples collected for comparability to determine whether or not the leakage candidate samples are statistically above background, which represents global fallout
- Transect samples to establish a statistical basis for radiological comparisons, and
- Marine shoreline stream and seep samples to identify likely marine contamination sources and to indicate the extent of radioactive contamination into the marine environment.

Because of the need to alert the public to the crucial results and conclusions of this study and because of concerns for unacceptably lengthening scheduling delays, only the currently available aquatic sampling results, based on 32 EPA samples, are presented in this report.

Aquatic Samples, as collected	Number	Prefix*
Cannikin vicinity	16	"C-#" or "XC-#"
Long Shot vicinity	7	"L-#" or "XL-#"
Milrow vicinity	6	"M-#"
Designated background	3	"B-#"
Total EPA aquatic samples	32	

*EPA "sample designations" are the same as reported here, except that the EPA prefix for Cannikin is "CN" rather than "C" used here, for Long Shot "LS" rather than "L" used here, for Milrow "MR" rather than "M" used here, and for designated background "BKG" rather than "B" used here.

Sampling Methodology

A primary concern in the 1997 study was determining whether replicates of the 1996 leakage candidates were significantly above atmospheric fallout levels. The field team set out to identify a mutually acceptable background stream with abundant aquatic moss. ATAG had specified an area northwest of Teal Creek Fault to assure no groundwater connection to the three blast cavities at Cannikin, Long Shot, and Milrow (Fig. 1). The background was set within the same geographical region as the test shot areas to assure comparability. The lower reach of an unnamed creek between Falls Creek and Limpet Creek was selected by the field party without dissent. This Background Creek flowed southwest from Mile 16.6 on the Infantry Road, then south into the North Pacific Ocean at (51° 30' 15" North, 178° 59' 57" East).

There was a disagreement whether the replicate of Greenpeace's sample GP#12 from White Alice

Falls (51° 28' 39" North, 179° 07' 29" East) was included in one of the transects or whether it would count as one of the seven samples allotted to Greenpeace for radiation leakage candidates. DOE resolved this question by adding this replicate as Sample XC-8.

Several improvements in the 1997 sampling were based on 1996 experience. Greenpeace brought a sensitive (0.1°F), water-resistant, fast-response (8 seconds) *delta tee meter* to find possible underground water seeps entering the bottom of White Alice Creek. This instrument was used to locate the bottom seep at Sample C-3A (51° 28' 33" North, 179° 07' 28" East). EPA brought temperature, pH, and conductivity instrumentation which provided general water quality information and introduced a new survey measurement — pH — for potential location of radioactive seeps on Amchitka.

EPA also brought sieves which permitted improved sample washing and retention of sediment fractions for possible future analysis.

Greenpeace anticipated particulates would be effectively filtered out of radioactive leakage as it flowed along groundwater pathways and then emerged from seeps. So Greenpeace had carefully washed its 1996 samples and used dry/ash weight ratios as an indication of sample quality. High ratios indicate the presence of less sediment. In these high ratio examples, it is more likely that radioactive material is incorporated into the biota.[13] One way to test if 1996 samples had taken on Am-241 from radioactive leakage rather than from worldwide fallout was to observe that none of the 1996 samples with low dry/ash ratios had detectable Am-241. Greenpeace sought even better washed samples in 1997 to obtain even higher Am-241 values as evidence of leakage.

DOE presumed the americium reported by Greenpeace in 1996 was linked to plutonium from atmospheric fallout. Better washed samples would remove all atmospheric particulates and so reduce fallout readings of both americium and plutonium in the new samples.

Washing the aquatic moss samples turned out to be one of the most important as well as the most comic aspects of the field effort.

The Washtub Club

For the above reasons, both Greenpeace and DOE favored aggressively better sample washing in 1997. Consequently, there was a spectacular moss-washing effort on Amchitka in June, with most of the field team usually on their knees on the tundra, with their hands in green stringy stuff in wash basins.

Photo courtesy Norm Buske

The result of this enthusiastic moss washing was improvement of the dry/ash weight ratio, from an average dry/ash=6 for the aquatic samples reported in 1996 to dry/ash=11 for the samples reported here for 1997. This doubling represents a substantial and important improvement.

Moss moving through the 1997 washing line.

Photos courtesy Norm Buske

Terrestrial moss to be sampled at XC-5 replicate of 1996 GP#11.

The candidate seep on the west side of Lower White Alice Creek contained the terrestrial moss sampled from this same spring in 1996. Sample XC-5, a replicate of 1996 GP#11, was taken from the free-flowing spring which did not have an accumulation of decaying vegetation. The pH measured 6.9. This spring flowed into a small, slow-moving tributary to the west side of White Alice Creek. This tributary was filled with aquatic moss, sampled as XC-1 (51° 28' 33" North, 179° 07' 20" East), comparable to the other 1997 samples. The vegetation at XC-1 contained decaying material. The pH was 6.8.

A lucky break for the field effort was discovery of aquatic moss bed on the southwest side of Cannikin Lake. So Sample XC-6 allowed a first check on whether radioactive leakage might enter the floor of Cannikin Lake, as Greenpeace hypothesized in 1996, but later doubted for theoretical reasons.

Greenpeace representative Norm Buske sampling *Fontinalis* at XC-1.

The weather during the 1997 sampling was exceptionally fine, allowing the already-described sample washing. But a negative side-effect of drier conditions in 1997 was less water at Long Shot replicate site XL-7 (51° 26' 04" North, 179° 10' 46" East). The aquatic moss and algae sampled in 1996 was not available in 1997. Instead, the seepage pit which had developed from the little spring observed in 1996 was partly filled with algae. The 2-yard wide pit did not contain apparent decaying vegetation. Its pH measured 6.6. Algae Sample XL-7 became a sample of non-conforming medium, having a low dry/ash ratio, limiting the interpretation of its results in comparison to the Study Background of *Fontinalis* aquatic moss. XL-7 was gently rinsed in deionized water.

Meanwhile, EPA had been diligently drying the collected samples for transportation and readiness for ashing and then gamma counting.

Photo courtesy Norm Baske.

A free-flowing spring and stream flowing southeast. Location of sample XL-7.

Determination of Study Background

A decision was made in the 1997 study to use a conservative model for defining fallout from atmospheric nuclear testing, or *Study Background* levels, found in the samples. Study Background of any measurable quantity is the reference value against which leakage candidates are compared. If there is Am-241 from leakage in some candidate sample, that value will be significantly higher than Am-241 in the Study Background.

If Greenpeace were allowed to select all the Study Background samples, then Greenpeace might conceivably choose samples sheltered from fallout and call these background. Thus candidate samples representing ordinary fallout conditions might well measure significantly above background.

To avoid the prospect of such a false-positive result, DOE was properly allowed to pick the study background samples so the agency had its best shot at selecting a location subject to maximum fallout contamination. Before the field work, ATAG had specified that the study background samples should be collected outside the region of the three blast sites. This was to ensure that background samples were not inadvertently contaminated by the radioactive debris under the island. So DOE got its best shot at picking a high-fallout

background, with the constraint that it could not pick locations likely to be contaminated by radioactive debris under the island.

The samples DOE picked seemed adequate for these purposes, and all field party members accepted the selections. The aquatic background samples for which acceptable data have been reported are B-1A and B-1C.

But there is another consideration. If the Study Background is in fact relatively contaminated by fallout, it would show high values of Am-241. There is surely a range of Am-241 values in biota on Amchitka. This variability has to be considered in the Study Background if it is to be honestly representative as a comparison for diverse kinds of samples.

This consideration prompted Greenpeace to propose including C-1 and L-1 transect samples into the Study Background, for the specific purpose of assuring a more representative Study Background by including realistic variability. Greenpeace made this proposal before any study results were known. Since both of these samples, C-1A and L-1C, were so close to the respective Cannikin and Long Shot GZs, this proposal had some risk of improperly elevating the Study Background because of contamination that might be present at the GZs. So this addition of more varied samples into Study Background is a conservative proposal that might over-estimate both true background Am-241 and background variability.

So, some candidates that are truly contaminated by leakage from the underground radioactive debris might not appear significantly above this Study Background. But the reader can be confident that any sample identified as significantly above this Study Background probably is contaminated by radioactive leakage.

Analytical results of these four Study background samples appear in Table 2. The Am-241 Study Background, for the purposes of this report, is the mean of these four sample Am-241 values, with their unbiased standard deviation: **1997 Am-241 Study Background: 55±34 fCi/gm-ash.**

Table 2

Study Background — Americium-241.

Sample	pH	Dry/Ash	fCi/gm-ash	Comment*

Study Background Samples — Am-241 and Pu-239/240 [fCi/gm-ash].

Sample	pH	Dry/Ash	Am-241*	Pu-239/240	Designation**
C-1A	8.0	13.7	94.0 ±18.4**	88.2 ±3.6	Cannikin, post-sampling, pre-data
L-1C	8.2	8.5	4.2 ±14.1	18.7 ±1.4	Long Shot, post-sampling, pre-data
B-1A	7.4	17.8	64.8 ±17.3	108.8 ±4.2	Pre- and post-sampling
B-1C	7.6	21.2	56.1 ±13.9	123.6 ±4.9	Pre- and post-sampling

STUDY BACKGROUND: Am-241 = **55 ±34** (±62%).**
dry/ash = 15.3.
Am/Pu = 0.58 ±0.36

* All background samples are primarily Fontinalis, aquatic moss. Some candidate sample media differ from this background medium. See Fig.1 for sample locations.

** The "±" value given for each background sample is precision at one standard deviation counting uncertainty. The mean precision of these four samples is ±15.9 fCi/gm-ash. The total variation (at one standard deviation) of this set of the 4 background samples is ±37.4 fCi/gm-ash. The listed Study Background standard deviation of ±34 fCi/gm-ash subtracts (as variances) the precision from the total variation. All Am-241 values are corrected for Detector #9 blank; see text for details.

The 1997 Samples

See Fig.1 for locations of the samples for which gamma Am-241 data are reported. Individual samples discussed in this report are described as follows:

Sample	ATAG#	EPA#	Mo-Da	Medium	Setting
B-1A	BKG-1A	723423	6-14	Font.a.m.*	free-flowing reference stream
B-1B	BKG-1B	723417	6-14	Font.a.m.	as above, essentially a duplicate
B-1C	BKG-1C	723420	6-14	Font.a.m.	as above, essentially a duplicate
B-2C	BKG-2C	723415	6-14	Fucus.mm**	intertidal zone, pre-selected background
C-1A	CN-1A	723348	6-09	Font.a.m.	narrow, upper reach, White Alice Creek
C-2B	CN-2B	723397	6-12	Font.a.m.	White Alice Creek, just below Cannikin Lake
C-3A	CN-3A	723383	6-11	Font.a.m.	sub-bottom seep into lower White Alice Creek
C-3B	CN-3B	723385	6-11	Font.a.m.	upstream reference for C-3A
L-1C	LS-1C	723437	6-16	a.m.—>	Drepanocladus aq.moss, Long Shot mud pit
L-2C	LS-2C	723403	6-13	Font.a.m.	free-flowing, joined drainage from XL-7.
M-2A	MR-2A	723429	6-15	Font.a.m.	confluence of Heart & Tent Lk branches of Clevenger Creek, below Milrow
M-2C	MR-2C	723427	6-15	Font.a.m.	downstream of M-2A, below Milrow
M-3B	MR-3B	723364	6-10	Font.a.m.	downstream, added Clevenger Cr. drainage
XC-1	XCN-1	723393	6-12	Font.a.m.	discharge from XC-5 / GP#11 spring outflow
XC-2	XCN-2	723370	6-10	Ent.mm***	White Alice Creek outflow into Bering Sea
XC-4	XCN-4	723372	6-10	Ent.mm	shoreline seep northwest of White Alice Cr.
XC-5	XCN-5	723395	6-12	t.m.****	GP#11 replicate, clear flowing, at-spring
XC-6	XCN-6	723399	6-13	a.m.—>	Sphagnum squarrosum, Cannikin Lake bed
XC-8	XCN-8	723379	6-11	Font.a.m	White Alice Falls replicate of GP#12
XL-7	XLS-7	723407	6-13	alga*****	free-flowing seep at 1996 GP#3 location

* "Font.a.m" = ***Fontinalis neomexicanus***, aquatic moss

** "Fucus.mm" = ***Fucus distichus***, brown marine macroalgae

*** "Ent.mm" = ***Enteromorpha intestinalis***, green marine macroalgae

**** "t.m." = terrestrial moss. No genus ID presently available

***** "alga" = unidentified brown algal agglomeration, washed downstream as disrupted

Samples not listed above or located in Fig.1 are described in the text. For more detailed description of samples and their locations, see the EPA, Amchitka, Alaska, Special Sampling Project, 1997 Final Results [EPA, vol.1.].

Photo courtesy Norm Buske.

Sample XL-7 draining on fiberglass screen after rinsing.

Statistically Sound Background

It is proposed in this report that any 1997 candidate sample found to contain more than 110 fCi/gm-ash is sound statistical proof of radioactive leakage at Amchitka.

Assuming the Am-241 Study Background for the 1997 aquatic samples is 55 ±34 fCi/gm-ash and assuming that Study Background is normally distributed, then there is a (one-sided)

5% chance of a background sample being randomly less than 1.65 sigma below the mean or a 5% chance of a background sample appearing 1.65 sigma above the mean. For the Study Background sigma = ±34 fCi/gm-ash, 1.65 sigma = 56 fCi/gm-ash. This invites the following rule of thumb interpretations: (1) Background samples with Am-241 values less than zero (55–56 = -1 fCi/gm-ash) are unlikely, because Am-241 activities cannot be less than zero. (2) A comparable Amchitkan aquatic vegetation sample with Am-241 value greater than 110 fCi/gm-ash (55+56 = 111 fCi/gm-ash) is probably above background.

The 1997 ATAG Study Results

The results summarized in Table 3 have passed EPA quality control tests and have been validated in a later section of this report. The two validated 1997 replicates of 1996 samples are highlighted. These 1997 results can be tested statistically against the Study Background to determine whether these leakage candidates contain Am-241 significantly elevated above background. This is the central test of the 1997 study.

Table 3

Aquatic Candidate Samples — Am-241 and Pu-239/240 [fCi/gm-ash].

Sample	pH	Dry/Ash	Am-241*	Pu-239/240	Description**
XC-1	6.8	14.2	**167.7±19.8**	111.5 ±6.0	Cannikin leakage
XC-6	8.2	5.6	9.2 ±13.6	19.4 ±2.8	Cannikin Lake, exploratory sample
C-2B	8.2	8.3	14.8 ±14.4	36.1 ±1.9	Discharge from Cannikin Lake
C-3A	8.4	10.9	57.7 ±11.3	42.4 ±2.7	Cannikin, seep into White Alice Cr.
C-3B	8.4	7.6	2.9 ±14.7	26.6 ±1.7	Cannikin, upstream of C-3A
XL-7	6.6	2.4	**148.9±16.4**	227.0 ±8.1	Long Shot leakage
L-2C***	7.3	9.4	58.3 ±17.7	65.6 ±7.5	Long Shot, downstream of XL-7
M-2A	8.2	13.9	70.3 ±18.1	71.8 ±4.4	Milrow, at Heart Lake confluence
M-2C	8.1	13.2	126.0 ±20.7	92.3 ±4.7	Milrow, just downstream of M-2A
M-3B	7.9	8.8	80.2 ±17.2	51.7 ±2.9	Milrow, downstream of M-2C

* All Am-241 values are corrected for Detector #9 blank; see "Sample Quality" for details.

** See Fig.1 for sample locations.

*** Sample L-2C was submitted to replicated alpha analysis with the independent Am-241 result of 72.8 ±7.1 fCi/gm-ash, which is confirming.

Am-241 is confirmed leaking at levels significantly above background

Two of the 1997 samples (XC-1 and XL-7) are replicates of 1996 samples confirming Am-241 leakage from Cannikin and Milrow. Both these replicates (167.7 ±19.8 and 148.9 ±16.4) are significantly above background at greater than 95% confidence. They exceed the statistical background threshold of 110 fCi/gm-ash. In addition, Sample M-2C is significantly above Am-241 Study Background though at a lower confidence level. Thus, the primary result of the 1997 study is:

Candidate vegetation in the aquatic environs of all three underground nuclear blasts on Amchitka have Am-241 significantly above background, evidencing radioactive leakage from underground nuclear debris. The Greenpeace discovery of radioactive leakage on Amchitka is confirmed by DOE's gamma results.

The Am-241 in these three samples is allocated as follows, with the Study Background called "Fallout" and that which is above background called "Leakage":

Am-241 Leakage vs. Study Background (Fallout) in candidates [fCi/gm-ash]

Source	Sample	Total	Fallout	Leakage	Leakage/Total
Cannikin	XC-1	168	55	113	67%
Long Shot	XL-7	149	55	94	63%
Milrow	M-2C	126	55	71	56%

DOE's Fallout Theory Challenged: Sample Washing Produces Higher Am and Am/Pu Result

A critical question for the 1997 study was how Am-241 could be found in surface waters on Amchitka. Americium is usually a particulate which rapidly attaches to anything it touches in a groundwater pathway and so would be filtered out. Greenpeace's answer is that the high Am-241 values in the Amchitka groundwater represent americium dissolved during the post explosion cool-down. The dissolved Am-241 levels will increase with sample washing. Meanwhile, if the plutonium is indeed particulate fallout, its measured levels will decrease with improved washing. So improved washing of the 1997 samples would yield much higher Am/Pu ratios. Greenpeace predicted the maximum Am/Pu ratio for the 1997 study would be greater than 1.5.[14]

Two samples in the 1997 study satisfied the Greenpeace prediction for maximum Am/Pu:

Sample	Am/Pu Ratio
M-3B	1.551
XC-1	1.504

If DOE was correct in assuming 1996 americium levels were the result of worldwide fallout, then thorough sample washing would wash both the americium and plutonium equally out of the samples. If these elements were the result of atmospheric fallout, they would be in the form of particulates attached more or less firmly to the surfaces of the biota. The ratios would approximate the Am/Pu=0.33 of worldwide average atmospheric fallout.[15] But Am/Pu ratios can be increased by washing sediment off. Americium is not linked to Plutonium in the sediment fraction.

The Study Background ratio against which these two candidates are compared is also noted at the bottom of Table 2: Study Background Am/Pu = 0.58 ±0.36.

Under a range of assumptions, XC-1 has an Am/Pu ratio that is statistically significantly above this background level. Whether or not M-3B is significantly above this background at the 95% confidence level depends on evaluation of assumptions used in the significance test.

Individual Am/Pu ratios in Table 4 are surely sensitive to details of sample species or environmental setting, but relatively high Am/Pu ratios are found in samples identified as radioactive leakage candidates by other indications. This is evidence of excess Am-241 in the system. By way of comparison, one published study of Am/Pu ratios in marine products found 8-fold variations with a maximum of Am/Pu<1.1.[16]

Meanwhile, with support of Greenpeace's treatment of dry/ash ratio and successful predictions, two extrapolations and two scalings based on dry/ash ratios are suggestively included in Table 4, and described just below it.

Table 4

High Am/Pu Comparisons, some extrapolated or scaled

Key

{t.m.} = terrestrial moss in the seep
{Font.} = Fontinalis, an aquatic moss
{m/a} = aquatic moss-algae mat
{algae} = aquatic algae

(~xyz) = extrapolated or scaled
(xyz) = datum value assumed

	Dry/Ash	Am-241 (by gamma)	Pu-239/240	Am/Pu
Cannikin				
1996 GP#11 {t.m.}	7.9	74. ±24.	23. ±1.*	3.2
1997 XC-5 {t.m.}	13.5	(~126.)**	20.5 ±1.6	(~6.)**
1997 XC-1 {Font.}	14.2	167.7 ±19.8	111.5 ±6.0	1.5
1997 C-3B {Font.}	7.6	2.9 ±14.7	27.6 ±1.8	0.1
1997 C-3A {Font.}	10.9	57.7 ±11.3	42.4 ±2.7	1.4
1996 GP#12 {m/a}	4.2	41. ±12.	37. ±1.*	1.1
1997 XC-8 {m/a}	8.6	(~84.)**	29.7 ±1.5	(~2.8)**
Long Shot				
1996 GP#3 {m/a}	14.1	94. ±40.	204. ±3.*	0.5
1997 XL-7 {algae}	2.4	148.9 ±16.4	227.0 ±8.1	0.7
1997 XL-7: ***scaled***:	(9.4)**	(~583.)**	(227.)	(~2.6)**
1997 L-2C {Font.}	9.4	58.3 ±17.7	65.6 ±7.5	0.9
Milrow				
1996 — none from Clevenger Creek				
1997 M-2A {Font.}	13.9	70.3 ±18.1	71.8 ±4.4	1.0
1997 M-2C {Font.}	13.2	126.0 ±20.7	92.3 ±4.7	1.4
1997 M-3B {Font.}	8.8	80.2 ±17.2	51.7 ±2.9	1.6
1997 M-3B: ***scaled***:	(13.5)**	(~123.)**	(52.)	(~2.4)**

* by LANL [D.W. Efurd, letter report to Frank Maxwell, LANL (June 4, 1997) Table III.]

** Extrapolation and scaling, as follows:

XC-5, by 1996 extrapolation: 74 fCi/gm-ash X (13.5/7.9) = ~126. fCi/gm-ash
XC-8, by 1997/96 dry/ash: 41 fCi/gm-ash X (8.6/4.2) = ~84. fCi/gm-ash
XL-7, dry/ash scaled to L-2C: 149 fCi/gm-ash X (9.4/2.4) = ~583. fCi/gm-ash
M-3B, by dry/ash: 80 fCi/gm-ash X (13.5/8.8) = ~ 123. fCi/gm-ash

Discussion of Ratios

The ratios above mean study background (0.58 ±0.36) and well above world fallout ratios (.33) indicate likely leakage candidates. A discussion of each result follows:

• Cannikin: GP#11, XC-5, XC-1: The terrestrial moss at 1996 GP#11 was replicated and better washed in 1997 XC-5. The plutonium content remained the same or decreased slightly. Based on the near doubling of dry/ash ratio (from 7.9 to 13.5), the Am-241 content for 1997 is estimated at ~126 fCi/gm-ash in XC-5. As this terrestrial moss is in the seep; whereas, *Fontinalis* XC-1 is a couple yards away, almost on the side of White Alice Creek, the Am-241 in XC-1 would be expected to be diluted some by stream water, and Am-241 in XC-5 would be expected to be higher than the 167.7 fCi/gm-ash in XC-1. So the extrapolation in Table 4 of Am-241 = ~126 fCi/gm-ash for XC-5 is likely an under-estimate. But even with this likely under-estimate, the Am/Pu ratio of XC-5 would be ~6. Meanwhile, the 1996 ratio of Am/Pu=3.2 was already impressive, and even the diluted ratio Am/Pu=1.5 in the nearby XC-1 *Fontinalis* is well above the global fallout level of Am/Pu=0.33 in sediments.

• Cannikin: C-3B, C-3A: This pair of *Fontinalis* samples was collected from White Alice Creek, downstream of the seep at XC-1 a few hundred yards upstream of White Alice Falls. The exceptionally low Am-241 (3 fCi/gm-ash) and low Am/Pu ratio (0.1) at C-3B shows that the XC-1 seep has not substantially polluted White Alice Creek. Although the higher value (58 fCi/gm-ash) of Am-241 at C-3A just downstream of C-3B is not above Study Background, the rise in Am-241 is apparent, and the ratio of Am/Pu=1.4 suggests possible radioactive leakage at this seep in the bottom of White Alice Creek.

• Cannikin: GP#12, XC-8: In this replicate sampling, 1997 XC-8 was much better washed than 1996 GP#12. This better washing visibly almost eliminated the small algal fraction of the sample apparent in 1996, and so altered the sample medium to a degree. With the doubling of the dry/ash ratio from 4.2 in 1996 to 8.6 in 1997, plutonium decreased from 37 to 30 fCi/gm-ash, suggesting wash-out of particulates. The americium is extrapolated to ~84 fCi/gm-ash, which would imply Am/Pu=~2.8 with the better washing of 1997. Meanwhile, the 1996 ratio of 1.1 was already evidence of an important distinction between the americium and plutonium at White Alice Falls. Meanwhile, the rise in Am-241 from 58 fCi/gm-ash at C-3A, a few hundred yards upstream, to an extrapolated ~84 at White Alice Falls, combined with a doubling of Am/Pu from 1.4 to ~2.8 at White Alice Falls suggests the bulk of radioactive leakage from Cannikin is entering White Alice Creek at White Alice Falls. There is a large volume of water spilling from White Alice Creek into the Bering Sea.

• Long Shot: GP#3, XL-7, L-2C: The 1997 XL-7 replicate of 1996 GP#3 from a seep which had developed into a pit was confounded by a change in sample medium which limits interpretation of XL-7 results. This change in medium is shown by the exceptionally low dry/ash=2.4 ratio of XL-7. With the abundance of particulates this low ratio evidences, it is not surprising that the plutonium level increased (from 204 to 227 fCi/gm-ash). In consideration of the algal medium of XL-7 scaling to the dry/ash=9.4 of L-2C downstream of XL-7 is tenuous, but suggestive. The scaled Am-241 = ~583 fCi/gm-ash is dramatic and leads to a scaled Am/Pu=~2.6 ratio. At downstream L-2C, Am-241 = 58 fCi/gm-ash has returned to Study Background level, and the dry/ash=0.9 ratio does not suggest the presence of other radioactive seepage. So the Am-241 leakage might have no substantial effect beyond the little tributary that GP#3/XL-7 feeds.

• Milrow: M-2A, M-2C, M-3B: *Fontinalis* Sample M-2A was collected from the Tent Lake Branch and downstream of the confluence with the Heart Lake Branch which comes from the Milrow area. M-2C was

collected just downstream of M-2A, and M-3B was collected farther downstream in Clevenger Creek. This reach of Clevenger Creek is swampy with widespread seepage. Scaling Am-241 in M-3B up dry/ash=8.8 to 13.5 (the average of M-2A and M-2C), Am-241=~123 would be comparable for M-3B. Both Am-241 and Am/Pu ratios are then seen to rise down through the Clevenger Creek swamp. The situation is comparable to that in the Cannikin system near White Alice Falls, with the underground nuclear debris from Milrow only one fifth the Cannikin debris, and Clevenger Creek flowing at only a fraction of White Alice Creek.

Cobalt-60 Detected in 1997 Data

Both DOE and Greenpeace expressed hopes the 1997 study would be sensitive enough to detect some other long-lived leakage radionuclide, such as cobalt-60. Co-60 is produced in nuclear reactors and explosions by neutron activation of nearby, natural cobalt and iron. Co-60 has a radioactive decay half-life of 5.3 years. This means that Co-60 left in the nuclear debris under Amchitka would have decayed over some 5 half-lives, or to about 1/32 of the original Co-60 present.

The four Study Background samples had Co-60 activities as follows (fCi/gm-ash): C-1A = 18 ±10; L-1C = —5 ±10; B-1A = 3 ±10; and B-1C = 7 ±10. The 1997 Study Background of cobalt-60 is calculated from these four values to be: **6 ±10 fCi/gm-ash.** This Co-60 Study Background is indistinguishable from zero. However, two 1997 samples counted positive to two standard deviations precision:

Co-60 [fCi/gm-ash]

L-2C = 28 ±11
XC-2 = 21 ± 8

Sample L-2C, downstream of leakage replicate LS-7, does not show other indications of radioactive leakage.

XC-2 was an *Enteromorpha* sample collected below White Alice Falls; so the *Fontinalis* Study Background of 6 ±10 fCi/gm-ash was not applicable. The only other *Enteromorpha* sample counted was XC-4, from a candidate seep into the Bering Sea, west of White Alice Falls. The only other macroalgae counted on Det#9 was designated *Fucus* background sample B-2C.

Analytical results for the three macroalgae samples together with published biological concentration factors are summarized as follows:

Macroalgae samples analyzed on Det#9

	Enteromorpha		*Fucus*	Biological
Sample:	XC-2	XC-4	B-2C	Concentration
Dry/Ash:	5.4	2.6	3.7	Factor
Am-241:*	14.5 ±10.5	27.4 ±12.6	–172.1 ±14.0**	5,000 - 10,000
Pu-239/240:	2.9 ± 0.7	5.8 ± 0.7	6.1 ± 0.8	500 - 5,000
Co-60:	21.3 ± 7.5	0.2 ± 9.2	1.7 ± 3.7	1,000 - 50,000

*Am-241 values are blank corrected.

**The highly negative Am-241 value for B-2C is attributed to an exceptionally strong, natural thorium-234 interference peak at 63.3 KeV. Am-241 gamma analyses are subject to such false negative results in samples having high uranium-thorium content.

The field team collected both these green *Enteromorpha* macroalgae samples from high in the intertidal zone, while the brown *Fucus* macroalgae was taken from low intertidal. Both *Enteromorpha* samples would have been immersed in fresh water for part of each tidal cycle, while the salinity at B-2C (26 ppt) showed only modest influence of a small freshwater seep.

The artificial radioactivities (listed above) for these three intertidal samples might be referenced to biological concentration factors representative of estuarine and marine conditions. A published range of applicable biological concentration factors is listed in the right-hand column, above.[17] The ranges of concentration factors are substantial, and they depend on many factors which are not controlled nor even measured in the 1997 study. The seemingly high Am/Pu ratios for samples XC-2 and XC-4 are too sensitive to counting and blank uncertainties to warrant confidence.

Of americium, plutonium, and cobalt; cobalt exhibits the greatest range of biological concentration factors in marine macroalgae. But of the three, Co-60 is the most likely to concentrate in biota. So there is some merit in comparing these three samples relative to detection of Co-60 in XC-2. XC-2 has significant Co-60 elevation above the reference levels of either of XC-4 or of B-2C.

These results provide the first evidence of Co-60 leaking from Cannikin.

DOE Lab Failures and Delays: Devil in the Details?

The study encountered serious difficulties and delays in laboratory analyses which were managed by a DOE contractor with EPA as "the primary technical service provider."[18]

By far the most significant failure of the analytical process, was two out of three gamma detectors used by EPA had insufficient Am-241 sensitivity for the purposes of this study. Only gamma results from one detector (Det#9) were useful. Suspected polonium-210 (Po-210) interference compromised all but one of the alpha results for Am-241. Greenpeace recommended that the plated samples be submitted to clean-up chemistry, replated, recounted by alpha spectrometry, and reverified to obtain accurate alpha Am-241 results. At the time of this writing, there has been no DOE response to this proposal to salvage the bulk of the data for the 1997 study.

Lab Delays Compromise Analytical Integrity

The collected samples were partly prepared in the field in consideration of the tight schedule for reporting to the public by October 1997. But EPA did not initiate background counting for the gamma detectors until July 12. Extended gaps in the proposed schedule started with the delay of the lab work.

DOE presented preliminary results of the EPA gamma analyses to ATAG members on October 23. This was the first indication that two of its three gamma detectors were of inadequate sensitivity for the purposes of the study. One solution would have been for DOE to begin re-analyzing some of the more important samples - including replicates from the 1996 study - on the sensitive gamma detector. But DOE Project Managers chose instead to destroy the gamma samples. If EPA had followed its own specifications, ashed material sufficient for repeat gamma analysis would have been retained.

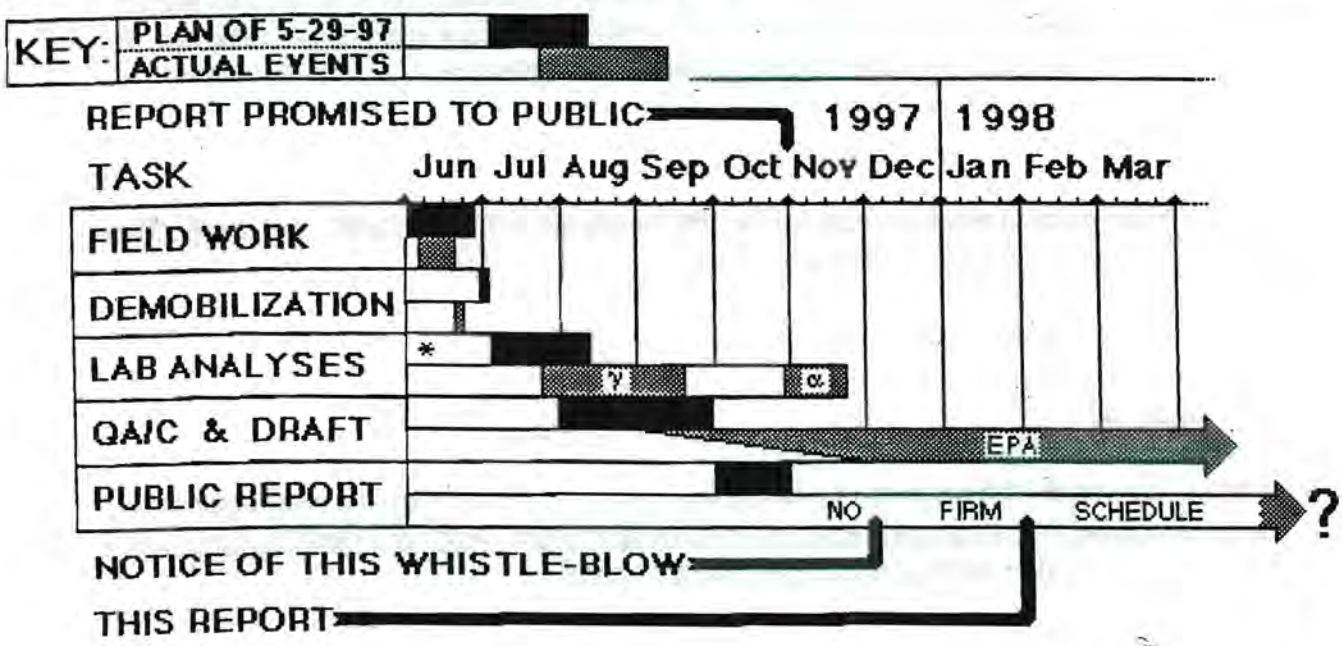
The lab also strayed from Standard Operating Procedures in its alpha analysis by using ash samples which were too large. By using samples in the 20-30 gram range for its gamma analysis (rather than recommended 10 gram samples), the lab would have left sufficient material for repeat gamma analysis. Project Managers opted to prepare all or almost all the ash for each of its aquatic samples "to achieve the largest possible sample volume for satisfactory alpha results."[19] Thus, by one management decision (see related discussion below) the entire set of ash samples were spiked with radioactive tracers and dissolved in nitric acid. This almost destroyed any possibility of further gamma analysis.

Greenpeace began to express loud concerns for the timeliness and usefulness of what was coming out of the lab. No specific reason for the increasing delay was provided by DOE or its lab. Within the actual period of five full months that were available for lab analysis (June 23 through November 23), DOE could have analyzed all 41 samples using the one sensitive gamma detector and reported the results. Alpha analysis could have been completed within that same time period by analyzing batches after gamma counting. And sufficient ash could have been retained for any required re-analysis.

At the 2 December 1997 ATAG meeting Greenpeace asked for the anticipated schedule for completion of the 1997 study and its reporting to the public. Greenpeace was unable to obtain any firm completion date for this already overdue study and notified DOE it would get study results and conclusions to the public as expeditiously as possible.

At present, the 1997 study has yielded only a few gamma analyses and no qualifiable alpha data. The DOE-managed lab record has not demonstrated an understandable record of extended struggles to overcome serious problems. Rather, it shows a history of empty work intervals which delayed completion of its study and obfuscated the otherwise clear implications of the few valid data.

Figure 4
1997 STUDY FLOW CHART: PLAN vs ACTUAL



*One-month offset error in original: "Start 6/2/97, Finish 7/11/97" is corrected here.

DOE Laboratory Quality Failures

In addition to its repeated delays, the DOE laboratory made numerous data management decisions which are questionable. In reviewing more than 1,600 pages of results and procedural logs, it is clear laboratory analytical quality at DOE was often inadequate. With public oversight of the project, DOE's credibility and performance under agreed upon standards were on the table for all to see. One of the country's most sophisticated laboratories continuously made poor choices and violated accepted scientific protocols. Laboratory analytical quality seems to have been deliberately compromised.

Technical review of the data indicates:

- Two-thirds of the 1997 samples were analyzed on government gamma detectors insensitive to Am-241.
- DOE's alpha analyses deviated in important ways from the relevant Standard Operating Procedures (SOPs), compromising satisfactory results.
- Necessary corrective measures were under-defined and inconsistent, precluding satisfactory Pu-238 and Am-241 alpha analytical results.
- The "clean-up" chemistry applied to selected alpha analyses was not defined in relevant SOPs.
- DOE's contractor laboratory failed to address standard quality control procedures for alpha analytical accuracy, invalidating all but one alpha Am-241 datum.[20]

Detailed technical discussions for each of these problems follows.

Government Gamma Spectrometry Insensitive to Americium

Thirty-two samples were analyzed by means of gamma and alpha spectrometry for americium-241 (Am-241) and other radionuclides. To answer the crucial question of whether 1997 replicates are significantly above background, the precision and accuracy of the 1996 Greenpeace analysis had to be matched. The one-sigma (counting uncertainty) precision of the Greenpeace samples was:

1996 Precision: ±25 fCi/gm-ash

EPA employed three gamma spectrometers for the 1997 analyses — Det#1, Det#2, and Det#9. Their average reported precisions for counting 1997 samples were

Det#1: 1997 Precision: ±72 fCi/gm-ash
Det#2: 1997 Precision: ±85 "
Det#9: 1997 Precision: ±17 "

Only the Det#9 equipment had the necessary precision for detection of Am-241 in the 1997 replicate samples. Thus, only the Det#9 gamma data are considered in this report; Det#1 and Det#2 gamma data are set aside as inadequately sensitive for the main purposes of this study.

DOE's Alpha Spectrometry deviated from Standard Operating Procedures

Alpha spectrometry is a second laboratory method for analyzing radiation levels in samples. It provides for more potentially accurate results, but is subject to numerous pitfalls with an ashed sample medium. Plutonium and americium analysis by alpha spectrometry involve specific chemistry. The applicable SOPs are specific. The validation of these results can be routine, rather than a customized process as in the case of americium-241 gamma spectrometry.

The EPA alpha spectrometry for Am-241 and for plutonium passed the lab's quality assurance and quality control tests, but failed Greenpeace quality screening.[21] Statistical checks suggested bias and analytical errors. Comparisons of the actual procedures to the relevant SOPs revealed substantive non-compliances and deviations from the SOPs.[22]

Plutonium Analysis by Alpha Spectrometry

Review of the DOE/EPA plutonium analyses reveals substantive conceptual and procedural defects. DOE/EPA has little regard for deviation from the sample size specification of the SOP and there are non-compliances in reporting. The clean-up chemistry crucial for the checks reported in Table 5 (below) is not defined in either Standard Operating Procedures, nor the specific method for this study.[23] Confirmation of these results is not defined. When analytical problems were encountered, the lab seems to have solved them on an ad hoc basis without adequate conceptualization of the potential impact on the data set nor on Quality Assurance / Quality Control (QA/C).

For example, the ashed samples used by the EPA were at least twice the optimum size, with four exceptions. Larger samples can cause interference and chemically insoluble residues which prevent good analysis.

Chemistry checks on these samples are provided in Table 5:

Table 5

Analytical checks for plutonium in samples.

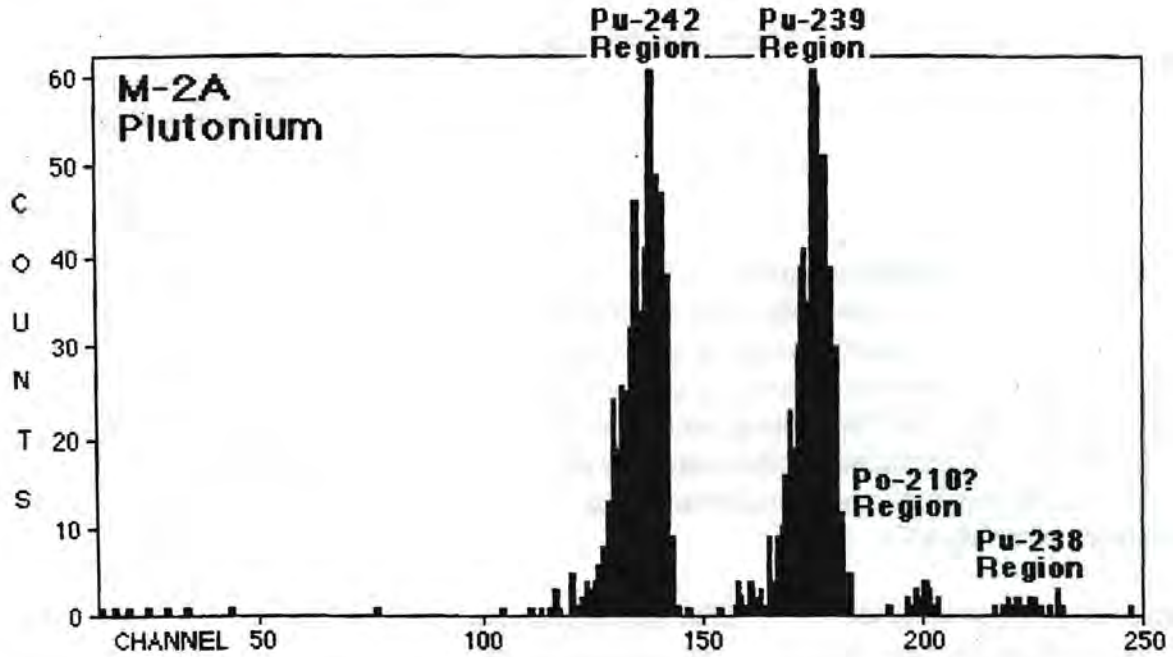
Sample B-1C	Original	Reanalysis	Report
Pu-239/240 [fCi/gm]:	123.6 ±4.9	118.8 ±6.3	123.6 ±4.9
Pu-238 [fCi/gm]:	2.9 ±0.5	4.5 ±1.0	2.9 ±0.5
Mass [gm]:	20.0	7.5	
Yield [%]:	90.2	88.8	
Date [Mo-Da-97]:	10-30	11-02	

Sample C-4A	Original*	Replate	Report
Pu-239/240 [fCi/gm]:	4.7 ±0.8	7.0 ±0.8	7.0 ±0.8
Pu-238 [fCi/gm]:	3.1 ±0.6	0.1 ±0.3	<MDC
Mass [gm]:	30.0	30.0	
Yield [%]:	43.8	34.2	
Date [Mo-Da-97]:	10-30	11-04	

* Log note: "Spectrum showing Pu-238 interference"[24]

The Pu-239/240 analyses pass these two chemical checks. But many of the plutonium spectra have unidentified contaminant peaks. As a quality control matter, all substantial peaks warrant identification to appraise the likelihood of serious interference due to contaminants. Figure 5 (below) shows the plutonium spectrum for Sample M-2A.

Figure 5
Plutonium spectrum: Sample M-2A.



There is an alpha peak in the M-2A spectrum close to Channel 200, which is about 5300 KeV, and there are a few counts at the left end of the spectrum. The obvious candidate for the Channel 200 contamination is polonium-210 (Po-210) with an alpha peak at 5304 KeV. But the cautious analyst would not want to forget the possibilities of Am-243 at 5276 KeV, Cm-245 at 5362 KeV and Th-228 with a secondary (27% abundance) peak at 5340 KeV and a primary (73% abundance) peak at 5423 KeV, which is within the Pu-238 region.

Review of the plutonium spectra reveals other anomalous peaks of concern. The dramatic example is a low-energy spike in the L-2C spectrum.[25]

Although this review of the EPA Pu-239/240 documentation raises substantive concerns, these particular data are of adequate quality for the purposes of this study, and the Pu-239/240 data are all admitted at EPA tabulated values.

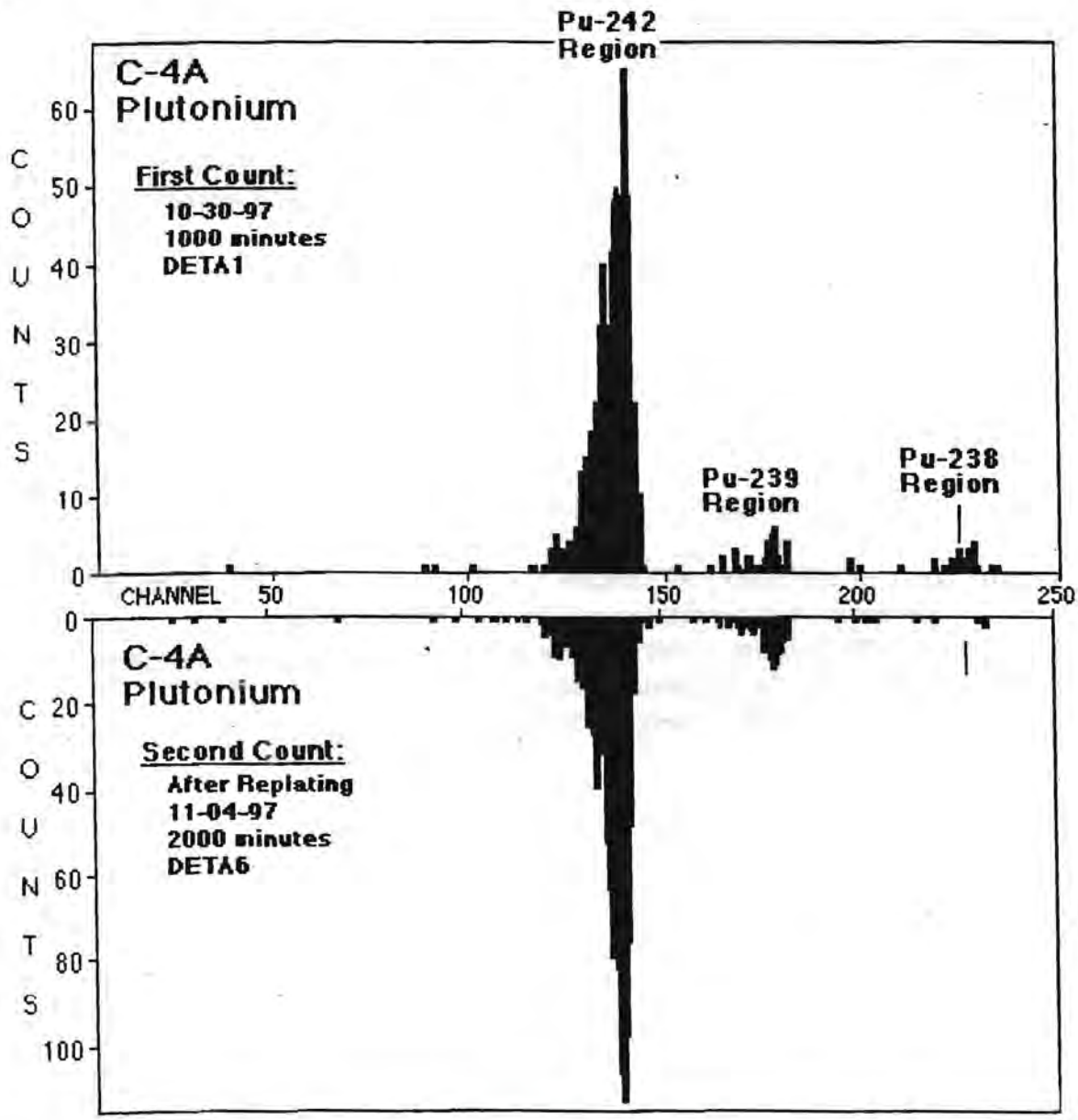
Following again the same review procedure as used for Pu-239/240, the EPA Pu-238 data are now reviewed. The treatment of Pu-238 in Sample C-4A shows non-recoverable errors in the Pu-238 procedure.

The difficulty begins with the basis for EPA's decision to do clean-up chemistry, to replate, and to recount Sample C-4C. EPA's documented rationale[26] is:

Interference in Pu-238 Region
Additional clean-up chemistry required
2000 minute count reported

Sample C-4A stands out when compared to other 1997 samples. It suggests the possibility of some contaminant. But there is not any set procedure employed for addressing it. The original B-1C spectrum and the replated and recounted spectrum are shown in Fig. 6, with the replated spectrum mirrored beneath the original, for comparison[27]:

Figure 6
Sample C-4A plutonium replicate.



The counts in the Pu-238 region were virtually eliminated in the second analysis, going from 3.1 ±0.6 fCi/gm to undetectable. EPA did not report this outstanding discovery of contamination in the reported Pu-238 region of Sample C-4A. The 97% decrease in Pu-238 is outside the stated replicate quality bounds of this 1997 study.

Two likely contaminants in this region of the spectrum are radon-222, short-lived daughter of naturally occurring radium-226, and the focus of this study: Am-241. Rn-222 has an alpha peak at 5490 KeV, which would be indistinguishable from the 5500 KeV peak of Pu-238. The alpha peak for Am-241 is at 5486 KeV. So there is likely either radium contamination or Am-241 appearing in the Pu-238 spectral region.

This report rejects all the EPA Pu-238 results.

Americium Analysis by Alpha Spectrometry is rejected

The alpha americium analysis began with the same flaw as the plutonium analysis. All the ashed samples were at least twice the optimal size for alpha Am spectrometry, except for the same four plutonium analysis samples.

Four samples were submitted to clean-up chemistry, replating, and recounting for the Am-241 analyses: L-2C "to clean up alpha peak separation," and B-1A, B-1B, and B-1C "to remove interference to Am-243 tracer peak."[28]

The original spectrum of Sample L-2C was blurred. The results were as follows:

Sample L-2C	Original	Replate	Report
Am-241 [fCi/gm]:	70.8 ±10.8	74.7 ±9.4	74.7 ±9.4
Mass [gm]:	30.0	30.0	
Yield [%]:	7.7	7.0	
Date [Mo-Da-97]:	11-17	11-19	12-02

All three pre-designated study background samples —B-1A, B-1B, and B-1C— had tracer yields greater than 150%. As the percentage of tracer that can possibly pass through the analytical procedure is necessarily between 0% and 100%, these impossibly high tracer yields suggest immediately the presence of some contaminant with a decay energy indistinguishable from the 5276 KeV energy of the Am-243 tracer. The obvious candidate is Po-210 with a decay energy of 5304 KeV.

But there are other possibilities:

EPA's Draft Sequential Method for Am-241 determination by alpha spectrometry mentions natural Th-228 alpha peaks at 5,420 KeV and 5,430 KeV as potentially interfering with the Am-241 peak at 5,490 and 5,440 KeV. Furthermore, the Pu-238 peak at 5,500 and 5,460 KeV could interfere with Am-241.[29] In addition to likely interference with the Am-243 tracer, other natural and artificial interferences are, thus, known to present potential analytical problems that might lead to unacceptable results.

The chronologies of three crucial background replicates are as follows, along with the Det#9 gamma

data which were already available to EPA at the time of the alpha analyses:

Table 6

Analytical chronology of the three pre-designated background samples.

EPA data	gamma*		alpha	
Sample B-1A	Det#9	Original**	Replate	Report
Am-241 [fCi/gm]:	59.2 ±17.3	9.5 ±0.6	33.3 ±5.2	33.0 ±5.2
Mass [gm]:	30.0	30.0	30.0	
Yield [%]:	—	150.6	8.8	
Date [Mo-Da-97]:	07-20	11-11	11-19	12-02

EPA data	gamma*		alpha	
Sample B-1B	Det#9	Original**	Replate	Report
Am-241 [fCi/gm]:	—	19.2 ±1.2	38.1 ±2.9	40.0 ±3.8
Mass [gm]:	—	20.0	20.0	
Yield [%]:	—	153.1	35.2	
Date [Mo-Da-97]:	—	11-11	11-19	12-02

EPA data	gamma*		alpha		
Sample B-1C	Det#9	Original**	Dup.Anal.	Replate	Report
Am-241 [fCi/gm]:	47.8 ±13.9	27.6 ±1.4	68.8 ±4.8	53.1 ±3.8	53.1±3.8
Mass [gm]:	20.0	20.0	7.5	20.0	
Yield [%]:	—	160.4	87.3	31.7	
Date [Mo-Da-97]:	08-01	11-11	11-17	11-19	12-02

* Without blank correction, unvalidated EPA gamma data.

** Log notes: "Po?" "Result not used —interference in Am-243 tracer region— clean-up chemistry required." [EPA, pp.1178, 1186, 1194].

In none of these three cases was any but the final, replated, recounted value reported in the EPA results.

EPA performed a duplicate analysis on 17 November which cleared up these problems. When the lab simply brought the 20-gm sample size within the 10 gm specification of the SOP, the interference seems to have been eliminated. That is, good alpha Am-241 results were seemingly obtained by following the SOP instructions.

The logical approach would have been for the laboratory to have then re-analyzed all the samples in compliance with the SOP instructions to avoid unsatisfactory analyses. But instead, the lab did not enter any control comment on either the Review and Transfer Screen sheet or Data Summary sheet for this Duplicate Analysis of Sample B-1C.[30] EPA then submitted the original 20 gm B-1C sample (along with the other two pre-designated background samples) to a special chemical clean-up treatment and replating.

By November 20, when the replated alpha results were *peak-searched*, the lab had solid evidence that the SOP warning against some 1997 Amchitkan samples exceeding 10 gms for alpha Am-241 analysis

was important. That evidence came from the Duplicate Analysis of B-1C, from the clean-up chemistry and recounting of all three pre-designated background samples and Sample L-2C.

The implication is that the alpha results are quite sensitive to the analytical procedure — whether samples of 10 gm are analyzed according to the SOP or whether over-sized samples are submitted to clean-up chemistry and replated. This difference in procedure amounts to about 25% difference in the Am-241 results for Sample B-1C. This procedural difference exceeds the duplication assurance level in the Final Report.[31]

With no time for mistakes, DOE's lab undertook a known-to-be dangerous deviation from SOP for the stated purpose of improving Am-241 precision. To take such a risk of analytical failure with so little time to overcome problems does not make sense.

The effect of these deviations was to lower Am-241 alpha values. That effect was applied selectively to the 1997 samples by selecting different sample sizes and by selectively applying clean-up chemistry. The actual effect of replating all three background samples was to bring all three key, pre-designated background samples into agreement with the Det#9 data. Without this special treatment, the replicate candidates would have tested as much above pre-designated background by alpha spectrometry as they had by gamma. See Table 7.

Table 7

Chronology of crucial, comparable Am-241 results [fCi/gm-ash].

Analyses—>	—>	—>	—>
Timeframe:	Jul.-Sep.	mid-Nov.	late
Sample	Det#9 gamma	1st alpha	reported alpha
XC-1	167.7	82.7 ->	->
XL-7	148.9	125.6 ->	->
Candidate	158.3	104.2	104.2
B-1A	64.8	9.5	33.0
B-1C	56.1	27.6	53.1
Background	60.4	18.6	43.0
Candidate minus Background	97.9	85.6	61.2

This sort of consideration thwarts detailed review of the alpha Am-241 results. The lab operations are too distant from usual standards to allow ordinary review. The effect is to render the belated alpha Am-241 data broadly unreviewable on procedural grounds and thus unallowable.

In each of the three alpha replications of background Am-241 in Table 9, the result reported by EPA is more than 90% above than the original value. This conflicts the EPA's assurance of counts being within ±20% of the original results.[32] Such reporting omissions represent a laboratory management problem and are additional grounds for rejecting results.

Evidence of Po-210 contamination is anticipated. These three examples and the lack of analytical assurances to the contrary indicate some amount of Po-210 contamination in the 1997 alpha analyses for Am-241. Such contamination would show as depressed alpha results for Am-241. The EPA alpha data are compared to the blank-corrected Det#9 gamma data for Am-241 (from Tables 2 and 3) as follows:

Table 8

Comparison of gamma and alpha results for aquatic vegetation samples

Am-241 [fCi/gm-ash]:

Sample:	XC-1	XC-6	C-1A	C-2B	C-3A	C-3B	XL-7	L-1C	L-2C
Det#9 gamma*:	167.7	9.2	94.0	14.8	57.7	2.9	148.9	4.2	58.3
mean EPA alpha:	82.7	6.3	54.6	13.9	15.8	14.6	125.6	4.3	74.7
gamma/alpha:	2.0	1.5	1.7	1.1	3.7	0.2	1.2	1.0	0.8

Sample:	M-2A	M-2C	M-3B	B-1A	B-1C	**MEAN**
Det#9 gamma*:	70.3	126.0	80.2	64.8	56.1	**68.2**
mean EPA alpha:	46.0	40.9	43.5	33.0	53.1	**43.5**
gamma/alpha:	1.5	3.1	1.8	2.0	1.1	**1.6**

* Blank corrected.

The EPA alpha analyses for Am-241 average less than two-thirds of the corresponding gamma values. Such analytical undervaluation of Am-241 is consistent with Po-210 contamination tentatively identified by EPA in two of the samples and seemingly not procedurally quantified or excluded in any samples except L-2C.

Alpha spectrometry failures include:

- the SOP for alpha Am-241 analysis warns of unsatisfactory results if optimal sample size is exceeded, which regularly occurred in the EPA alpha analyses;
- three out of four cleaned-up, replated, recounted samples did not confirm the original counts;
- Po-210 was in the system but uncontrolled as evidenced by Figure 5, etc.;
- there was a lack of any logical procedure which would mitigate these considerations.

The EPA alpha results for Am-241 must be excluded for the purposes of this report, with the exception of Sample L-2C.

It is thus feasible to use this one validated alpha analytical result to confirm the corresponding Det#9 gamma datum, as follows:

Sample L-2C: Am-241 confirmation [fCi/gm-ash]

by Det#9 gamma	58.3 ±17.7
by alpha	72.8 ± 7.1

As these two independent analyses of Sample L-2C have overlapping precision bounds, they accord statistically. This is the one and only confirmation of the Det#9 gamma results for the 1997 study. This confirmation of the gamma results by alpha spectrometry is adequate for the purposes of this report.

Validation Summary

The 1600-page Final Results report of EPA lab analyses provides sufficient information, as reviewed here, to adequately evaluate the existing EPA data for the purpose of answering the crucial question of whether Cannikin and Long Shot are leaking long-lived radioactivity into the Amchitkan aquatic environment. For this purpose, the 1997 EPA data are accepted, as follows:

Data Which Meets Criteria for Acceptability

- Det#9 gamma analytical results of Am-241 for the 14 ashed, 1997 Amchitka, aquatic vegetation samples, zero-corrected for blank.
- No Det#1 and Det#2 gamma analytical results for Am-241.
- Omission of other gamma radionuclide analyses, particularly Be-7 and Cs-137, as beyond the necessity and feasibility of this Data Quality assessment.
- The replicated alpha Am-241 results for Sample L-2C.
- All alpha analytical results for Pu-239/240
- No alpha analytical results for Pu-238.

Greenpeace recommended to DOE and ATAG that all americium samples of this study should be submitted to uniform clean-up chemistry, replated, recounted, and then be adequately repeated to assure sufficient reduction of interference.[33]

With this validation now completed, there is no scientific reason to further delay reporting the results and conclusions of this study to the public.

The authors hope that the more extensive data audit process will succeed, and the final DOE report will differentiate between acceptable and unsatisfactory analytical data and so allow valid conclusions.

The Threat of the U.S. Nuclear Complex

Before the U.S. government exploded three nuclear bombs under Amchitka, the public was assured of absolute safety. Growing public concerns before the largest of these blasts — the 5,000,000 ton Cannikin on November 6, 1971— were judged to be "a tempest in a blinkin' teapot," by Judge Hart, who reviewed the lawsuits against the AEC.[34]

Thirty-eight hours after the Cannikin shot, the earth collapsed, and White Alice Creek vanished into the

depression. Mechanical containment of radioactivity had been breached, and the inward half of a radioactive leakage pathway opened. For the next quarter century the AEC and its successor, DOE, assured the public there was no reason for any concern over Cannikin or any of the hundreds of other underground U.S. nuclear explosions:

> There is essentially no possibility that a significant release of radioactive material from an underground nuclear test could go undetected. Similarly, there is essentially no chance that radioactive material could reach a pathway to humans and not be discovered by the Environmental Protection Agency.[35]

DOE summarized the particular monitoring history for Amchitka up to the present study: "Results of monitoring programs indicate no evidence of gamma-emitting radionuclide or tritium contamination leaking from any of the shot areas, except for tritium at the Long Shot (surface ground zero) area."[36]

Thus, the question of any gamma-emitting radionuclide —such as Am-241— leaking from Cannikin or Long Shot was a clear, well-defined technical position for government management of the nuclear weapons complex. The government position is uncompromising: Radioactive leakage into the open environment was and is impossible, and it has been proven not to exist.

Greenpeace accepted the challenge posed by those DOE assurances and sent a scientific expedition to Amchitka in 1996. Greenpeace concluded that Cannikin and Long Shot are leaking Am-241 into the open, aquatic environment and thence into the Bering Sea.

DOE and Greenpeace agreed to terms and conditions of this test to be conducted: DOE and Greenpeace would return to Amchitka in 1997 to confirm or refute whether Cannikin —the largest-ever underground nuclear explosion— is leaking Am-241. This would be the largest-ever scientific test of the technological credibility of the U.S. nuclear weapons complex.

The crucial, agreed test of credibility was based on statistically significant elevation of replicate samples selected by Greenpeace in comparison to background samples selected by DOE. Then too, there were other testable predictions Greenpeace had made that would provide additional assurances of this agreed test outcome.

This is the first report of the outcome of this nuclear credibility test: The U.S. nuclear weapons complex has failed this agreed, scientific credibility test.

In particular, not only do replicate candidates test significantly higher than Study Background, but the other testable predictions have verified the conclusion that Cannikin is leaking. By means of better sample washing, Am-241 values were increased and Am/Pu ratios were elevated —more evidence of radioactive leakage rather than a worldwide fallout origin of the americium. Cobalt-60 was detected downstream of Cannikin and Long Shot. The first solid evidence that the Milrow shot is also leaking is reported.

DOE was wrong about one of the important assurances it has held out to the public: DOE's underground explosions have leaked radioactivity into the open environment and government monitoring has failed to detect it. This is merely a demonstrable, technical defect in the U.S. nuclear weapons complex. All

complex, highly technological systems have defects.

The crucial question is how management of such a system responds to demonstrations of defects: Does management actively seek out evidence —even hints of problems— and evaluate those problems and aggressively correct not only those problems but other problems that might be inferred from that evidence? Is the U.S. nuclear weapons system operated with a modern, risk-management approach? Are Greenpeace's discoveries at Amchitka to be harbinger to systemic failures by the DOE to manage its *radioactive* weapons complex?

As the 1997 study progressed and the evidence came in, DOE engaged in various activities which, early on, had the effect of postponing publication of the bad news. But as time passed and something had to be reported belatedly to the public, the alpha spectrometric data were systematically abused.

Although the damages done to the data late in the study are complex and technical in nature, the evidence is clear: DOE management of the U.S. nuclear weapons complex is of the old school in which bad news is hidden. This conflicts with sound risk management and makes the entire system inherently risky.

With a massively integrated, complex system like the U.S. nuclear arsenal, the overwhelming risk is of an unanticipated catastrophe. A catastrophe can occur with no substantial warning.[37]

This is the threat of the U.S. nuclear complex. All Americans and other peoples are threatened by ongoing, unmanaged nuclear risks institutionalized in the bureaucratic structure of DOE and the Department of Defense.

If these risks of catastrophic nuclear weaponry accidents are to be brought under rational control, the American public will have to gain control over this secret complex which is presently owned and operated by the U.S. government outside the usual checks and balances of this democracy.

Finally, we see that Amchitka is leaking some long-lived radioactivity into streams near Cannikin and Long Shot, and probably Milrow too. These streams flow down onto the Bering Sea shore or into the Pacific Ocean. Upon entry into the ocean, the radioactivity, which is readily detectable but not grossly above background levels on the island, is quickly diluted and rapidly spread.

This pollution problem cannot conceivably be of a magnitude comparable to the implications of the loss of DOE's scientific credibility reported here. But DOE's concerted efforts to cover up radioactive pollution to keep the public unconcerned do not bode well. It is not clear that the heart of the radioactive leakage on Amchitka has yet been discovered. It is only clear that DOE is doing whatever it can to frustrate discovery of problems that make DOE look bad and invite public scrutiny and even oversight. So ways and means outside government agencies will have to be found to determine the kind and state of radiological and nuclear problems that have been held secret for half a century within the U.S. nuclear military complex.

Recommendations

1 The radioactive leakage sites on Amchitka should be mapped and characterized chemically and radiologically in 1998.

2 Radiological interferences with the tracer used in the EPA alpha analyses for Am-241 should be removed from all the samples by *clean-up* chemistry, and the samples should be recounted and confirmed free of interfering contaminants, to provide accurate, comparable Am-241 results for the final report of the 1997 study. This would multiply the value of the DOE study.

3 The U.S. government should expeditiously modernize its concepts, theories, monitoring programs, and technical management of the U.S. nuclear weapons complex.

4 Non-governmental oversight and monitoring are urgently required, inasmuch as the U.S. government itself *owns and operates* the U.S. nuclear weapons complex almost entirely in secret from the public. Technological defects grown secretly over the last half-century must be identified and characterized before catastrophic harm is done. This is feasible in the present era of peace and national security.

5 The public and Congress should consider cautiously, carefully decommissioning the vast U.S. complex of weapons of mass destruction. The system is shown here to be scientifically unsound and therefore catastrophically dangerous.

Endnotes

[1] N. Buske and L. Josephson, SEARCH, "Hanford Reach Project, Spring 1986 Data Report," (April 1986). U.S. Geological Survey, Subsurface Transport of Radionuclides in Shallow Deposits of the Hanford Nuclear Reservation, Washington — Review of selected previous work and suggestions for further study, Open-File Report 87-222 (1987).

[2] David Robie, Eyes of Fire, New Society Publishers (1987) 1.

[3] Cousteau Foundation, Scientific Mission of the Calypso at the Mururoa Site of Nuclear Testing (November 1988), trans. from French by M.D. Davis, for Greenpeace (July 1989).** The review by N. Buske, "Cesium-134 at Moruroa" (September 1990) was the technical basis for the Rainbow Warrior expedition in December 1990, confirming traces of Cs-134 in carefully sampled plankton in international waters.

[4] Nuclear Flashback. (October 1996.) The Return to Amchitka. Report of a Greenpeace scientific expedition to Amchitka Island, Alaska— Site of the largest underground nuclear test in U.S. history.

[5] Letter of October 31, 1997 to Secretary of Energy Hazel O'Leary.

[6] DOE NVOO, "Amchitka Island Fiscal Year 1997 monitoring effort, project management plan," (May 1997) App.B.

[7] EPA, "Amchitka, Alaska Special Sampling Project, 1997, Sampling and Analysis Plan," (May 1997) App.A. This is virtually the wording approved by ATAG in the April draft. The "Sampling and Analysis Plan" was never approved by ATAG. Instead, these drafts by DOE and EPA, together with the video and tape-recorded transcripts of the ATAG meetings were considered to be definitive.

[8] Cannikin Leaking!

[9] "Cannikin Leaking!", Fig. 6, p.16.

[10] simplified from Table 2 of "Cannikin Leaking!" p.17.

[11] see "Nuclear Flashback" p.25 for a general hypothesis of Am-241 migration.

[12] D.W. Efurd, LANL, letter report to Frank Maxwell (June 4, 1997) provides the results and interpretation. D.W. Efurd, "Plutonium concentrations as a function of particle size in water Sample ER-20-5#1" in Isotopic Fingerprinting of Samples Collected on Amchitka Island During 1996 Sampling Effort (September 10, 1997) describes migrating plutonium as particulate.

[13] NF. p.18, 20.

[14] "Cannikin Leaking!" p.21.

[15] D.W. Efurd, G. G. Miller, et al., "Evaluation of the anthropogenic radionuclide concentrations in sediments and fauna collected in the Beaufort Sea and northern Alaska," LA-13302-MS, Los Alamos National Laboratory (July 1997).

[16] N. Hayashi, et al, "Determination of Pu-239/240 and Am-241 in environmental samples," Journal of Radioanalytical and Nuclear Chemistry, Articles, 115 (2) (1987) 376.

[17] IAEA, "Sediment Kds and concentration factors for radionuclides in the marine environment," (1985) Table VIII, p.45.

[18] DOE/NVOO, "Amchitka Island Fiscal Year 1997 monitoring effort, project management plan," (May 1997) 3.

[19] EPA p.5.

[20] See L.G. Kanipe, TVA, Handbook for Analytical Quality Control in Radioanalytical Laboratories, E-EP/77-4 (August 1977) 4-11 to 4-14.

[21] N. Buske, Greenpeace, "1997 Amchitka radiation study: confirm/refute Am-241 leakage, acceptance of EPA gamma and alpha data," prepared for ATAG (2 December 1997).

[22] Relevant SOPs are: NRA 1.12; "Simultaneous analysis of actinides in environmental samples"; and NRA 1.13, "Americium, curium and californium analysis," which continues to produce americium values [SAP, App.D]. The controlling consideration is the same for both the plutonium analysis [Sec. 11.0 of NRA 1.12] and the americium analysis [Sec. 10.0 of NRA 1.13].

[23] D. Farmer, EPA/R&IE, "Development of a sequential method for the determination of Pu/Am in environmental samples," (September 5, 1997) with attached "Simultaneous determination of plutonium-239(240) and americium-241 in freshwater aquatic moss and marine algae by alpha spectroscopy" (undated) 15 pp.

[24] EPA, 1108.

[25] EPA,1409.

[26] EPA, 1547.

[27] EPA, 1133, 1429.

[28] EPA, 1589.

[29] EPA/R&IE, "Simultaneous determination of plutonium-239(240) and americium-241 in freshwater aquatic moss and marine algae by alpha spectroscopy," (undated) draft, 1.

[30] EPA, pp.1445, 1478.

[31] EPA, 6.

[32] EPA, 006.

[33] The option of performing clean-up chemistry on all the 1997 alpha samples to salvage them was submitted by N. Buske to ATAG via mosquitonet e-mail upload on December 22, 1997. Buske/Greenpeace uploaded this recommended salvage on December 29th.

[34] Quoted in the Anchorage Daily Times (November 30, 1971).

[35] Congressional Office of Technology Assessment, The Containment of Underground Nuclear Explosions (1989) 74-76].

[36] See DOE/NVO, "Amchitka Island summary of historical data (February 1997), presented to the ATAG.

[37] There are several macro-scale risk assessments of the U.S. nuclear arsenal. The relevant concerns have been presented for the similar field of naval nuclear propulsion by N. Buske, "Technical evaluation of 'the safety of nuclear powered ships" (January 1993).