NVO-214

ENEWETAK FACT BOOK

(A RESUMÉ OF PRE-CLEANUP INFORMATION)

COMPILED BY

WAYNE BLISS
U.S. ENVIRONMENTAL PROTECTION AGENCY

COMPILED 1977
PUBLISHED SEPTEMBER 1982

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

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(A RESUMÉ OF PRE-CLEANUP INFORMATION)

COMPILED BY WAYNE A. BLISS
U.S. ENVIRONMENTAL PROTECTION AGENCY
FOR
ENEWETAK RADIOLOGICAL SUPPORT PROJECT

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FOREWORD

In 1977, soon after establishment of the Enewetak Radiological Support Project (ERSP) to provide radiological advice and assistance to the Defense Nuclear Agency, it became essential to assemble an "as is" description of the Atoll. We asked Wayne Bliss, of EPA's Environmental Monitoring Systems Laboratory, Las Vegas, Nevada, to take on this important task. Over the ensuing months, Wayne examined records, files and notebooks and, I often think, his crystal ball. He interviewed many old-timers and became himself a true authority on this tiny coral atoll which had sustained the multiple impacts of more than a decade of earth moving, construction and nuclear testing.

The record of Wayne's research became the Enewetak Fact Book. To all of the ERSP management team and to the DOD planners it became an indispensable tool. As now published, it becomes a part of the Enewetak history. Wayne Bliss has our thanks for a most valuable contribution.

Roger Ray
Project Manager
Enewetak Radiological
Support Project

Las Vegas
September 1982

TABLE OF CONTENTS

PROLOGUE

ENEWETAK FACT BOOK

Wayne Bliss
(Written in 1977 - before cleanup)

"Enewetak Fact Book" is a term which has evolved to describe a group of short treatises on the precleanup condition of the islands in Enewetak Atoll (Figure 1). These assemblages were compiled in a relatively short time in 1977 and have no formal structure nor have they been reviewed by any process normally afforded to the briefest technical note. Their purpose is to provide brief guidance to the radiological history and radiological condition of the islands for use in cleanup of the Atoll, i.e. cleaning up physical and radiological hazards which resulted from nuclear test operations conducted there from 1948 through 1958.

The information presented in the Fact Book has been gleaned from numerous sources which include formal reports, old and new; files, both agency and personal; and many interviews and discussions. Therefore, some of the information is popular opinion, some is inferential, but most of it can be substantiated by formal reports and experts from the testing program. The principal report for determining radiological conditions for cleanup is NVO-140, Enewetak Radiological Survey, Oct. 1973. Many of the figures herein are reproduced directly from that report.

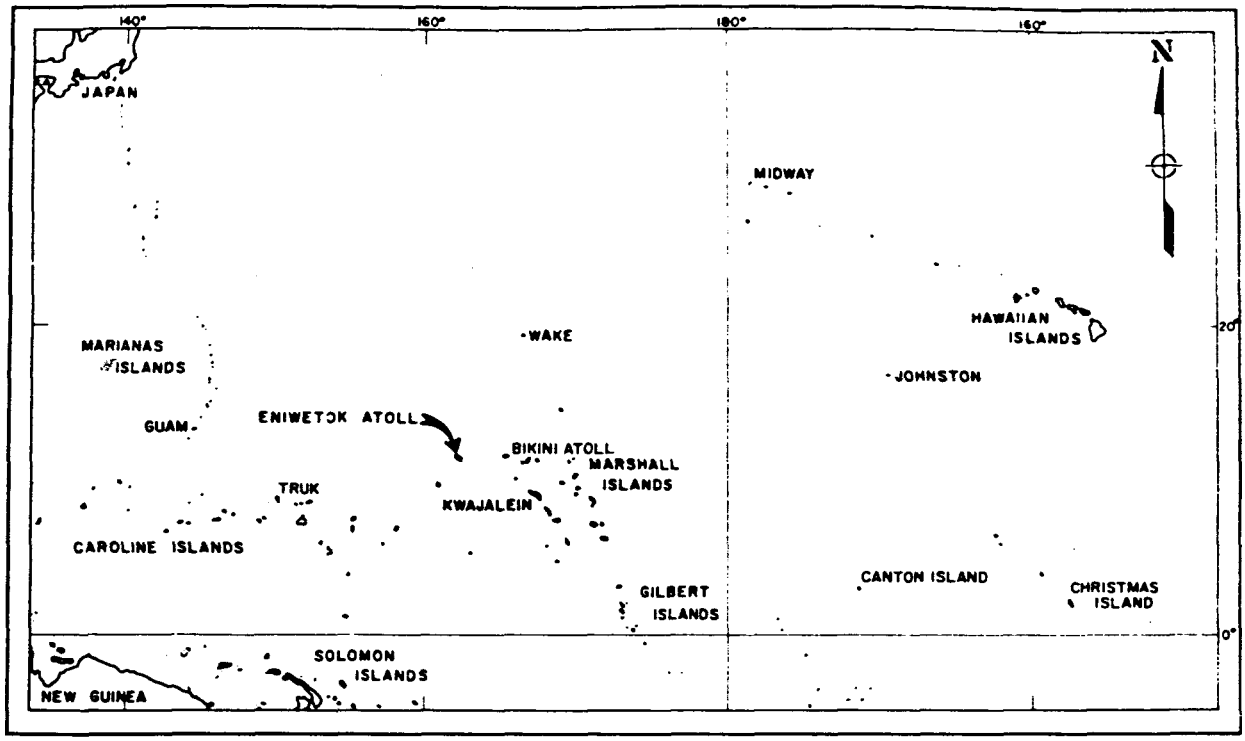
Other important reports are the Engineering Study for a Cleanup Plan (1972), and the Environmental Impact Statement (1975), both prepared for the Defense Nuclear Agency by Holmes & Narver, Inc.

Brevity has been a key factor in the composition of this Fact Book as one who must conduct a field operation cannot efficiently perform while carrying a reference library. Therefore, much of the information is presented very concisely and on map figures. It is necessary for the user of the Fact Book to be familiar with the test program at the Enewetak Proving Ground and be able to make logical inductions or refer to an appropriate reference for more detailed information.

The first nuclear test at the Enewetak Proving Ground was conducted on April 14, 1948 (Greenwich time). OPERATION CROSSROADS conducted at Bikini Atoll in 1946 consisted of two experiments to determine the effects of nuclear explosions on military hardware. OPERATION SANDSTONE conducted at Enewetak in 1948 was the pioneering attempt to scientifically evaluate nuclear explosion phenomena. All nuclear experiments at Enewetak were weapons related; however, they included various studies related to understanding the explosion phenomenon and blast effects.

Many additional studies were conducted such as measuring biological exposure and responses, evaluating detection instruments, comparing nuclear yield determination methods and so on.

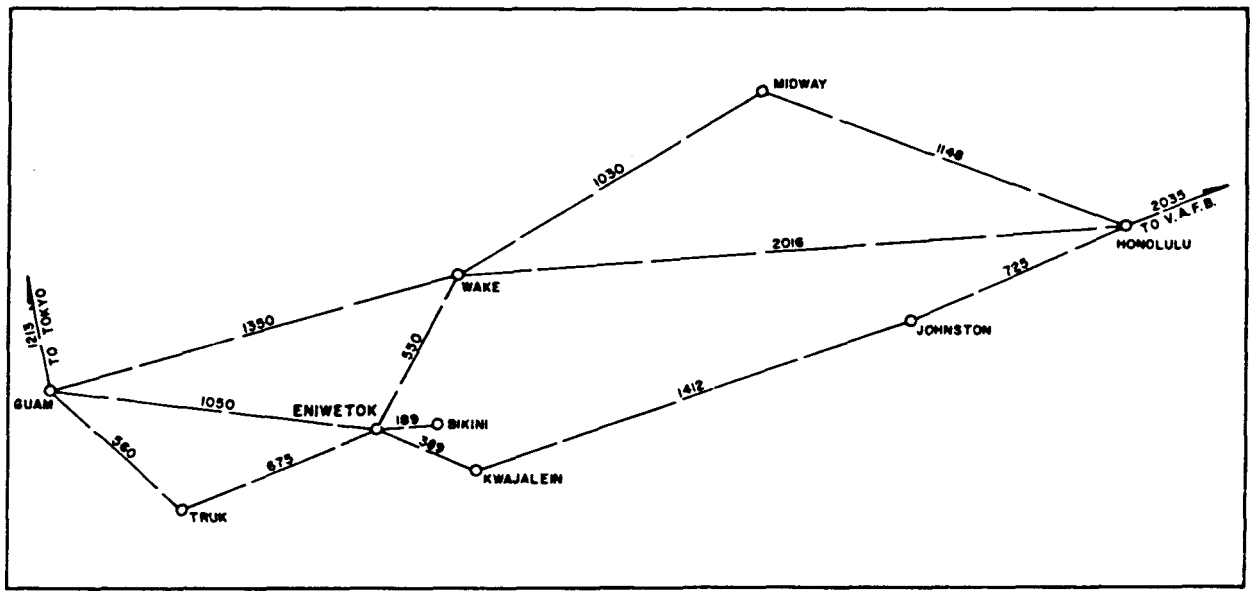
A typical operation at Enewetak consisted of facility construction by a contractor (Holmes & Narver, Inc.), conduct of the operation by a joint AEC-DOD task force, and an interim roll-up and preparation of the following operation by the contractor. Table 1 is a list of the nuclear operations and nuclear tests conducted at Enewetak.



REGIONAL MAP

300 0 300 600

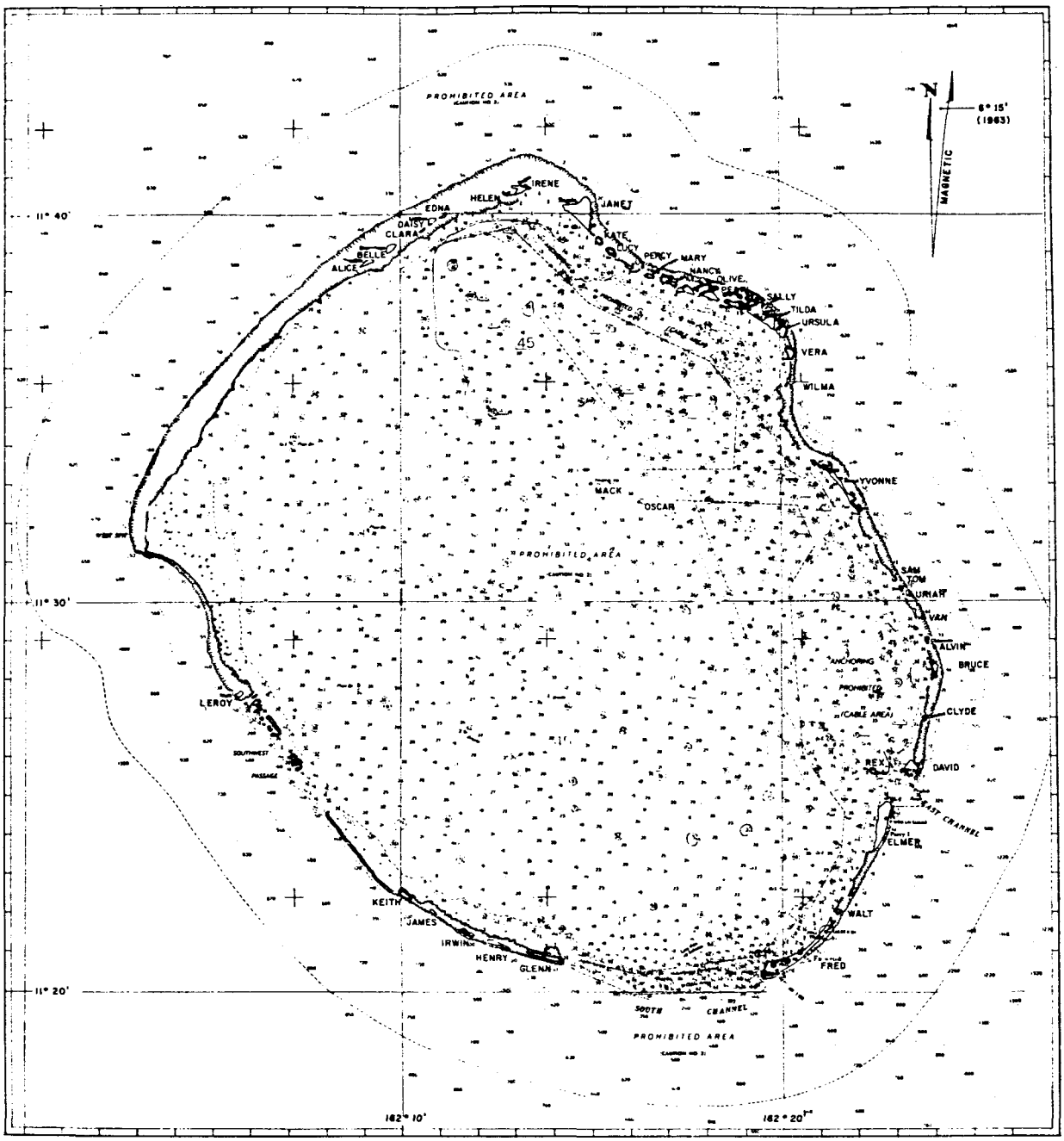
GRAPHIC SCALE IN NAUTICAL MILES



AIRLINE DISTANCES MAP

NO SCALE

FIGURE 1a. ENEWETAK ATOLL LOCATION MAPS



VICINITY MAP

10,000 5000 0 10,000 20,000

GRAPHIC SCALE IN FEET

SOUNDINGS IN FATHOMS

SCALE - 1" = 8330'

NOTE

ORIGIN OF COORDINATE GRID SYSTEM,
CORAL N-100,000 E-100,000

FIGURE 1b. ENEWETAK ATOLL LOCATION MAPS

TABLE 1

ENEWETAK PROVING GROUND

Operation/Event Name	Date (GCT)	Type & Height (ft) of Burst	Yield	Location
SANDSTONE				
X-RAY	4/14/48	Tower 200	37 KT[1]	Janet, west tip
YOKE	4/30/48	Tower 200	49 KT	Sally, west tip
ZEBRA	5/14/48	Tower 200	18 KT	Yvonne, north end
GREENHOUSE				
DOG	4/7/51	Tower 300	-	Yvonne, north end
EASY	4/20/51	Tower 300	47 KT	Janet, west tip
GEORGE	5/8/51	Tower 200	-	Ruby
ITEM	5/24/51	Tower 200	-	Janet, north tip
IVY				
MIKE	10/31/52	Surface (thermonuclear)	10.4 MT[2]	Flora
KING	11/15/52	Airdrop, 1500	500 KT	Yvonne, 2000' north
CASTLE				
NECTAR	5/13/54	Barge	1.69 MT	Mike Event Crater
REDWING				
LACROSSE	5/4/56	Surface	40 KT	Yvonne, north end
YUMA	5/27/56	Tower 200	-	Sally, west tip
ERIE	5/30/56	Tower 300	-	Yvonne, near runway
SEMINOLE	6/6/56	Surface	13.7 KT	Irene
BLACKFOOT	6/11/56	Tower 200	-	Yvonne, middle
KICKAPOO	6/13/56	Tower 300	-	Sally, north tip
OSAGE	6/16/56	Airdrop 670	-	Yvonne, middle
INCA	6/21/56	Tower 200	-	Pearl

1 KT = Kiloton defines energy equivalent to 1000 tons of TNT.
2 MT = Megaton = 1000 KT.

TABLE 1 (Continued)

Operation/Event Name	Date (GCT)	Type & Height (ft) of Burst	Yield	Location
MOHAWK	7/2/56	Tower 300	-	Ruby
APACHE	7/8/56	Barge	-	Mike Event Crater
HURON	7/21/56	Barge	-	Mike Event Crater
HARDTACK, PHASE I				
CACTUS	5/5/58	Surface	18 KT	Yvonne, north end
BUTTERNUT	5/11/58	Barge	-	Yvonne, 4000' SW
KOA	5/12/58	Surface	1.37 MT	Gene
WAHOO	5/16/58	Underwater 500	-	James, 1.4 mi S
HOLLY	5/20/58	Barge	-	Yvonne, 2075' SW
YELLOWWOOD	5/26/58	Barge	-	Janet, 6000' SW
MAGNOLIA	5/26/58	Barge	-	Yvonne, 3000' SW
TOBACCO	5/30/58	Barge	-	Janet, 4000' SW
ROSE	6/2/58	Barge	-	Yvonne, 4000' SW
UMBRELLA	6/8/58	Underwater 150	-	Glenn, 1.4 mi N
WALNUT	6/14/58	Barge	-	Janet, 6000' SW
LINDEN	6/18/58	Barge	-	Yvonne, 2000' SW
ELDER	6/27/58	Barge	-	Janet, 4000' SW
OAK	6/28/58	Barge	8.9 MT	Alice, 3 mi SW
SEQUOIA	7/1/58	Barge	-	Yvonne, 2000' SW
DOGWOOD	7/5/58	Barge	-	Janet, 4000' SW
SCAEVOLA	7/14/58	Barge	-	Yvonne, 560' SW
PISONIA	7/17/58	Barge	-	Yvonne, 12000' W
OLIVE	7/22/58	Barge	-	Janet, 4000' SW
PINE	7/26/58	Barge	-	Janet, 8500' SW
QUINCE	8/6/58	Surface	-	Yvonne, middle
FIG	8/18/58	Surface	-	Yvonne, middle

The zero points are located on the appropriate figures in each island report. Where these points have special impact, the report for that island will speak to that impact. General considerations which should be related to single shot zero points include:

> that shot contaminated debris may remain in the area as rigorous cleanup to prepare for succeeding shots was not necessary and often cursory cleanup included dozing contamination into the GZ area, particularly if there was a crater or depression, and covering the area with 'clean' soil.

Some considerations for multiple shot points and islands having multiple zero points are:

> That GZ areas were scraped, dozed and agitated in preparation for succeeding shots;
>
> new borrow pits were dug and perhaps old ones buried in the engineering process, thus burying contaminated material;
>
> cable trenches were reexcavated for cable replacement and contaminated material may have been introduced when the trenches were re-covered (e.g., Janet and Sally); contaminated soil was covered with clean soil to reduce personnel exposures;
>
> and, useable scientific stations were rehabilitated which may have required earth moving.

These considerations describe actions which are suspected because of experimental designs or the recollection of persons present at the time. If they were recorded, the records are now lost. Knowledge of high activity alpha sources appears more complete than gamma and beta sources; however, field instruments for detecting alpha activity were not well advanced in the 1950's—particularly the early 1950's—and some sources could have escaped notice.

Each island's Fact Book report contains figures which in turn contain much information important to cleanup. The figures are probably the most useful section of each report. The original copy for most of the figures comes from the Engineering Study for a Cleanup Plan.[1] In some cases sketches are provided which were drawn from figures dating back to the time of testing or from 1972 aerial photos. To each figure has been added information pertinent to radiological cleanup. Zero points have been identified. Known or suspected sites where contaminated material is buried are noted. The maximum exposure rate as measured in 1972 with a Na(T1)I scintillator survey instrument held at 1-m height is shown in the approximate location where the reading was taken. Maximum concentration values for ^{90}Sr, ^{60}Co, ^{239}Pu, and ^{137}Cs are shown for surface to 15-cm soil samples in the area where the sample was collected. Due to the heterogeneity of this radionuclide mix, these values may not exist coincidentally. Where ^{239}Pu concentrations are in the tens of pCi/g or show unusual trends, sample locations are shown and numbered as in NVO-140. Other references to sample locations by number are also as identified in NVO-140. In most cases the graphical representation of the above four radionuclides for the soil profile at that location is also shown. Only in a couple of cases is the exposure rate of contaminated material shown, as a resurvey and classification of debris will be conducted prior to the cleanup operation. In cases

[1]Figures in the Cleanup Plan are revisions of topographic maps prepared for the Atomic Energy Commission by Holmes & Narver in 1959.

where radio-contaminated debris is suspected but has not been reported elsewhere, this will be noted on the figure or in the narrative. Additional notes are made for points where a new look for contamination may be in order such as the drain outfall of the aircraft decontamination facilities on Fred (Enewetak) or the laboratory buildings on Elmer (Medren). A single line note of the opted use limits for rehabitation of Enewetak is included on the individual island figures. Of five proposed cases for rehabitation, Case 3 is considered most practical. In summary Case 3 specifies:

1. Pu cleanup to ERDA[2] guidelines on IRENE, PEARL and YVONNE.
2. No restrictions on fishing.
3. All radioactive scrap to be cleaned up from all islands.
4. Physical hazard and obstructive debris cleanup on all islands.
5. Living on southern islands, ALVIN through KEITH.
6. Subsistence agriculture limited to southern islands, plus KATE through WILMA, except that pandanus and breadfruit are limited to the southern islands.
7. No restrictions on travel except YVONNE pending cleanup.

The individual island figures specify the available uses but must be related to the above. For example, "Birds, eggs, subsistance and commercial agriculture" as noted for PEARL specifies that the island will be used only for harvesting wild birds and eggs and growing subsistance foods and commercial coconuts but excludes growing or using pandanus or breadfruit. Where these plants are included "unlimited agriculture" will be noted. Where Pu is noted as a Case 3 limit, the interpretation is that plutonium must be cleaned up to OPLAN 600-77 guidelines.

In the following text, islands are ranked in terms of "total H+1 hour exposure rate received," as a crude effort to estimate the relative amount of fallout deposited on each island. This is a technique devised by Lynch and Gudiksen, originally published in NVO-140, pp. 81-83. They normalized early time radiation readings to H+1 hour values and summed contributions from all nuclear tests on the atoll to arrive at a "total H+1 hour exposure rate received" value for each island. The relative rank assigned each island is stated in the discussion for that island.

[2]Energy Research and Development Administration, formerly Atomic Energy Commission and later Department of Energy.

June 16, 1977

Site Name: ALICE
Board of Geo.: BOGALLUA
Marshallese: BOKOLUO

ALICE is the northwesternmost island of Enewetak Atoll and has an area of 22 acres (8.9 hectares).

ALICE was not the site of any nuclear explosions; however, ranks 9th of the Atoll islands in total H+1 hour exposure rate received with 3,383 R/h. ALICE was the site of scientific stations and a steel mat landing strip. Much of the debris remains.

The maximum exposure rate measured in 1972 (NVO-140) was 170 uR/h at 1 m above the surface in the eastern interior of the island. Radioactivity in soil is fairly homogenous throughout the island and generally decreases with depth. The mean and range of observed activities exhibited by the surface samples for the following radionuclides are:

Radionuclide	Activity (pCi/g)	
	Mean	Range
^{90}Sr	80	14 - 430
^{137}Cs	36	5.6 - 141
^{239}Pu	12	3.9 - 68
^{60}Co	5.9	1.4 - 33

Soil sampling locations 23 and 25 (See Figure 2) near the northern edge of the island do not show a decrease with depth to the maximum sampled depth of 30 cm. This is likely a result of earth moving activities in the area of location 25 and wave disturbances in both. The ^{239}Pu level was less than 10 pCi/g from the surface to 30 cm in each case.

There are no known burials of radiocontaminated materials on ALICE. Scrap material on the island has been inconclusively classified as uncontaminated within the background levels of the island with the exception of a wrecked M-boat on the lagoon beach near the east end of the island.

CASE 3: BIRDS, EGGS, PICNIC

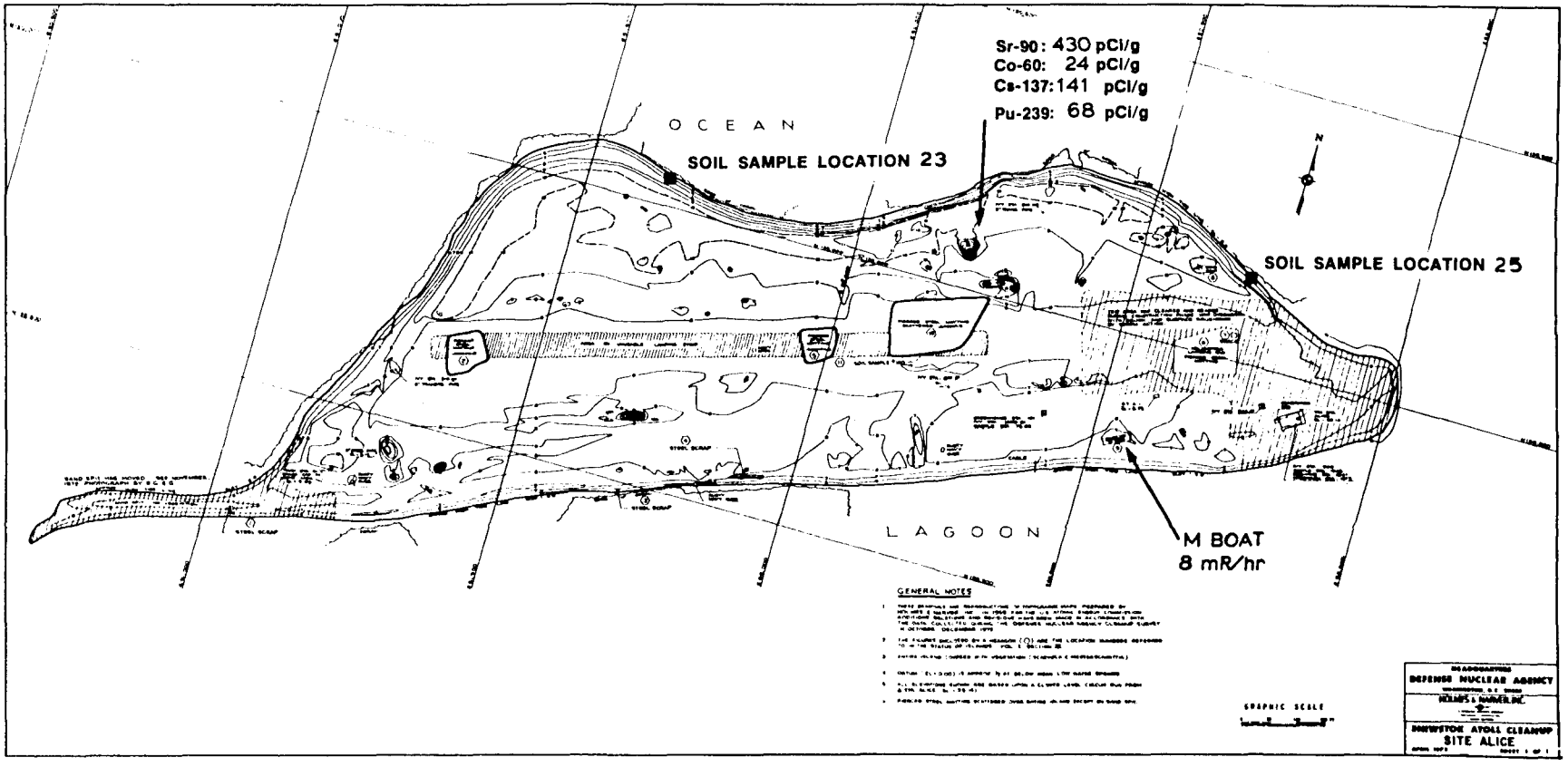


FIGURE 2. SITE ALICE

June 16, 1977

Site Name: BELLE
Board of Geo.: BOGOMBOGO
Marshallese: BOKOMBAKO

BELLE is in the northern portion of Enewetak Atoll and has an area of 31 acres (13 hectares). The island is vegetated from sparsely to very densely.

BELLE was not the site of any nuclear explosions; however, ranks 10th of the Atoll islands in total H+1 hour exposure rate received with 3,382 R/h. BELLE was the site of a few scientific stations during nuclear test operations.

The maximum exposure rate measured in 1972 (NVO-140) was 200 uR/h at 1 m above the surface in the northern interior of the island (Figure 3). Exposure rates were generally an order of magnitude higher on the northeast half of the island than on the southwest half. The mean and range of selected radionuclides in surface soil samples collected from these area types are:

Radionuclide	Activity (pCi/g)	
	Mean	Range
Areas of dense vegetation		
^{90}Sr	123	14 - 670
^{137}Cs	48	14 - 170
^{239}Pu	26	7.2 - 130
^{60}Co	10	3.1 - 30
Areas of sparse vegetation		
^{90}Sr	44	35 - 130
^{137}Cs	8.6	3.3 - 44
^{239}Pu	11	5.8 - 26
^{60}Co	4.6	2.4 - 9.6

It should be noted that ^{239}Pu in the top 5 cm of soil at locations 35, 37 and 100 are in excess of 40 pCi/gm; however, decrease rapidly with depth. Specifically the results are:

Location	Depth (cm)	^{239}Pu (pCi/g)
35	1	62
	3.5	200
	7.5	140
	20	11
37	1	130
	3.5	9.3
100	1	220
	3.5	56
	7.5	9

No radiocontaminant burials are known to have occurred on BELLE and none is suspected. Scrap material on the island is apparently not contaminated above background — 250 uR/h, surface contact. The quantity of scrap is small.

CASE 3: BIRDS, EGGS, PICNIC

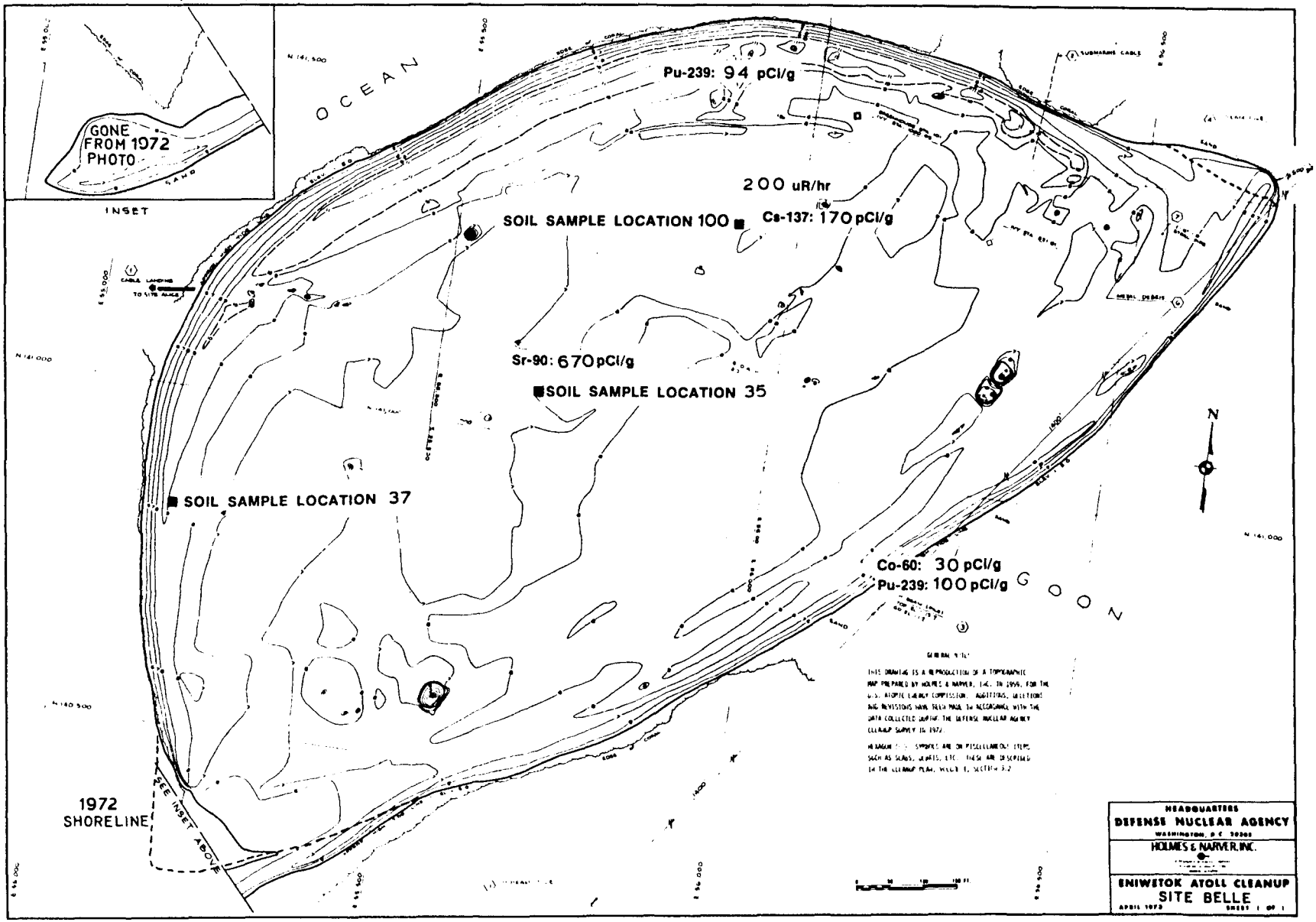


FIGURE 3. SITE BELLE

June 16, 1977

Site Name: CLARA
Board of Geo.: EYBBIYAE
Marshallese: KIRUNU

CLARA is in the northern portion of Enewetak Atoll and has an area of 7 acres (2.8 hectares).

CLARA was not the site of any nuclear explosions; however, ranks 11th of the Atoll islands in total H+1 hour exposure rate received with 3,154 R/h. CLARA was the site of one large and a few lesser scientific stations during nuclear test operations.

The maximum exposure rate measured in 1972 (NVO-140) was 100 uR/h at 1 m above the surface in the western midsection of the island (Figure 4). The mean and range of selected radionuclides from surface soil samples collected from CLARA are:

Radionuclide	Activity (pCi/g)	
	Mean	Range
^{90}Sr	65	13 - 310
^{137}Cs	26	5.6 - 110
^{239}Pu	22	3.5 - 88
^{60}Co	6.4	0.91 - 20

No known or suspected burial sites for radioactive materials exist on CLARA. The small quantity of scrap material to be found on CLARA is apparently not contaminated above the island background.

CASE 3: BIRDS, EGGS, PICNIC

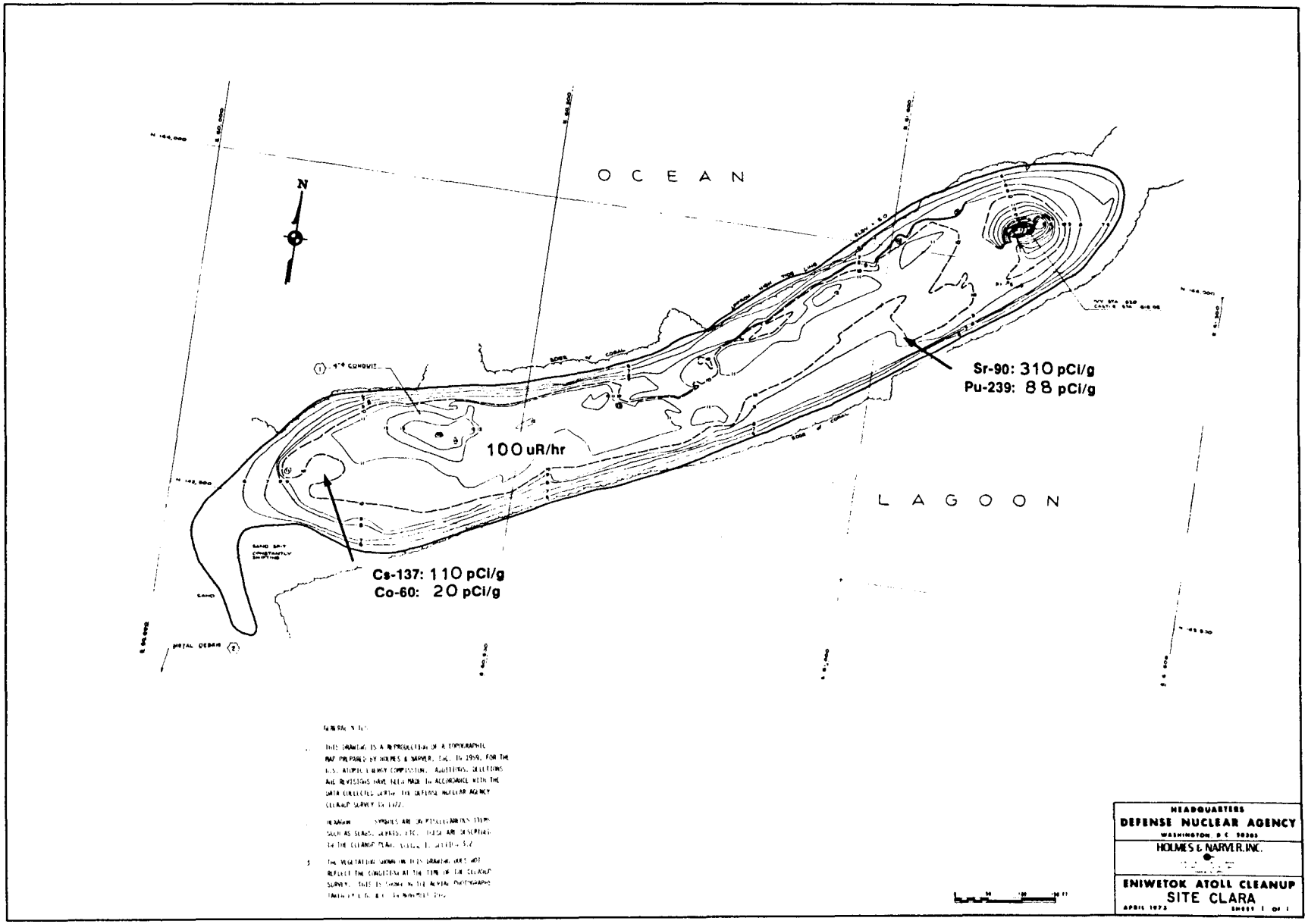


FIGURE 4. SITE CLARA

Site Name: DAISY
Board of Geo.: LIDILBUT
Marshallese: LOUJ

DAISY is in the northern portion of Enewetak Atoll and has an area of 21 acres (8.5 hectares). Vegetation on the island ranges from sparse on the lagoon side to relatively dense toward the ocean.

DAISY has no surface ground zeroes; however, ranks 7th of the Atoll islands in total H+1 hour exposure rate received with 3,354 R/h. DAISY is relatively free of physical remains from nuclear testing.

The maximum exposure rate measured in 1972 (NVO-140) was 140 uR/h at 1 m above the surface in the western interior of the island in the thicker vegetation (Figure 5). The relative density of vegetation appears to be proportional to residual radioactivity as shown below.

The mean and range of selected radionuclides in surface soil samples collected from these areas are:

Radionuclide	Activity (pCi/g)	
	Mean	Range
Areas of dense vegetation		
^{90}Sr	190	100 - 380
^{137}Cs	11	3.4 - 33
^{239}Pu	41	22 - 98
^{60}Co	11	6.4 - 26
Areas of sparse vegetation		
^{90}Sr	32	16 - 120
^{137}Cs	3.8	0.86 - 9.0
^{239}Pu	15	3.8 - 33
^{60}Co	0.85	0.37 - 7.4

Soil results from DAISY follow the premise that density of vegetation will be proportional to the decrease rate of radionuclides in soil with depth, i.e., surface levels may be higher in more densely vegetated areas but the concentrations of radionuclides decreases more rapidly with depth.

No known or suspected burials of radioactive materials exist on DAISY. The small amount of scrap material there is apparently not contaminated above the island background.

CASE 3: BIRDS, EGGS, PICNIC

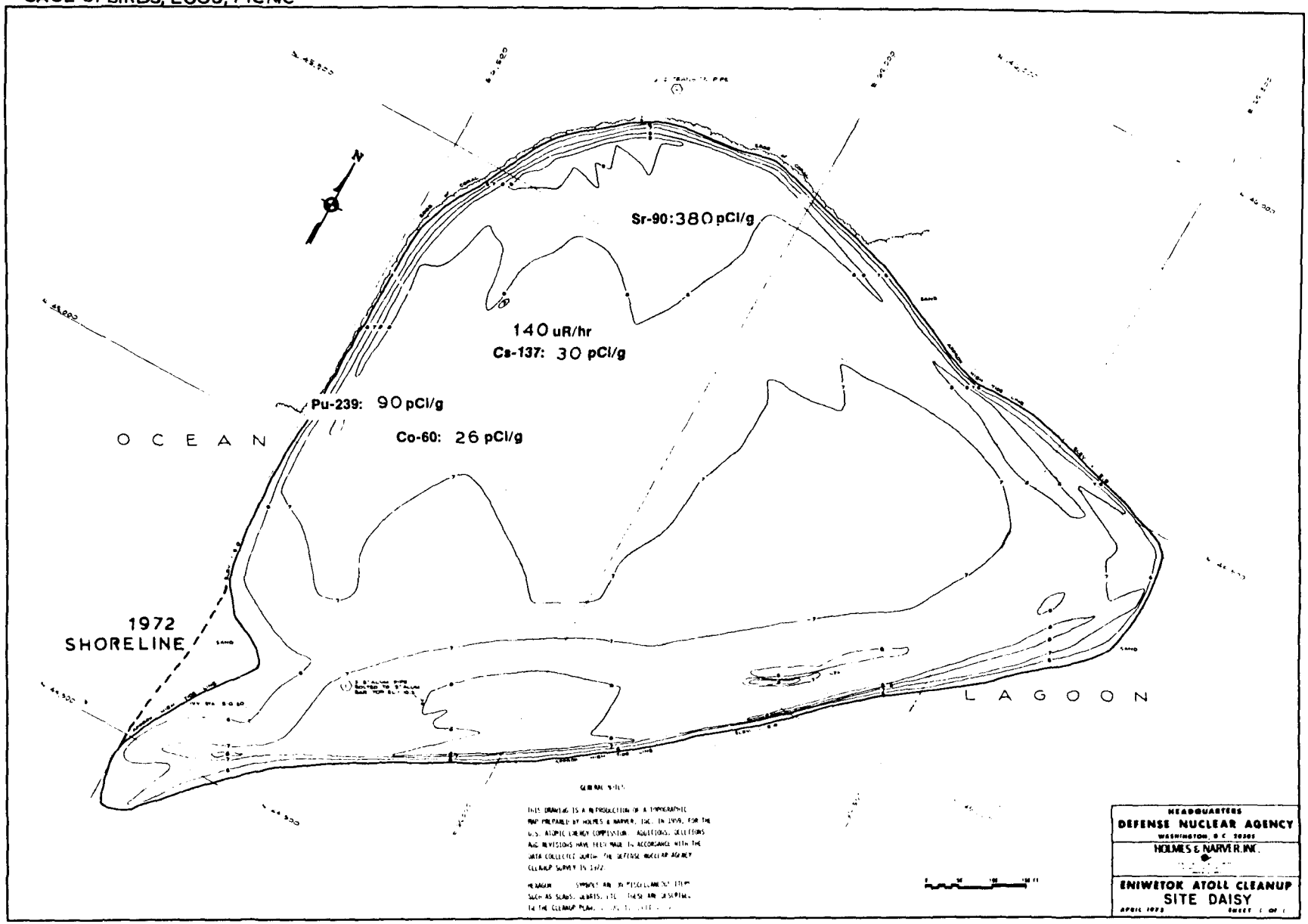


FIGURE 5. SITE DAISY

Site Name: EDNA
Other: SANILDEFONSO
Marshallese: BOKINWOTME

EDNA is little more than a sandbar in the northern portion of the Atoll (Figure 6). Comparison of a 1952 topographic map and the 1972 photo from NVO-140 show that the island has undergone great physical change.

EDNA has no surface ground zeroes. It ranks 3rd of all the Atoll islands in total H+1 hour exposure rate received with 9,533 R/h.

Of eight locations where soil samples were collected in 1972, the activities were:

Radionuclide	Activity (pCi/g)	
	Mean	Range
^{90}Sr	46	30 - 220
^{137}CS	4.2	2.7 - 6.4
^{239}Pu	18	13 - 24
^{60}Co	0.43	0.33 - 0.63

Radionuclide levels are quite homogenous, horizontally as well as vertically, in the soil which is likely due to wind and wave action on the small island.

No burial sites, contaminated scrap or structures are known to exist on EDNA.

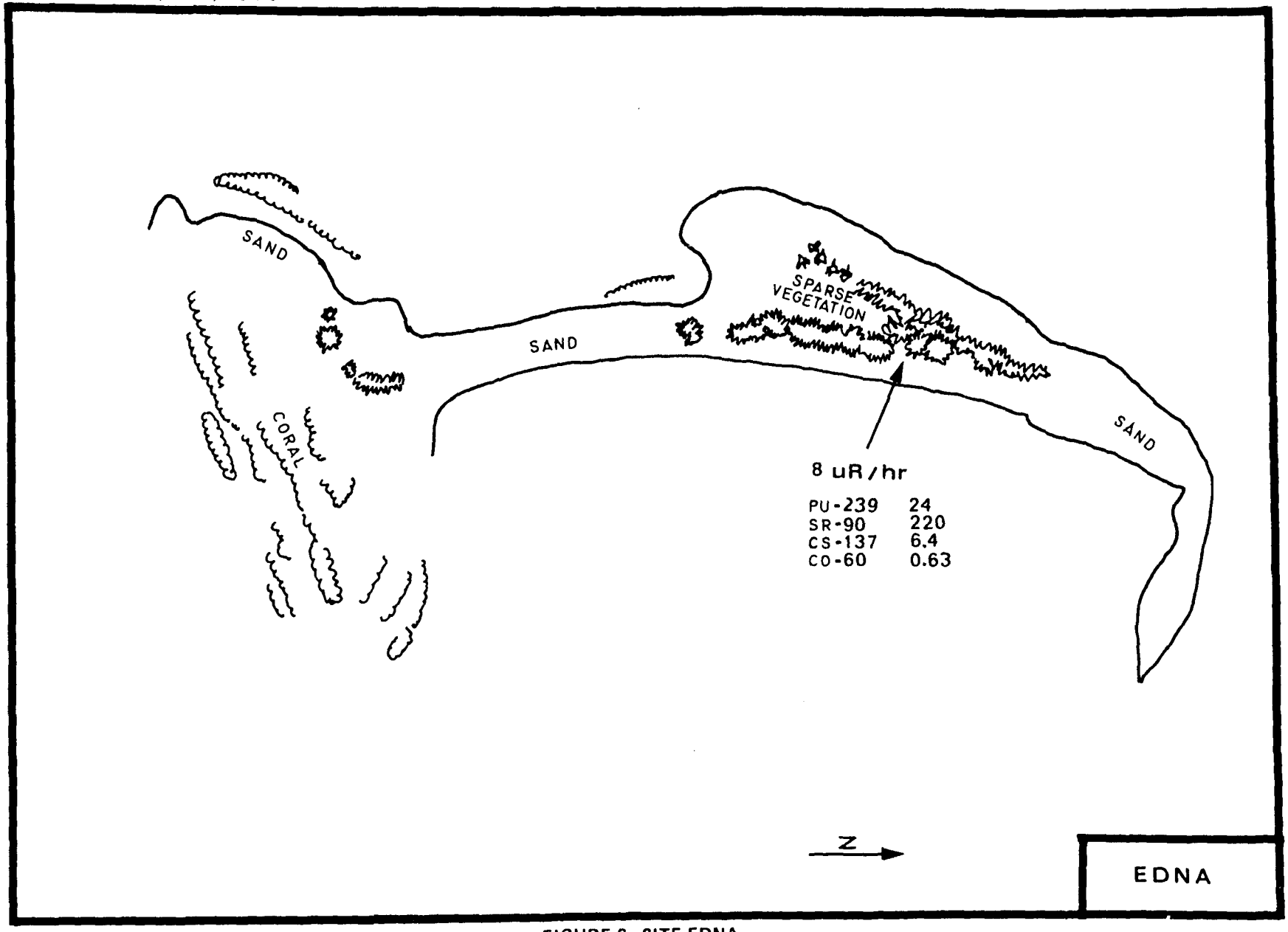


FIGURE 6. SITE EDNA

Site Name: FLORA and GENE
Other: ELUGELAB and TEITEIRIPUCCHI

FLORA and GENE have been blown away by nuclear explosives. For their sacrifice, inclusion in cleanup treatises seems a small tribute.

Prior to OPERATION IVY, GENE through IRENE were four islands in a linear arrangement at the north end of Enewetak Atoll. During nuclear test operations these islands were connected by various sytems of causeways, pipelines and cables. Figure 7 shows their original configuration.

FLORA was the site of the MIKE EVENT of OPERATION IVY. MIKE was an experimental thermonuclear device detonated October 31, 1952, which yielded 10.4 megatons. MIKE cast FLORA to the winds; however, her location was to be used for many succeeding barge shots.

GENE, the site of one forward area camp, served as a work area through OPERATIONS CASTLE and REDWING. As a result of the KOA EVENT, May 12, 1958, of OPERATION HARDTACK, PHASE I, GENE followed FLORA into oblivion. No radiological measurements have been made of these two areas in recent years. No estimate of cleanup, if any is warranted, has been made other than that incorporated with IRENE. Pipelines ran from IRENE to both MIKE and KOA and some of that debris may remain on the reef.

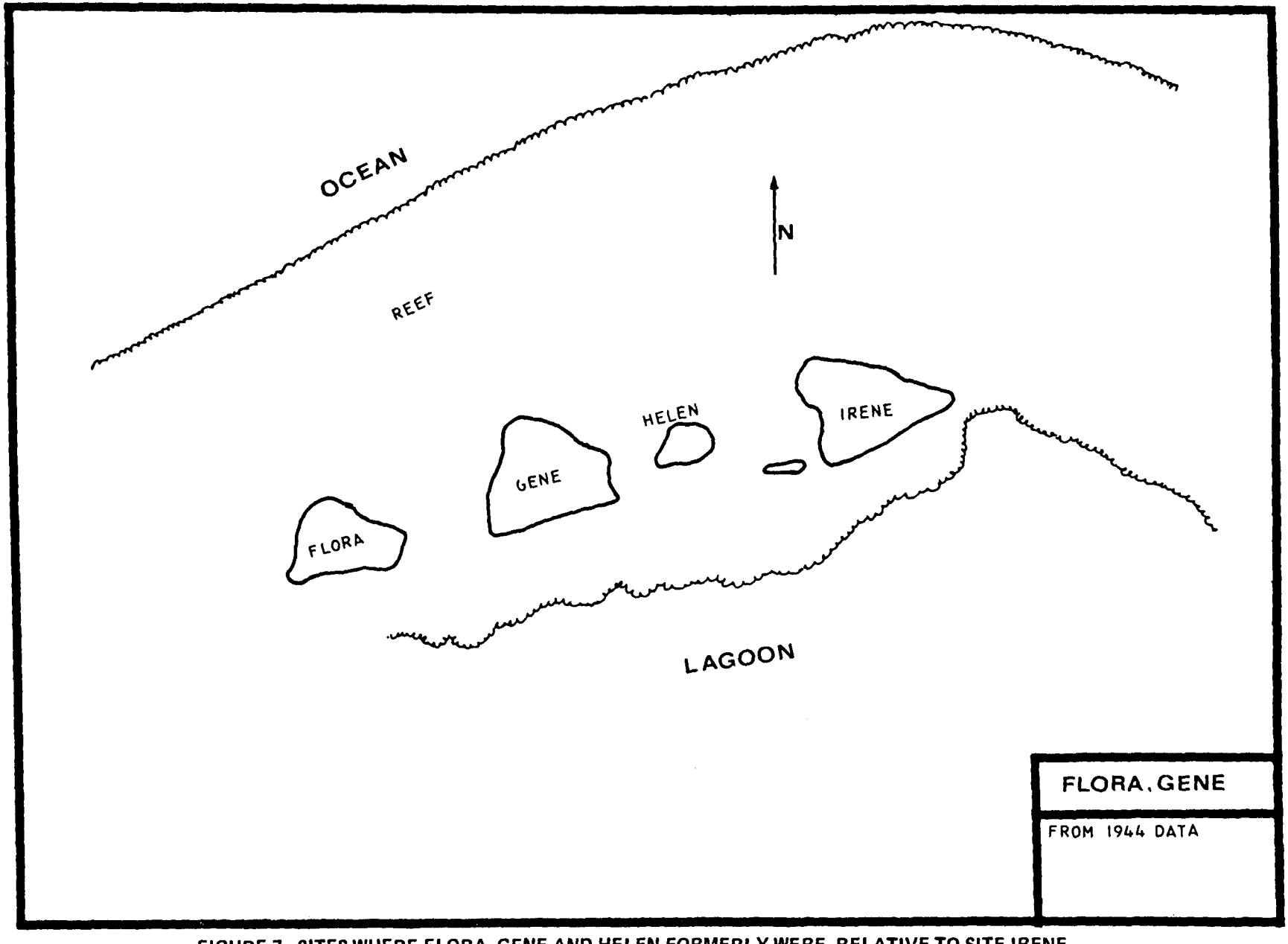


FIGURE 7. SITES WHERE FLORA, GENE AND HELEN FORMERLY WERE, RELATIVE TO SITE IRENE

Site Name: HELEN and IRENE
Board of Geo.: BOGEIRIK and BOGON
Marshallese: BOKAIDRIK and BOKEN

The sites HELEN and IRENE are the northernmost islands in Enewetak Atoll. HELEN has been shown to have an area of 5 acres and IRENE has 40 (a total of 18 hectares). Comparison of H&N topographic drawings and a 1972 aerial photograph show HELEN as a sandbar extension of IRENE. Reference to HELEN will include that land area west of E74,000 on Figure 8.

HELEN had no surface ground zeroes; however, the sandbar lies between and near many event sites. It ranks 5th of the Atoll islands in total H+1 hour exposure rate received with 5,277 R/h. The maximum exposure rate measured in 1972 (NVO-140) was 8 uR/h at 1 m above the surface.

IRENE was the site of the SEMINOLE EVENT executed on June 6, 1956 as part of OPERATION REDWING. A large water-filled crater remains from that event. IRENE was affected by the MIKE and KOA thermonuclear events as well as other events conducted in the MIKE CRATER. In summary, events of direct influence to HELEN and IRENE are:

Operation/Event Name		Date (GCT)	Location	Type
IVY	MIKE	10/31/52	FLORA	Surface
CASTLE	NECTAR	5/13/54	MIKE CRATER	Barge
REDWING	SEMINOLE	6/6/56	IRENE	Surface
	APACHE	7/8/56	MIKE CRATER	Barge
	HURON	7/21/56	MIKE CRATER	Barge
HARDTACK, PHASE I	KOA	5/12/58	GENE	Surface

As a result of these and 18 other events, IRENE ranks 4th of the Atoll islands in total H+1 hour exposure rate received with 6,184 R/h.

Extensive construction activities which involved the erection of test structures and the movement of large amounts of earth as well as blast effects and wave inundation have significantly altered the physical characteristics of the island. The radiological condition of the island is complex as NVO-140 shows.

The geographical distributions of the surface activities of radionuclides in soil are relatively heterogenous. Elevated ^{239}Pu, ^{90}Sr, and ^{60}Co activities appear immediately east and north of the SEMINOLE CRATER; however, ^{137}Cs seems to be most abundant within the central portions of the present land mass. The activities of various radionuclides distributed over the island to a depth of 15 cm (including the beaches) are:

Radionuclide	Activity (pCi/g)	
	Mean	Range
^{90}Sr	30	5.9 - 570
^{137}Cs	3.2	0.22 - 41
^{239}Pu	11	2.4 - 280
^{60}Co	5.4	0.12 - 520

^{239}Pu activities of about 100 pCi/g to depths as much as one meter have been identified for several areas on the island. These areas are cross-hatched on Figures 9 and 10.

Scrap material and debris are scattered throughout the area of IRENE, both on land and on the surrounding coral. Because of the extensive activities there during these test operations, more will be found. For example, a below-grade structure near IVY Station 600 was not surveyed in the Engineering Study for a Cleanup Plan, but should still be in place. Much of the debris is contaminated. Differentiation of what is and what is not comtaminated is difficult in the heterogenous background of the island.

No burial site created specifically for the disposition of radioactive materials is known to exist on IRENE; however, large amounts of contaminated soil and perhaps debris are suspected to be buried in the central portion of the island. It is know that throwout from the SEMINOLE EVENT was bulldozed aside from the crater to IVY Station 200 to provide line-of-sight (LOS) from that station to the MIKE CRATER. Similar action was probably necessary to construct an LOS pipe from HARDTACK Station 1410 to the KOA EVENT. Steel pilings from that pipeline are still in place.

CASE 3: BIRDS, EGGS, PICNIC (PU)

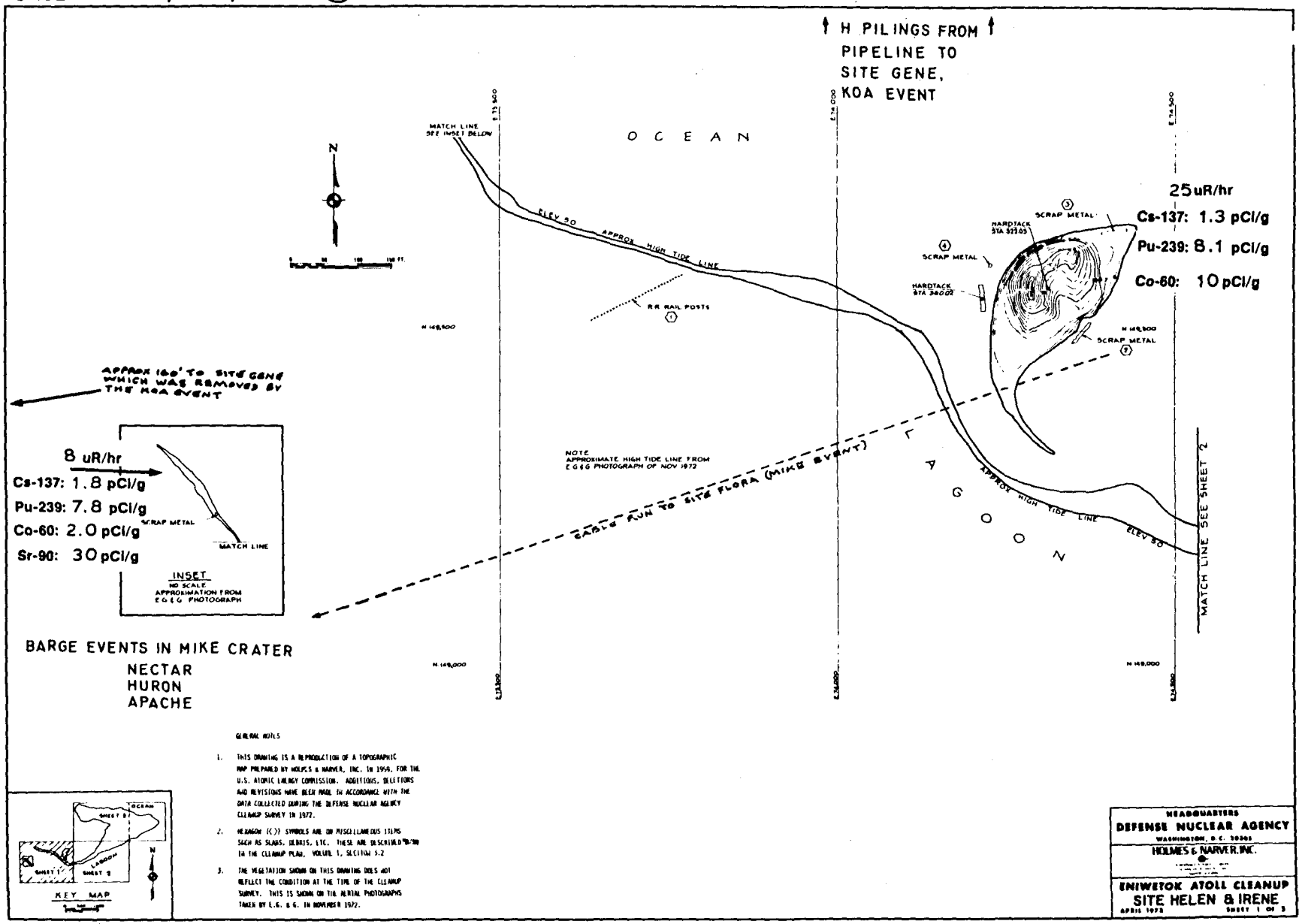


FIGURE 8. SITES HELEN AND IRENE, SHEET 1 OF 3

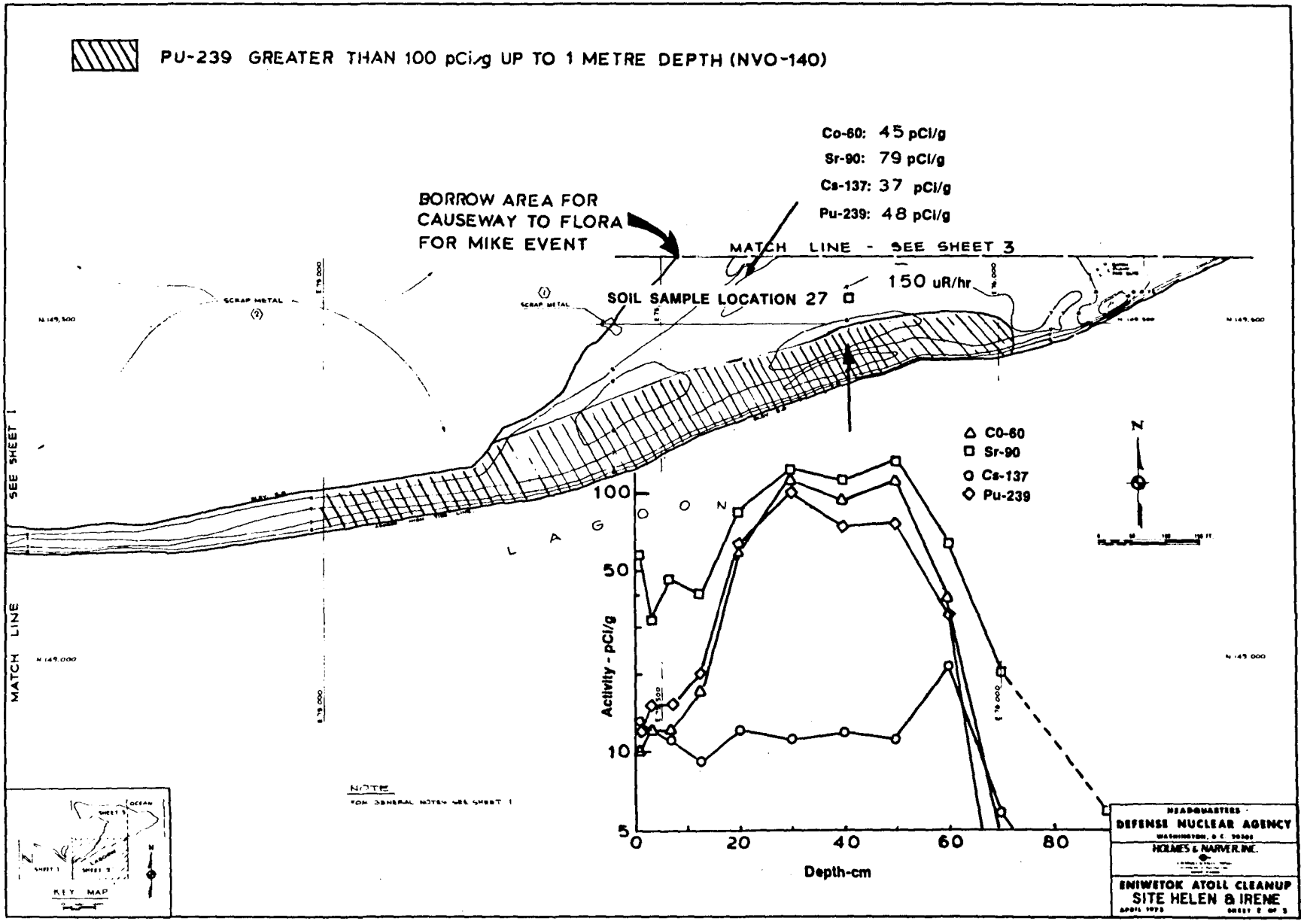


FIGURE 9. SITES HELEN AND IRENE, SHEET 2 OF 3

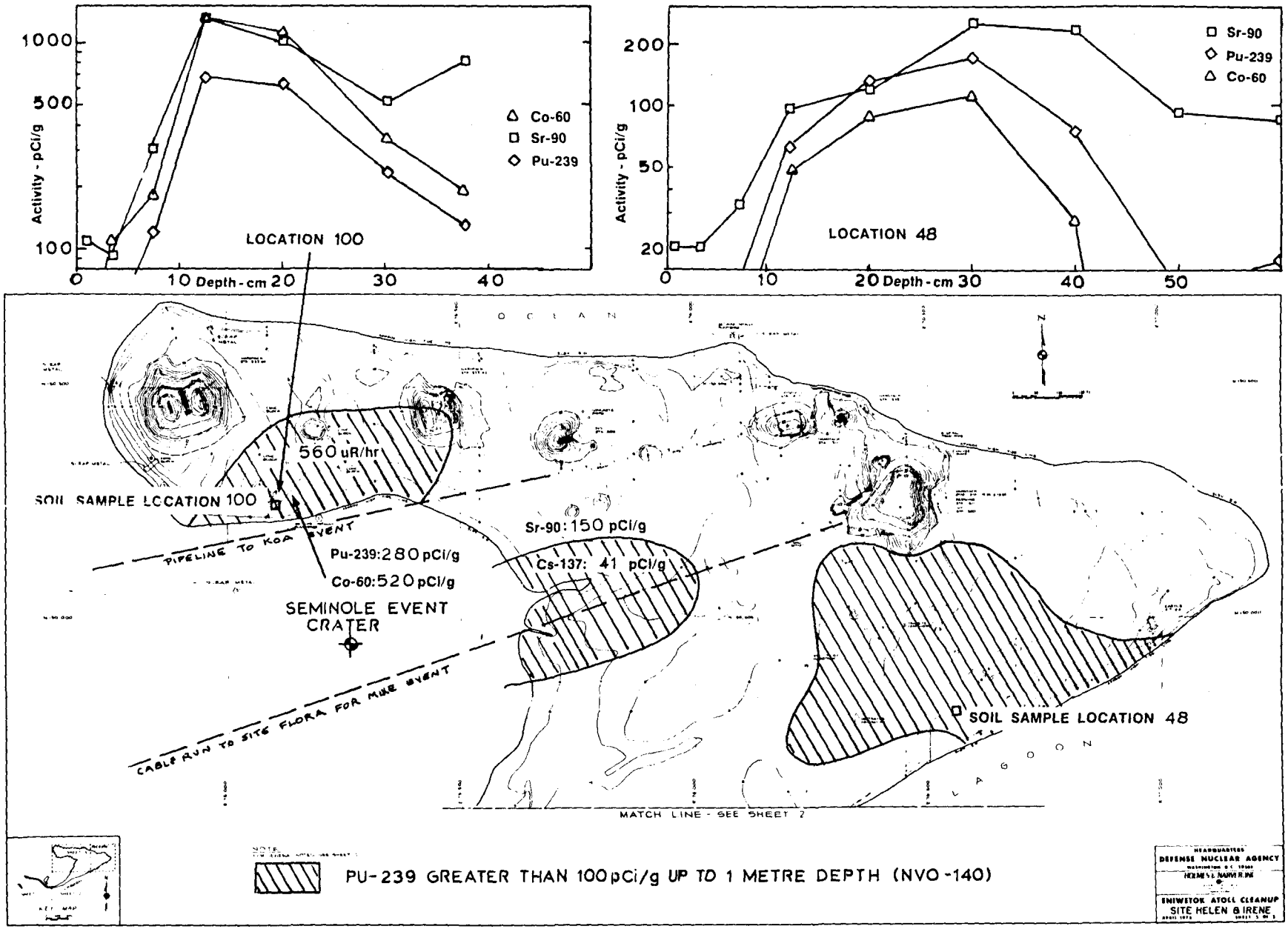


FIGURE 10. SITES HELEN AND IRENE, SHEET 3 OF 3

August 12, 1977

Site Name: JANET
Board of Geo.: ENGEBI
Marshallese: ENJEBI

JANET is the second largest island in Enewetak Atoll and the largest island in the northern part of the Atoll. JANET has an area of 290 acres (117 hectares) and is the former residence of the driEngebi people.

JANET exhibits extensive evidence of the conflict there in World War II and its use as a nuclear proving ground. With the exceptions of FRED and ELMER, JANET contains the largest amount of uncontaminated debris from nuclear testing.

Three nuclear detonations occurred on the surface of JANET and seven occurred in the lagoon nearby as indicated on Figure 11.

Operation/Event Name	Date (GCT)	Type & Height (ft) of Burst	Yield
SANDSTONE/X-RAY	4/14/48	Tower, 200'	37 KT
GREENHOUSE/EASY	4/20/51	Tower, 300'	47 KT
ITEM	5/24/51	Tower, 200'	-
HARDTACK I/YELLOWWOOD	5/26/58	Barge	-
TOBACCO	5/30/58	Barge	-
WALNUT	6/14/58	Barge	-
ELDER	6/27/58	Barge	-
DOGWOOD	7/5/58	Barge	-
OLIVE	7/22/58	Barge	-
PINE	7/26/58	Barge	-

The barge shots were conducted in the lagoon bearing 235° and ranging from 4,000 to 8,508 feet from HARDTACK Station 1312.

As well as the ground zeros of the three events above, JANET was the site of many instrumented scientific stations. A large concrete building, GREENHOUSE Station 3.1.1 or the Multi-Building, and a reinforced concrete bunker, HARDTACK Station 1312, which has 6-foot thick walls, are among those still standing. The camp area at the southeast side of the island consists mostly of concrete slabs in various states of deterioration. The compacted coral airstrip is overgrown as is most of the rest of the island. These features, and various coaxial cable runs, are shown in Figures 11 through 17 and summarized in Figure 18.

In addition, a High Energy Upper Stage (HEUS) rocket engine was tested on JANET in 1968. The engine used a fuel containing beryllium. Unfortunately, the engine, after operating normally for a short time, exhibited uncontrolled burning which resulted in destruction of the engine, spalling of the concrete on Station 1312 to which it had been attached, and contamination of the location by chemical forms of beryllium. The contamination has been effectively removed by decontamination and erosion such that there should no longer be a beryllium contamination problem on the surface. Some beryllium may be detected on the interior southwest corner of the structure.

As a result of fallout from 26 events, JANET ranks 8th of the islands in the Atoll for H+1 hour accumulated exposure rate with 3,501 R/h. The island was sampled extensively during the survey reported by NVO-140 as shown in Figure 19. The radionuclides in soil measured in all of the 15-cm-deep surface samples (excluding beach samples) closely follow a log normal distribution even though they were collected throughout the island from areas of widely differing vegetation densities and after various mechanical actions on the island surface. The standard geometric deviations were somewhat greater than other islands. Radionuclide concentrations exhibited by these surface samples were:

Radionuclide	Activity (pCi/g)	
	Mean	Range
^{90}Sr	44	1.6 - 630
^{137}Cs	16	0.57 - 180
^{239}Pu	8.5	0.08 - 170
^{60}Co	1.9	0.02 - 33

The geographical distribution of ^{90}Sr, ^{137}Cs, and ^{239}Pu, do not show any particular pattern, but elevated ^{60}Co levels were observed preferentially within the northeast corner of the island. The area is primarily north of the airstrip with a long finger extending south across the runway and halfway across the island. The mean activity within this area is about 2-3 times greater than that shown above.

The depth distributions of activity (Figures 20 through 34) show considerable variability between individual locations. Most distributions display a rapid decrease in activity within the top few centimeters (relaxation lengths of 3-10 cm) and subsequent leveling off in activity with increasing depth. A significant deviation was noted at Location 147 where plutonium levels were elevated in the layer between 50 and 90 cm below the surface. A smaller-scale, similar situation was encountered at Location 140, however, both are well below cleanup criteria.[1] The homogenous depth distribution at Location 143 is perhaps the result of post shot activities around the X-RAY and EASY ground zeros. NVO-140 Figures B.8.1.f (Figure 19) and B.8.2a through B.8.2n (Figures 21 through 34) are included for detailed soil profile information.

JANET was the site of the first test at Enewetak Proving Ground (X-RAY, 4/14/48) and was used through 1958. During these 10 years, many activities took place which may be important to cleanup but for which records have not been located. Existing information is often not sufficiently detailed to provide fact, therefore, inductive thought must be and has been used to define that information.

Past reports have used a standard assumption that burial of contaminated material occurred in all surface zero areas. Following SANDSTONE X-RAY the tower footings were blasted with high explosives and the steel stubs removed. The blasting did not scatter the concrete but fragmented it. A drawing dated 1951 shows "broken concrete" which may have included some tower footing material in an area north of GZ as shown on the enclosed figure. The footing was encrusted with plutonium. In preparation for GREENHOUSE, the area around the X-RAY crater was scraped, the material (pavement and sand) deposited in the crater and covered with uncontaminated material. Other decontamination included gathering and dumping of all debris remaining on the SANDSTONE experimental islands. Metal fragments within 1000 feet of old zero points were highly contaminated

[1]The AEC Task Group recommendations were general, and left considerable latitude for field interpretation. The criteria referred to here were the 40,100 and 400 pCi/gm which were used during the planning phase. For further discussion, see the Epilogue.

and were removed by picking up pieces individually and ultimately dumping them at sea or more likely in the lagoon. Identification of burial in the X-RAY crater should be possible through excavation using the presence of mixed sand, paving, and concrete as physical evidence and elevated levels of plutonium as radiological evidence.

The Environmental Impact Statement specifies two plutonium bearing "crypts" on JANET. These two areas are designated on Figures 11 and 17, one near X-RAY GZ and one near ITEM GZ. These are more likely land fill burials if they exist. No supportive evidence has been found.

The standard assumption of burial in the zero area applies for GREENHOUSE EASY and ITEM. No specific burial information for these shots is known nor are other sites specifically designated for radioactive disposal known to exist on JANET.

Although radioactivity levels in the soil are likely below those requiring remedial action, the opportunity was present for burial or mixing of contaminated surface soil into underlying soil for the many coax cable runs used on JANET. Their locations remain apparent as ridges of soil with more dense vegetation than the surrounding area. Coax runs were as deep as 5 feet below grade. Cables were excavated and replaced for succeeding operations. It is likely that surface soil was intermixed when the cables were recovered. Although some salvage efforts have been made, some buried cables probably remain. Cable burial also required borrowed fill which left borrow pits - also a convenient receptacle for disposal. It is not known if these were used for disposal; however, reports as well as interviews indicate that intraoperational cleanup activities occurred and their methods were often governed by expedience.

Figure 16 shows a water well north of the runway near its east end. Cleanup calls for removing the contaminated above-ground structures from the well and plugging the 16-inch casing. This well should be reconsidered for future use as a sampling source or irrigation source. Also JANET has a well developed fresh water lens which should not be disturbed any more than necessary during cleanup. This lens could be an important future resource to the northern Atoll.

CASE 3: BIRDS, EGGS, PICNIC

STANDARD ASSUMPTION OF GZ BURIAL APPLIES

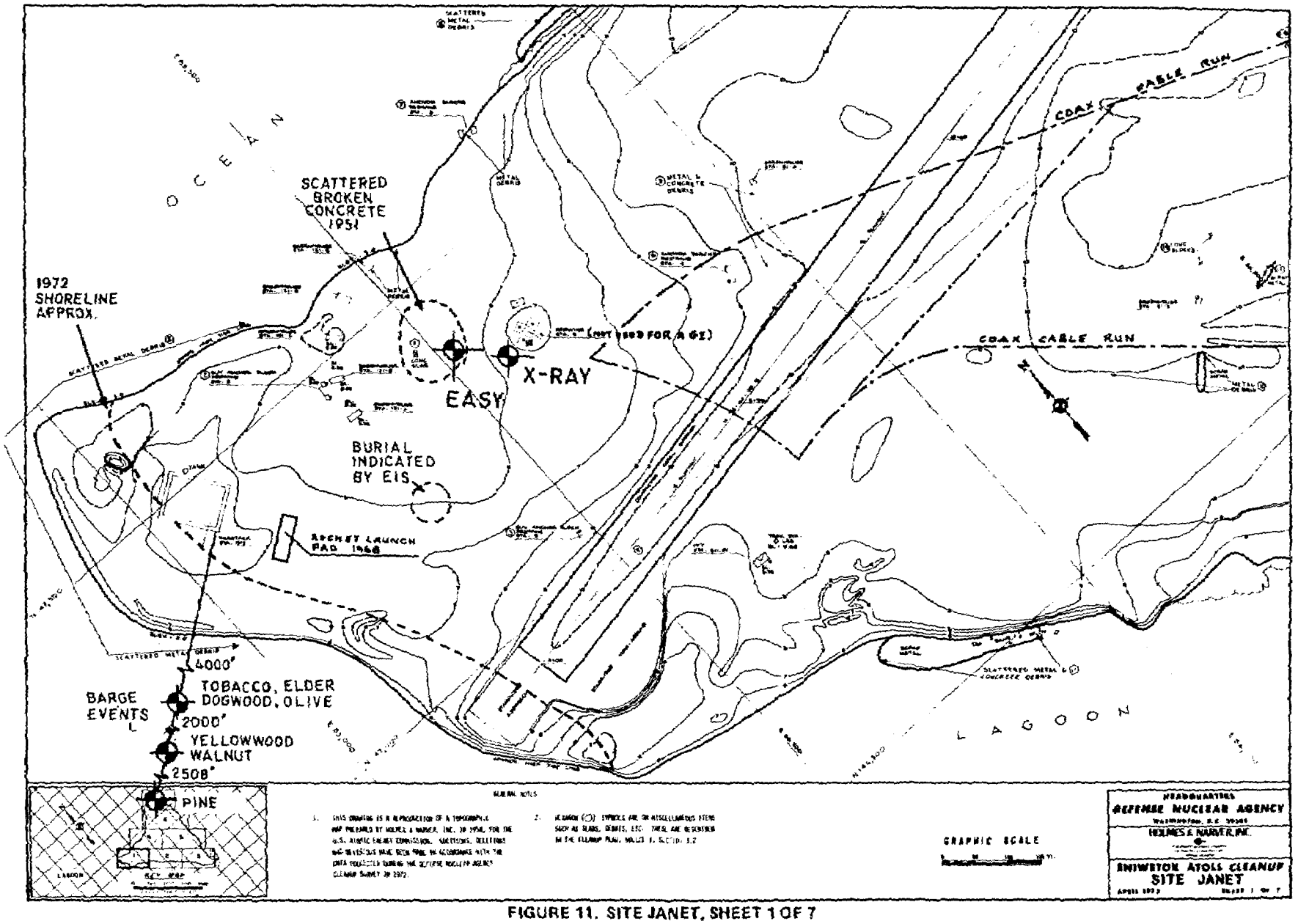


FIGURE 11. SITE JANET, SHEET 1 OF 7

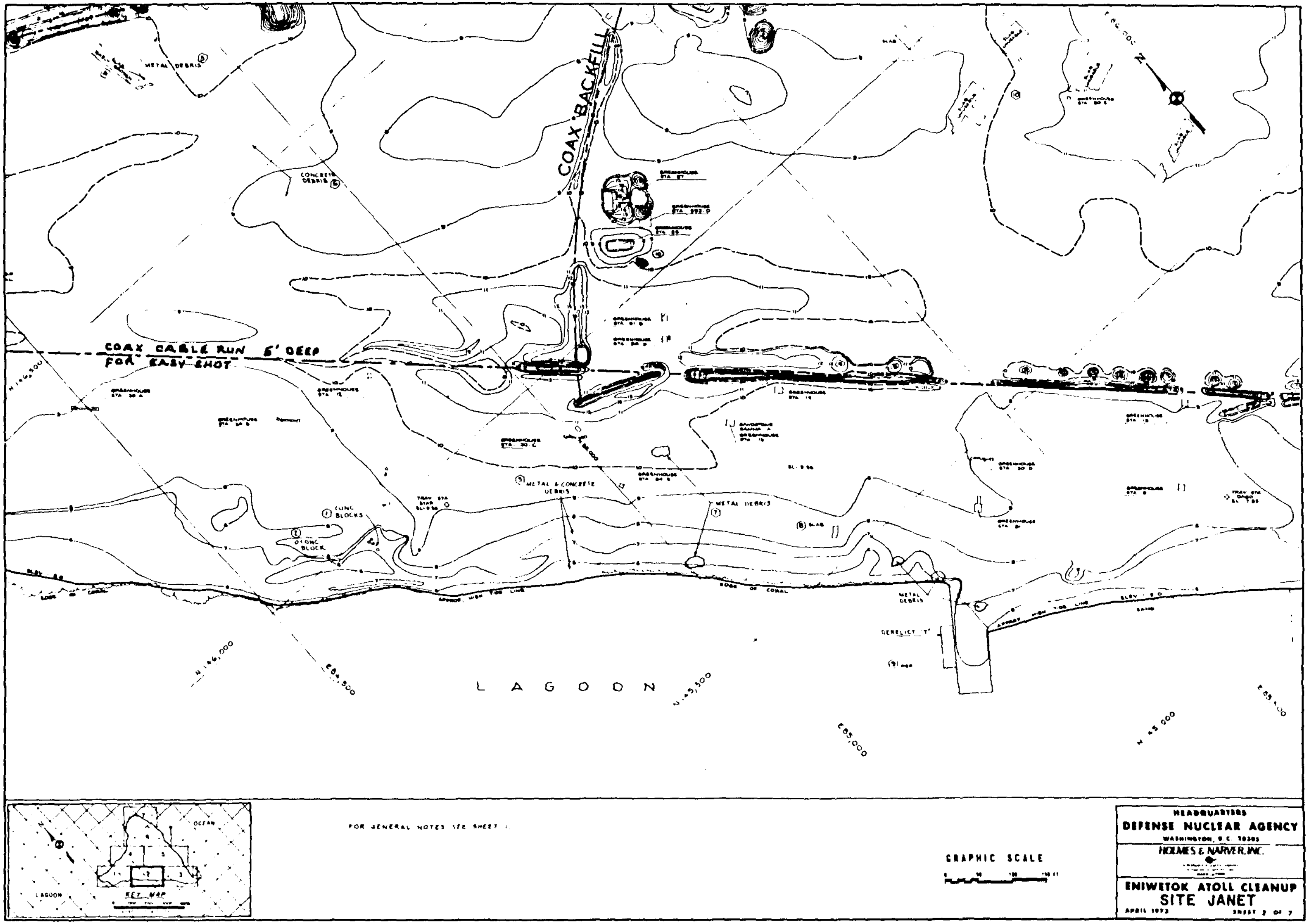


FIGURE 12. SITE JANET, SHEET 2 OF 7

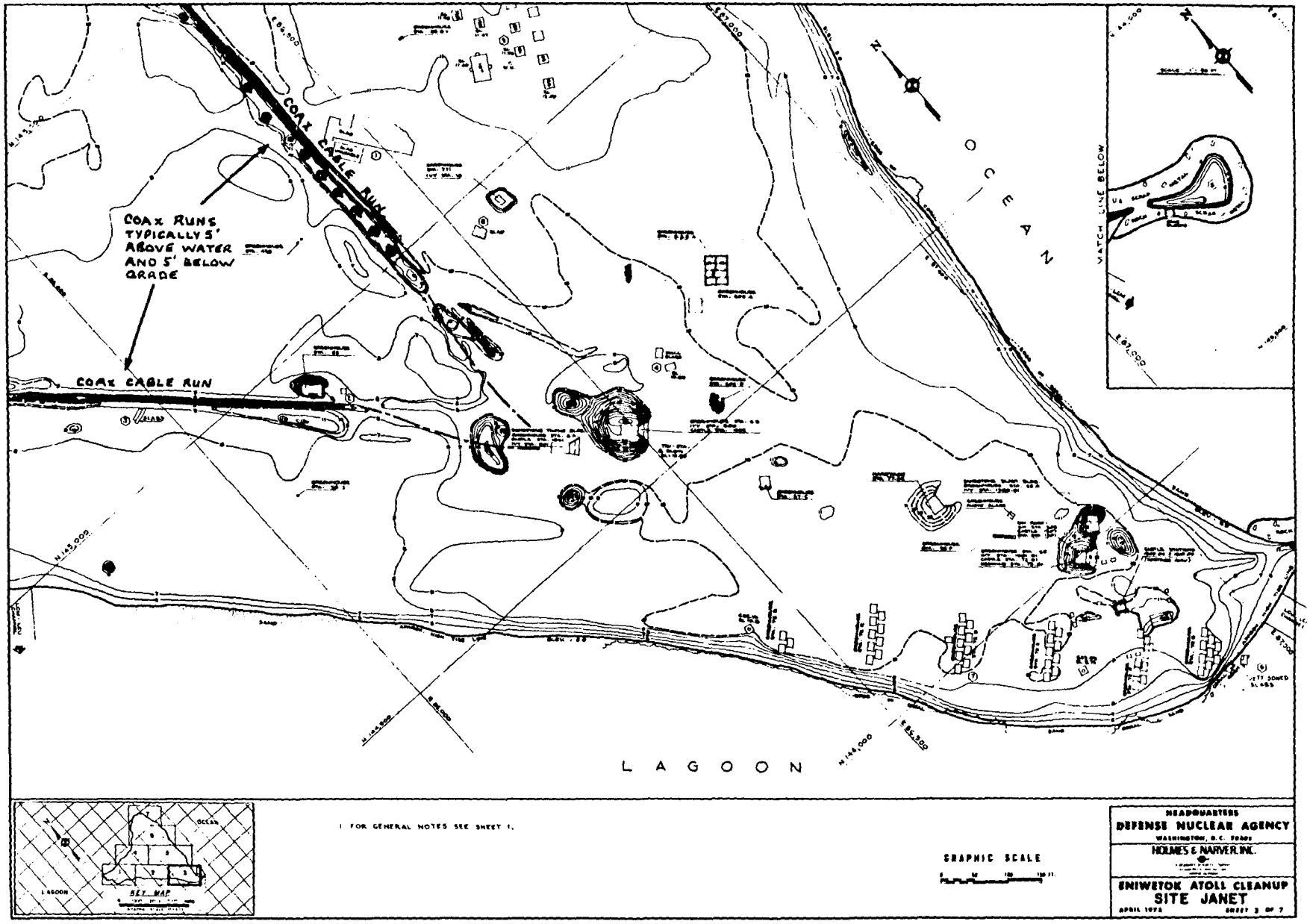


FIGURE 13. SITE JANET, SHEET 3 OF 7

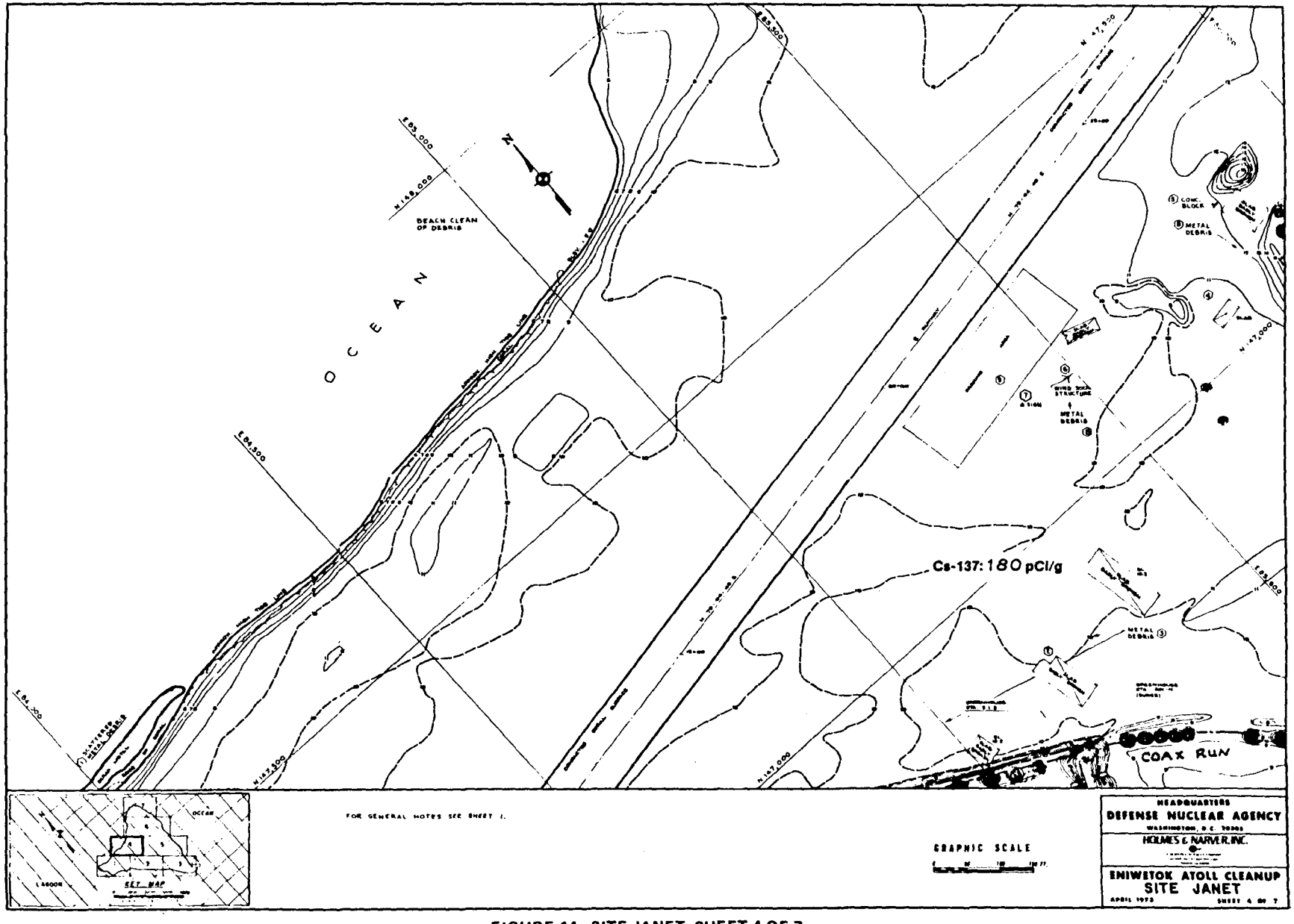


FIGURE 14. SITE JANET, SHEET 4 OF 7

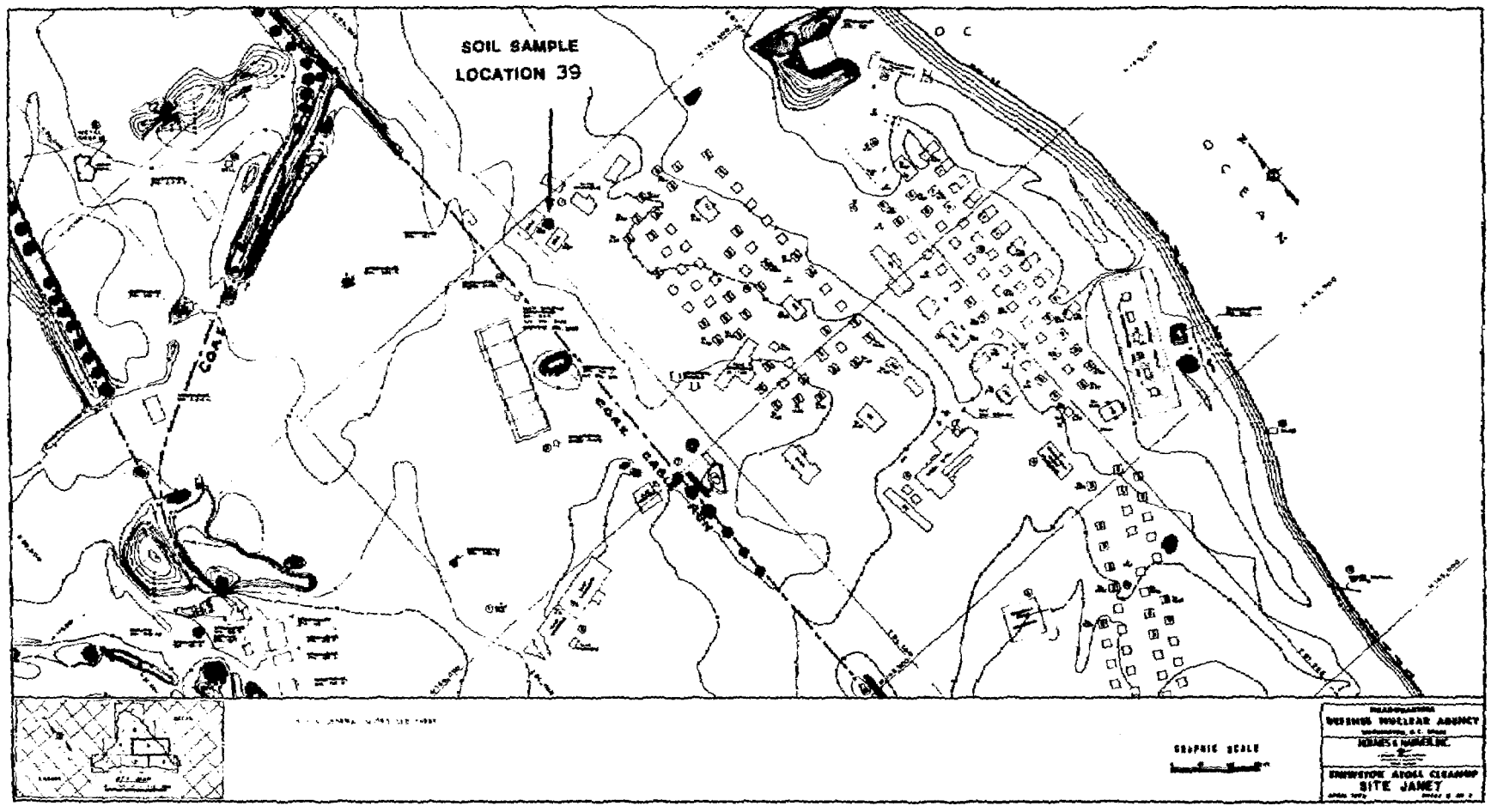


FIGURE 15. SITE JANET, SHEET 5 OF 7

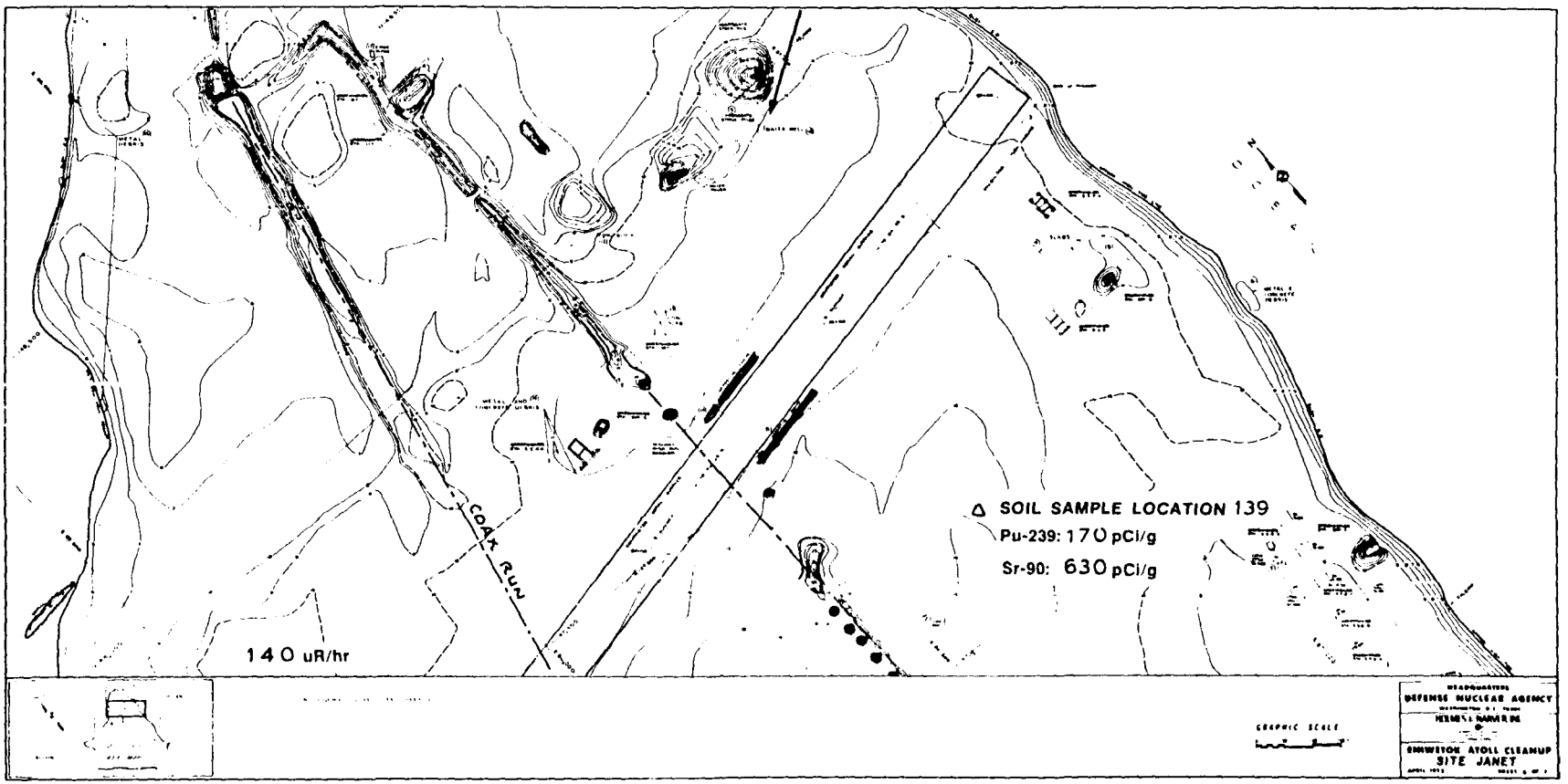


FIGURE 16. SITE JANET, SHEET 6 OF 7

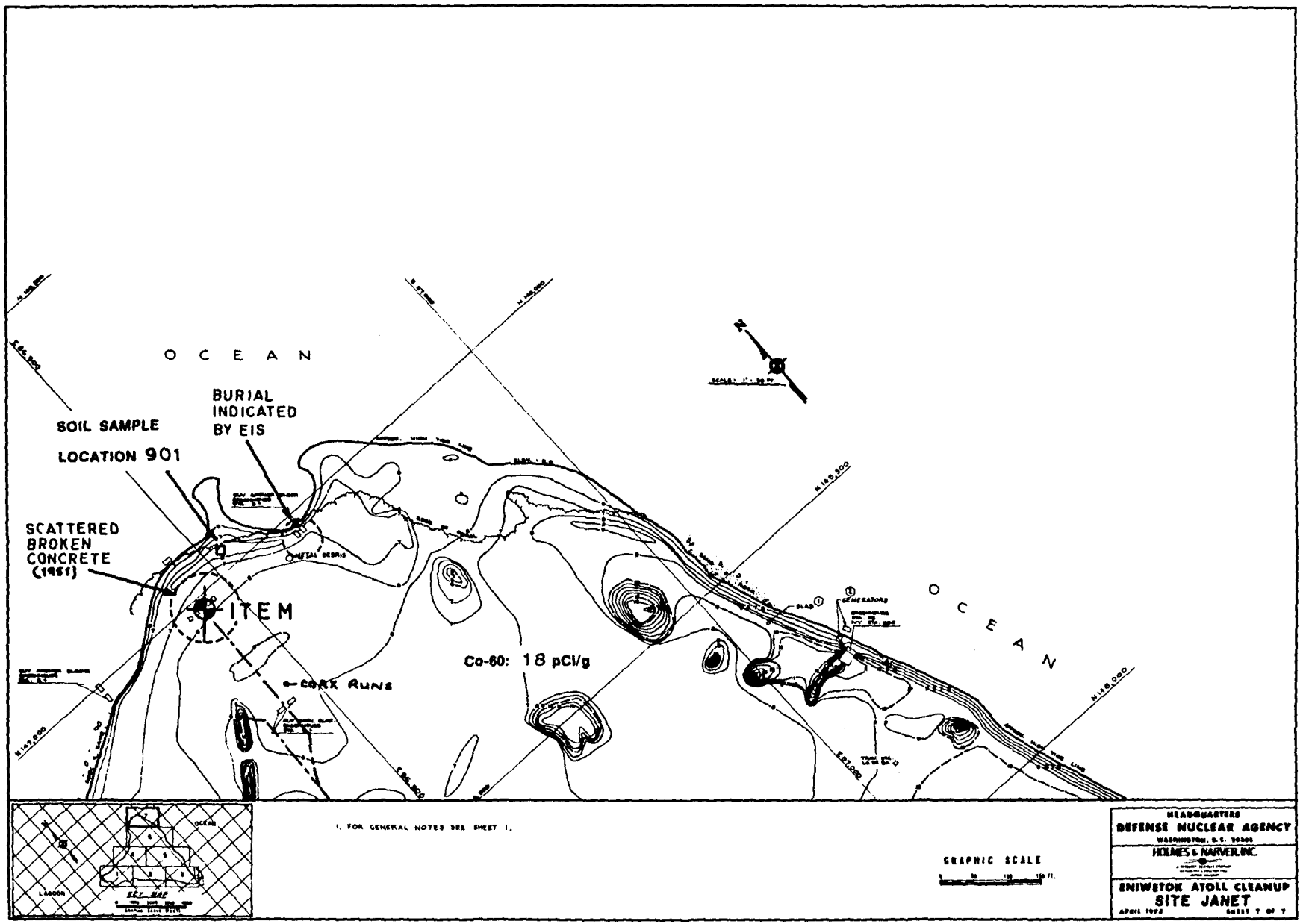


FIGURE 17. SITE JANET, SHEET 7 OF 7

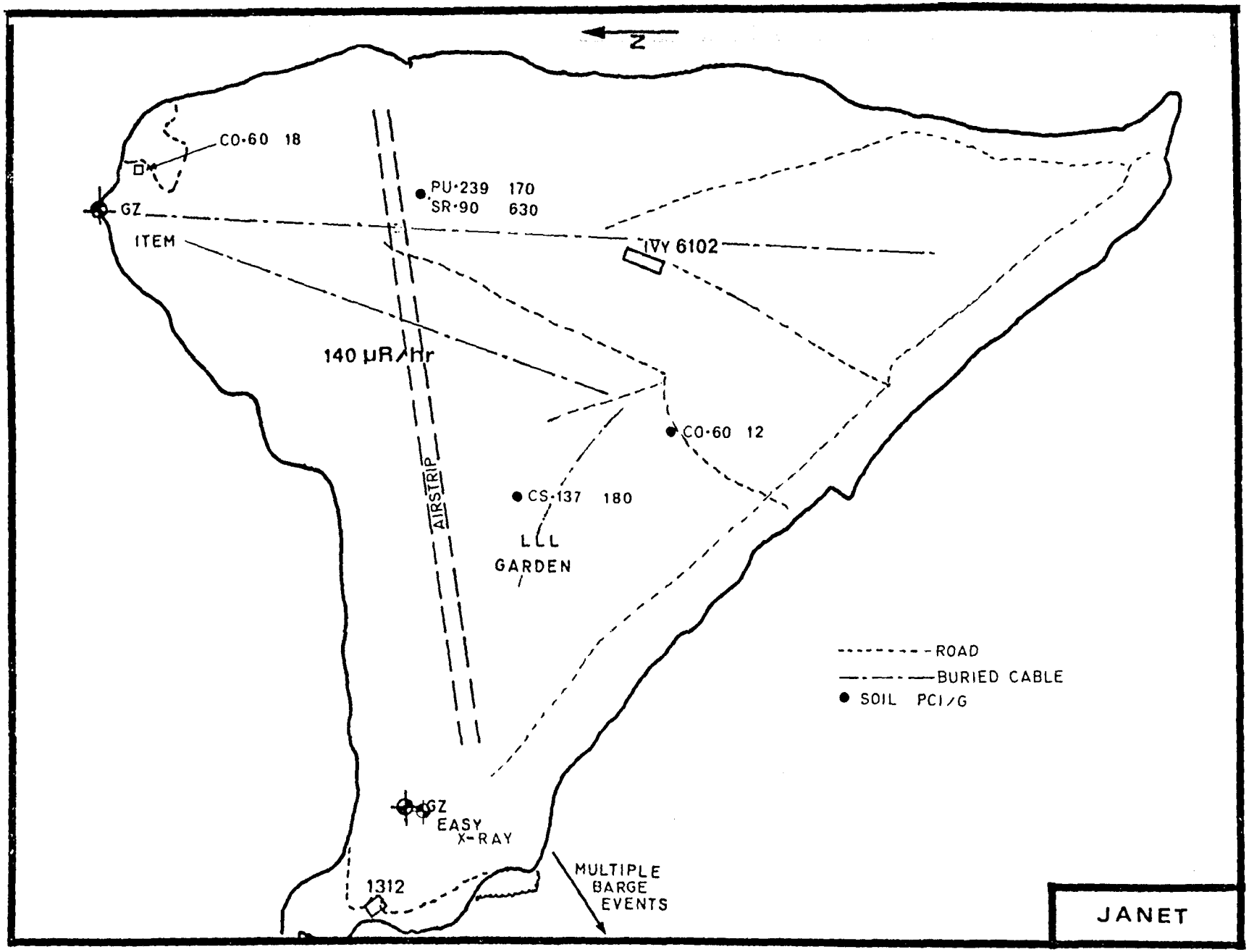


FIGURE 18. SITE JANET, PRINCIPAL FEATURES

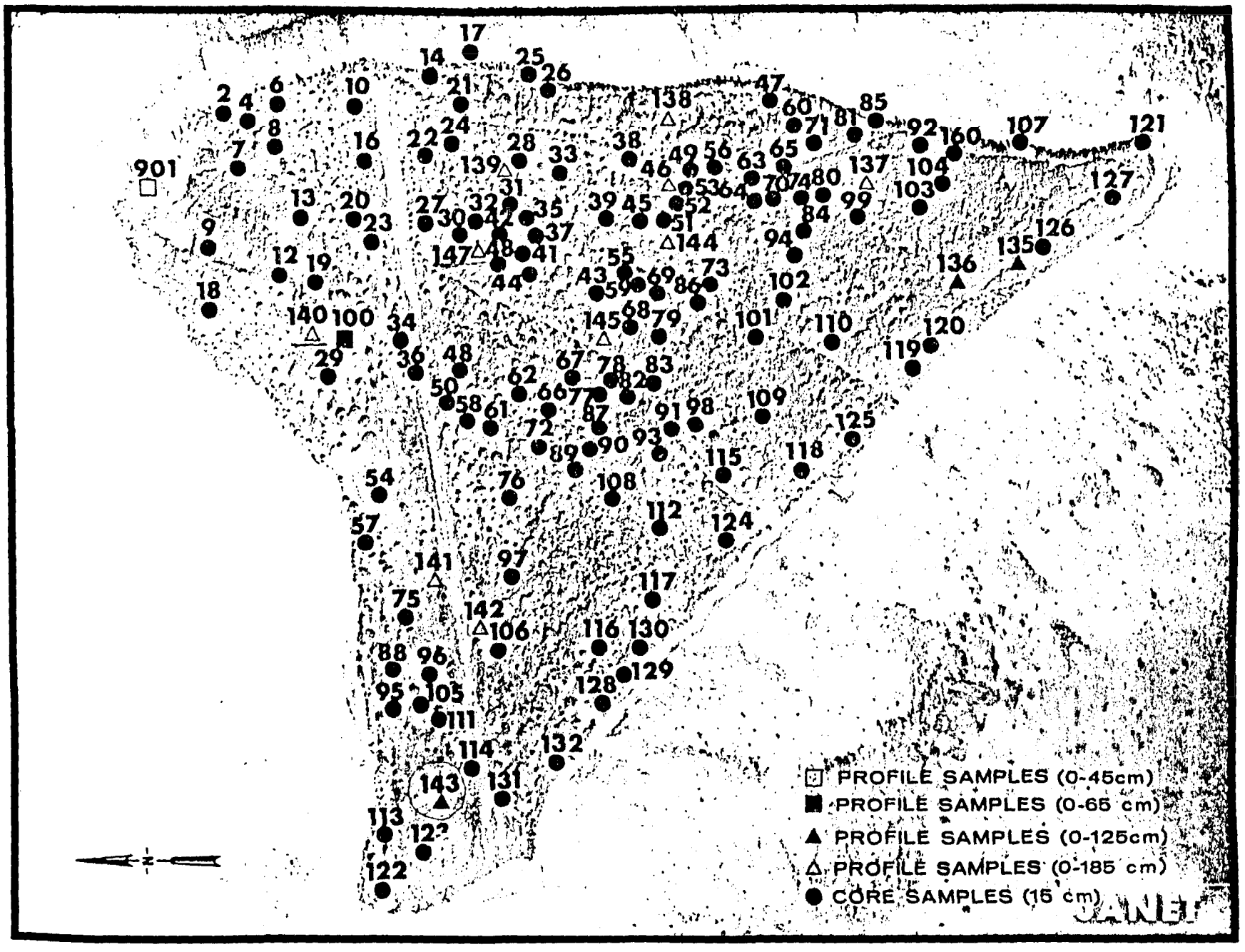


FIGURE 19. SOIL SAMPLE LOCATIONS

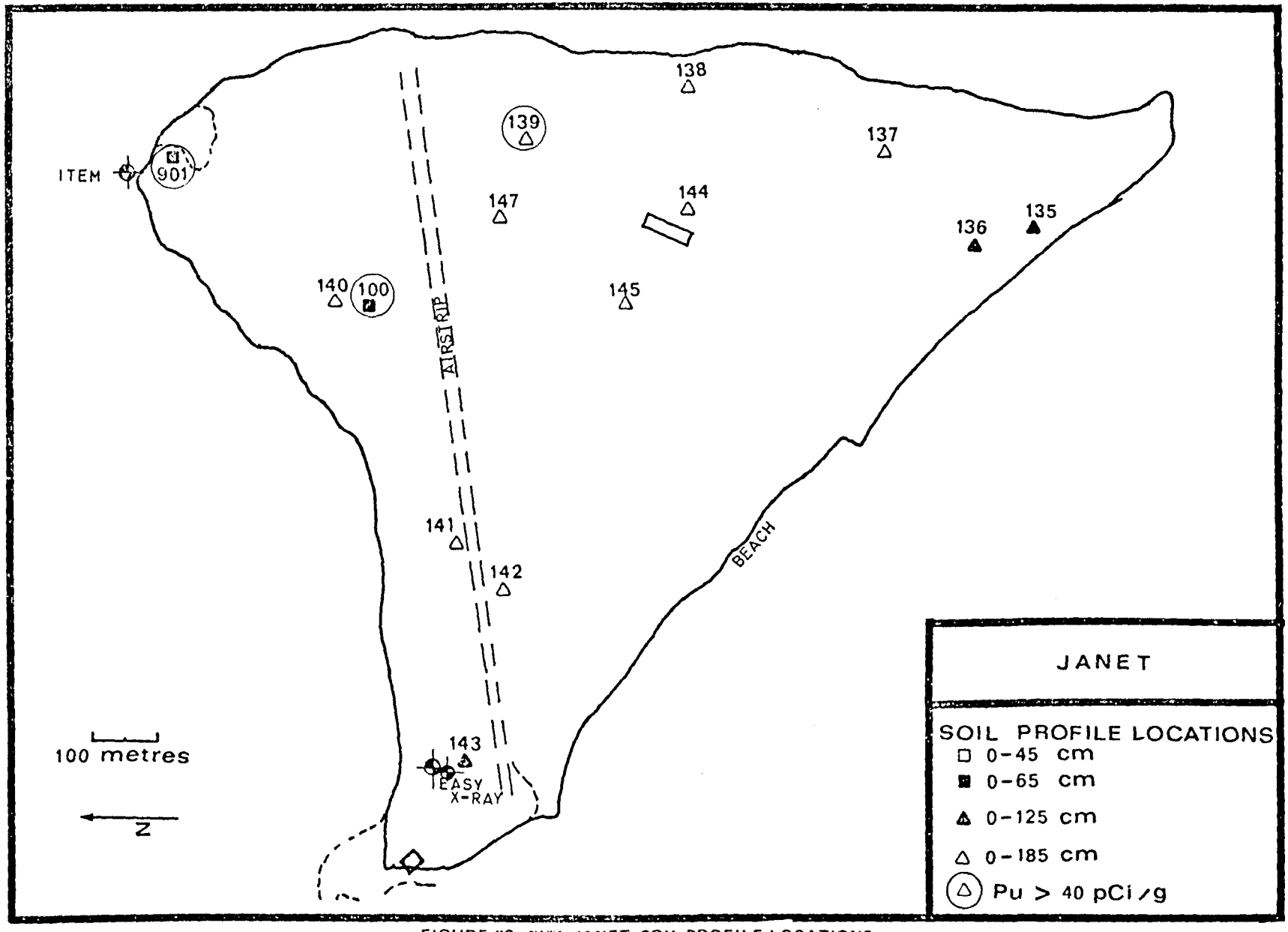


FIGURE 20. SITE JANET, SOIL PROFILE LOCATIONS

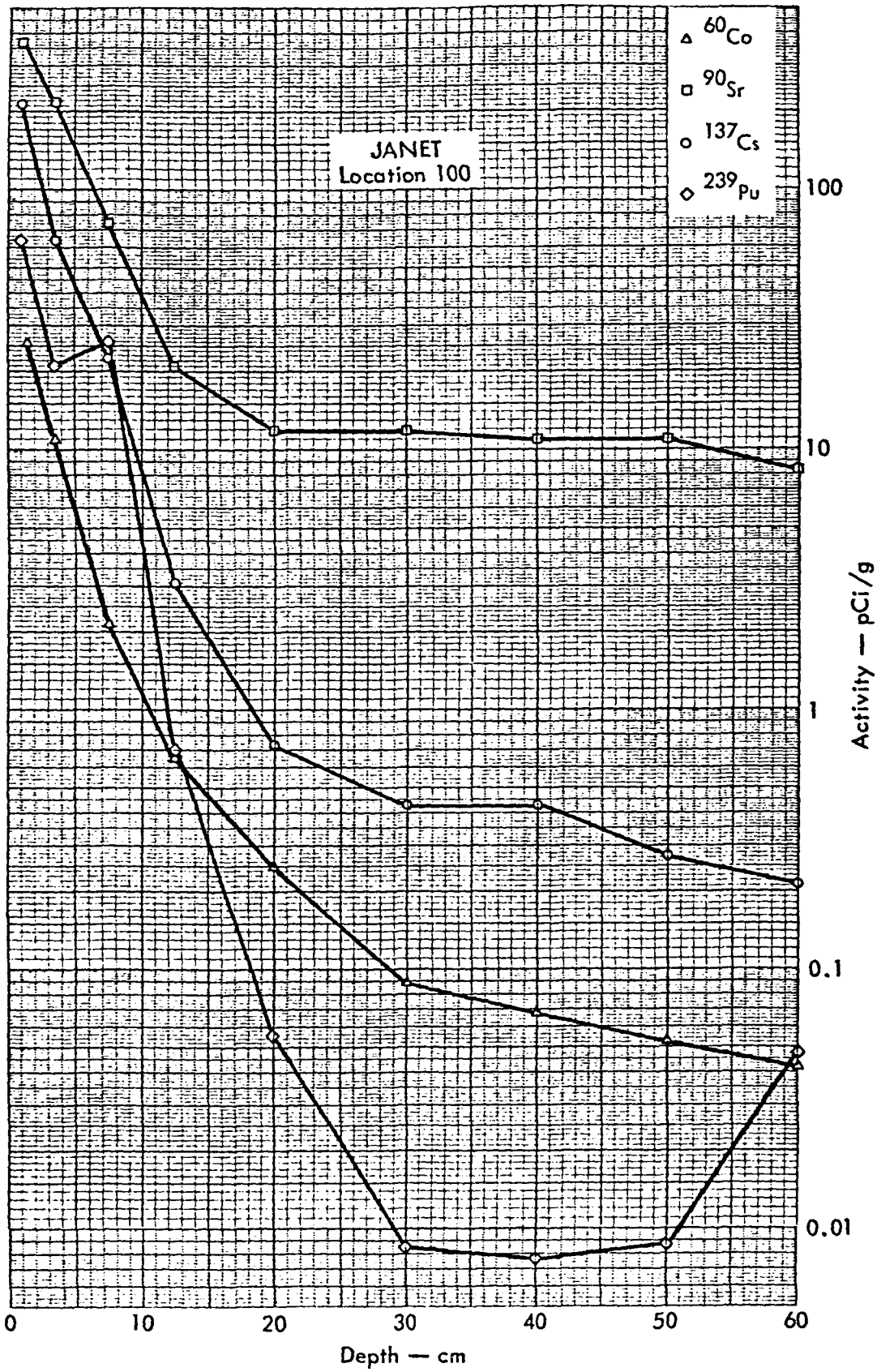


FIGURE 21. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

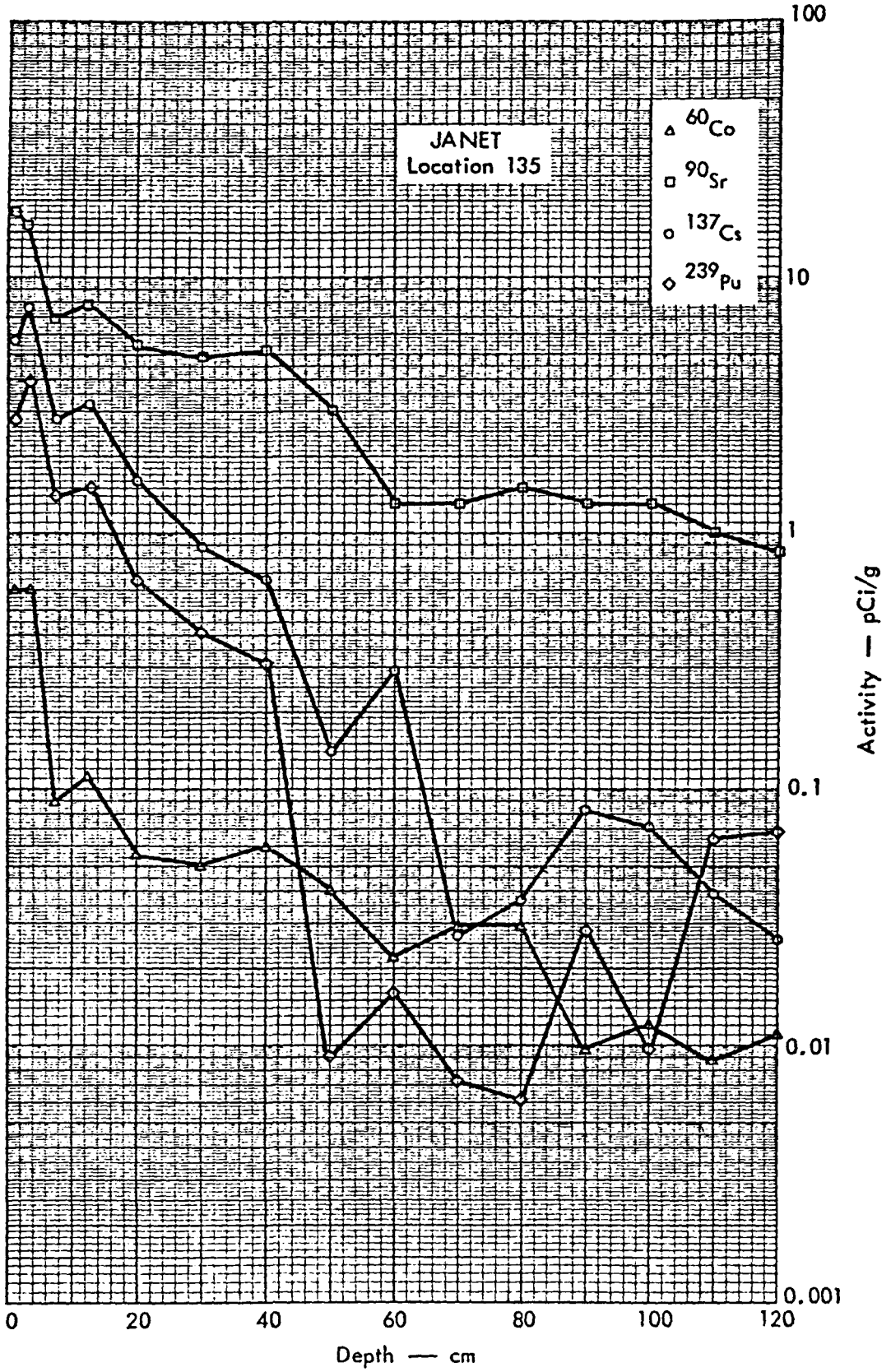


FIGURE 22. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

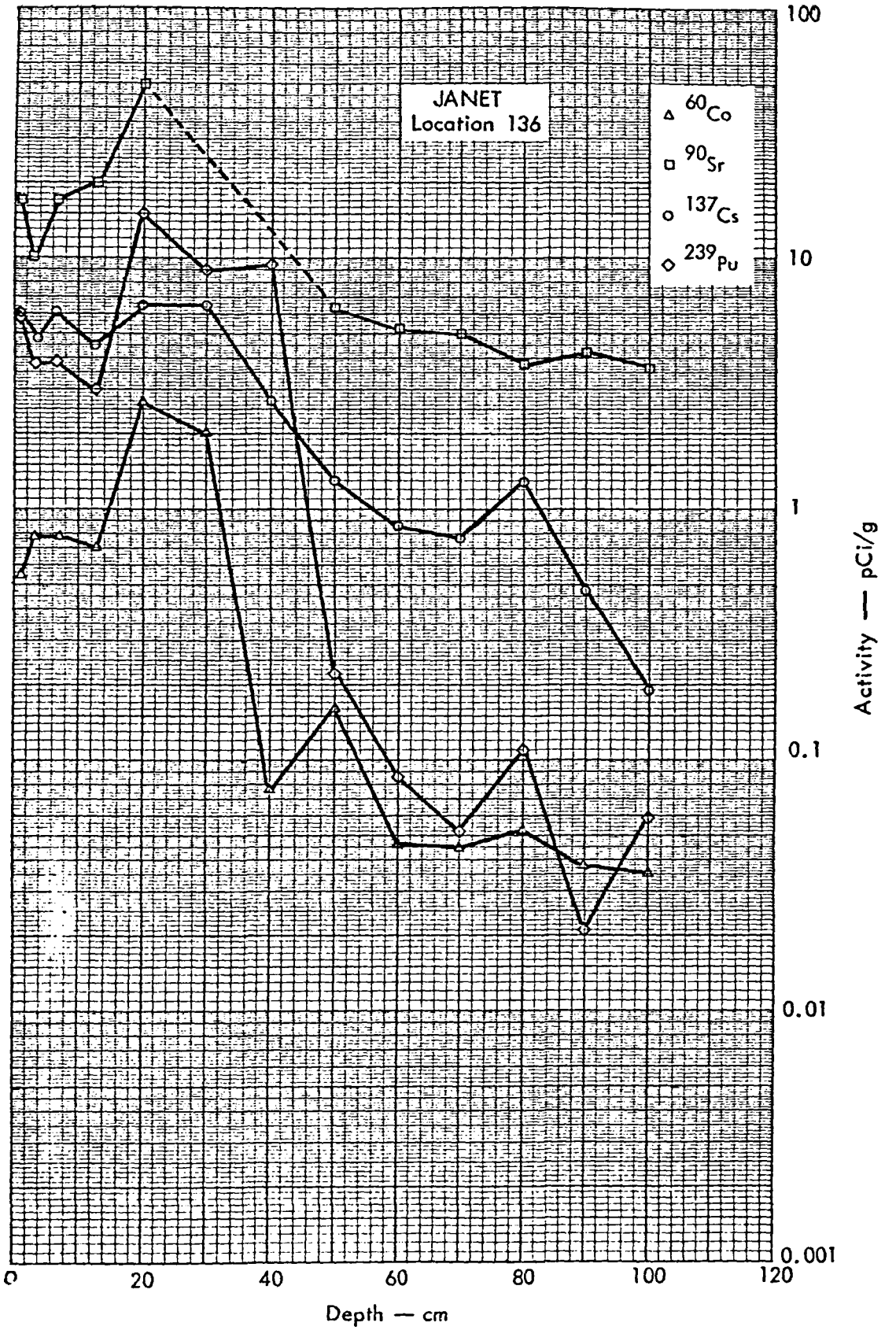


FIGURE 23. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

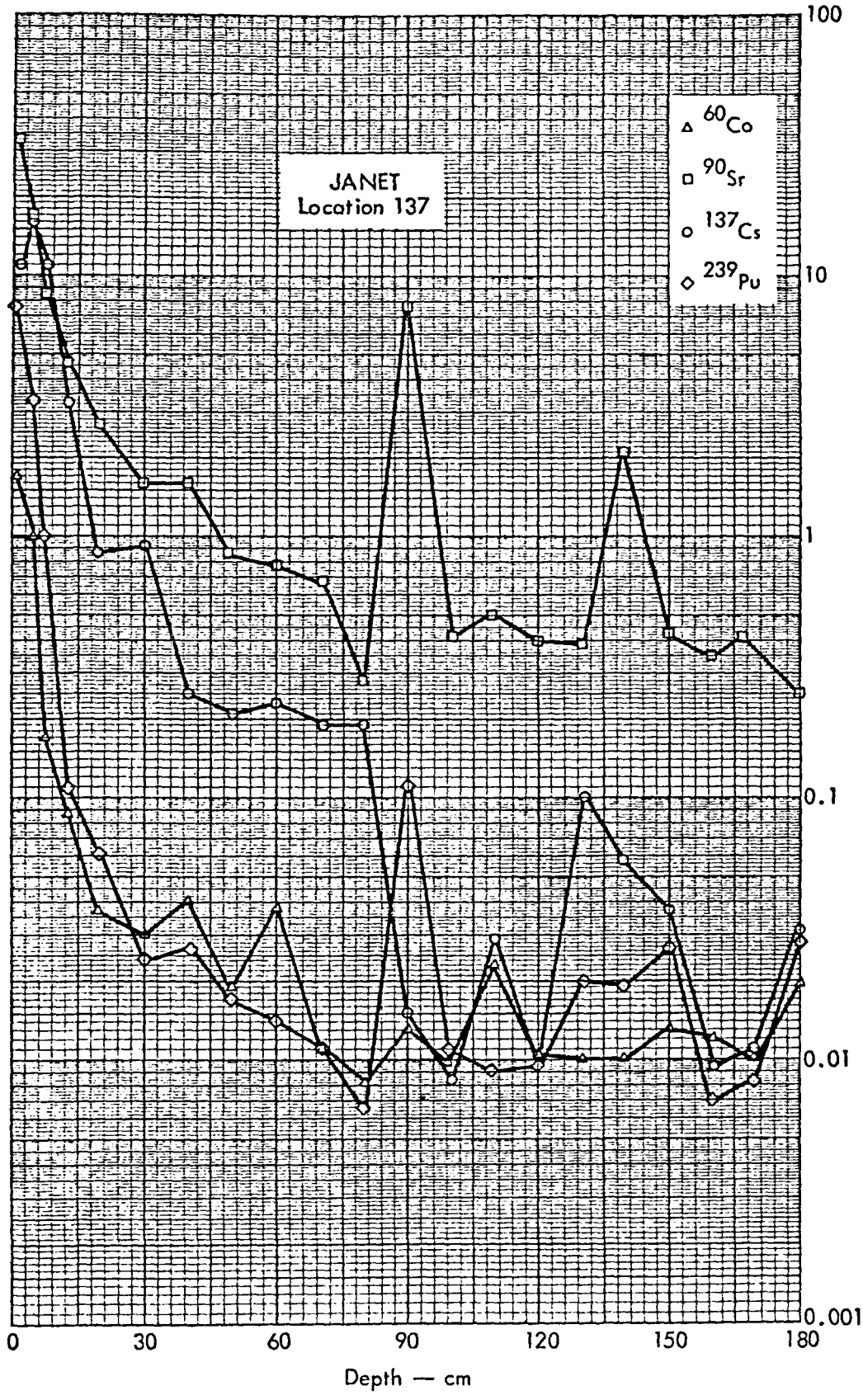


FIGURE 24. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

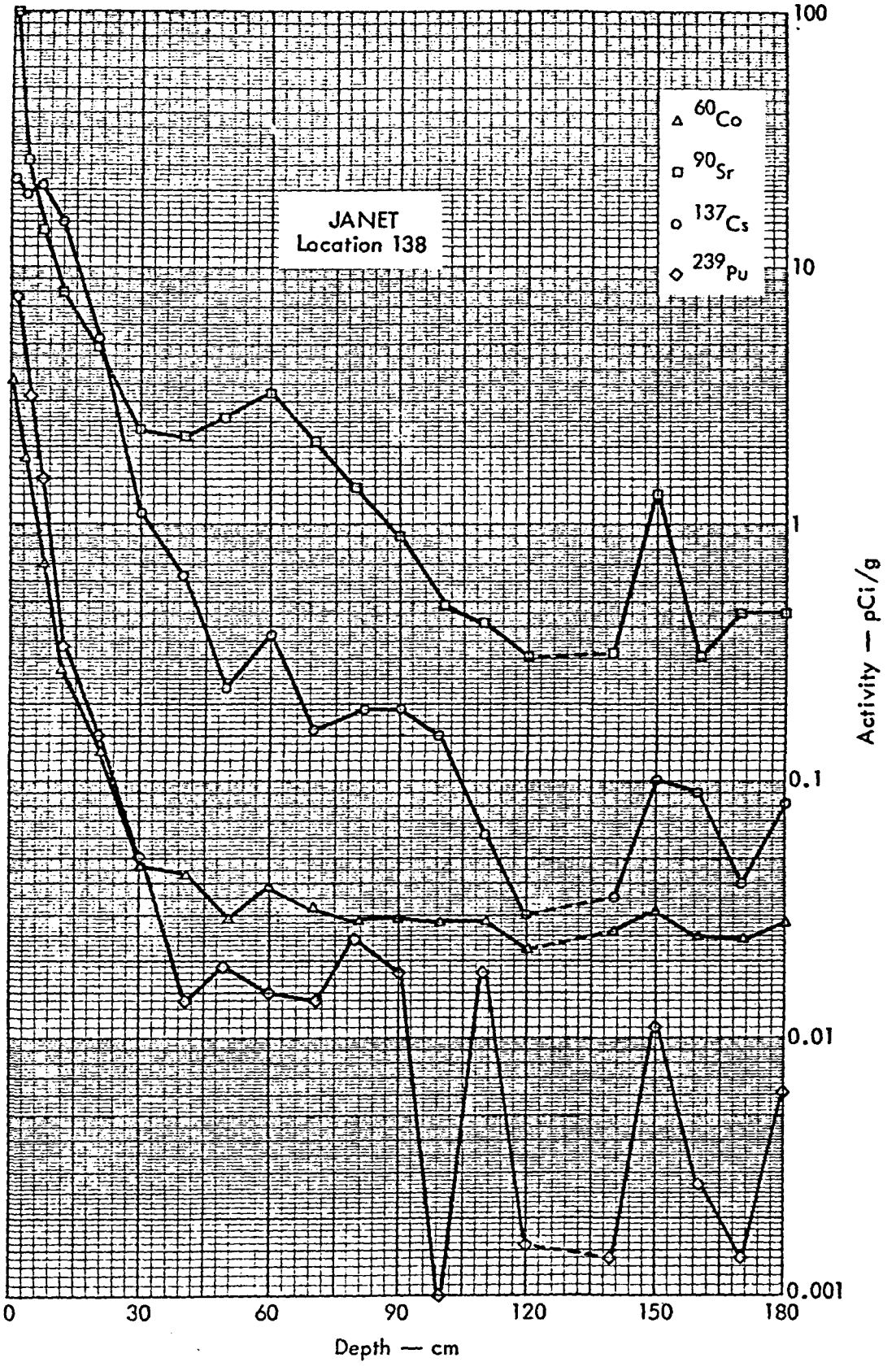


FIGURE 25. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

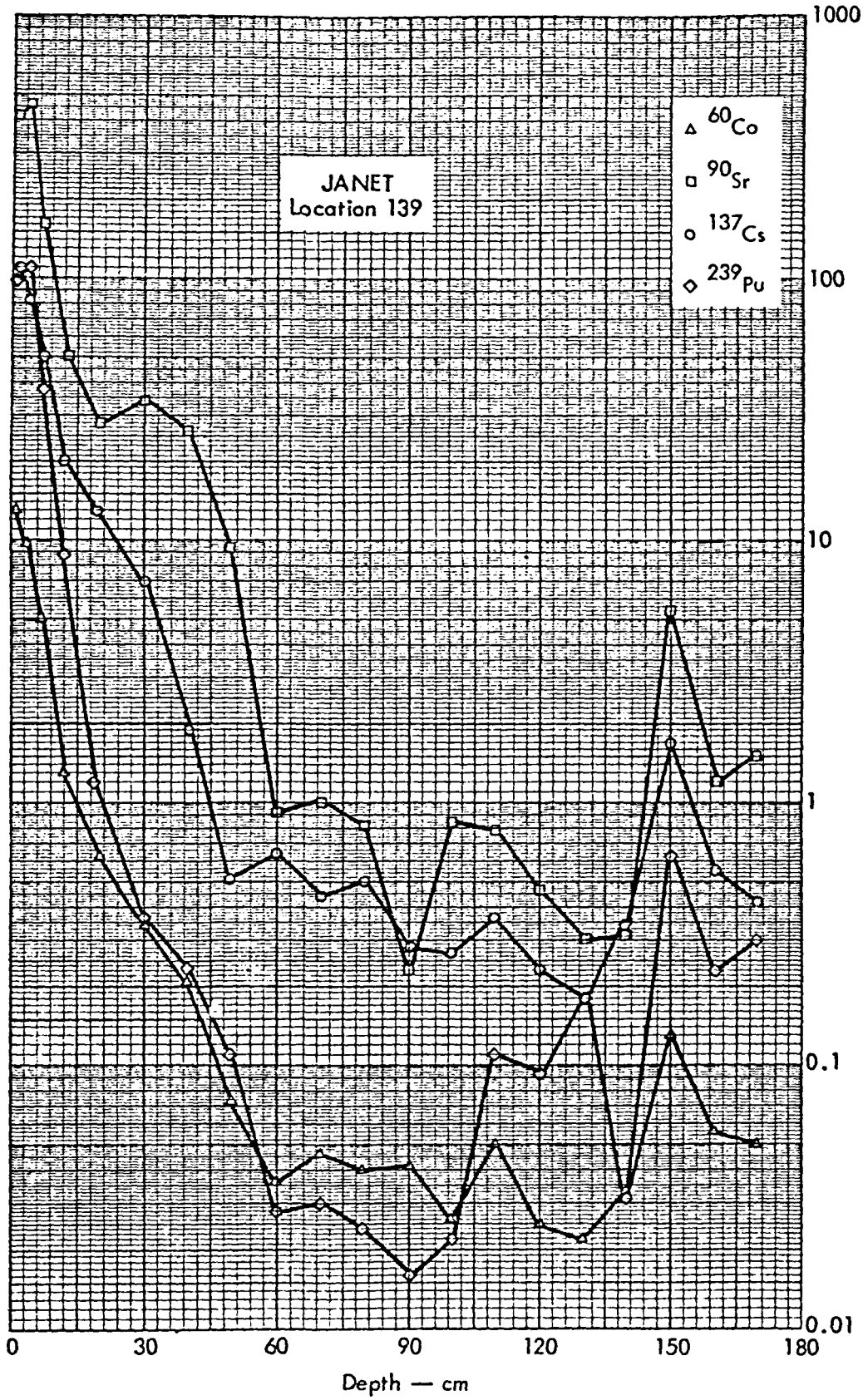


FIGURE 26. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

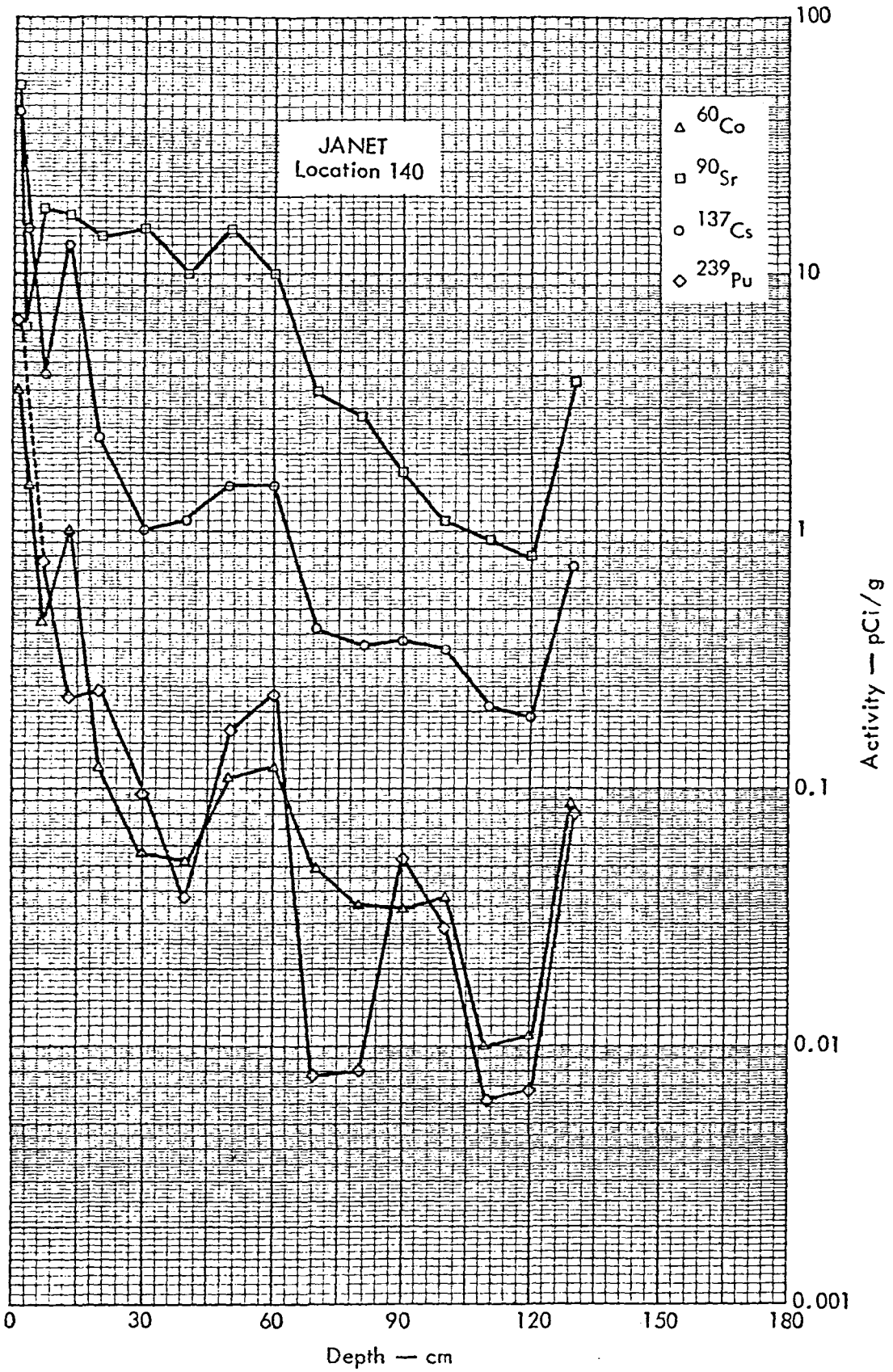


FIGURE 27. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

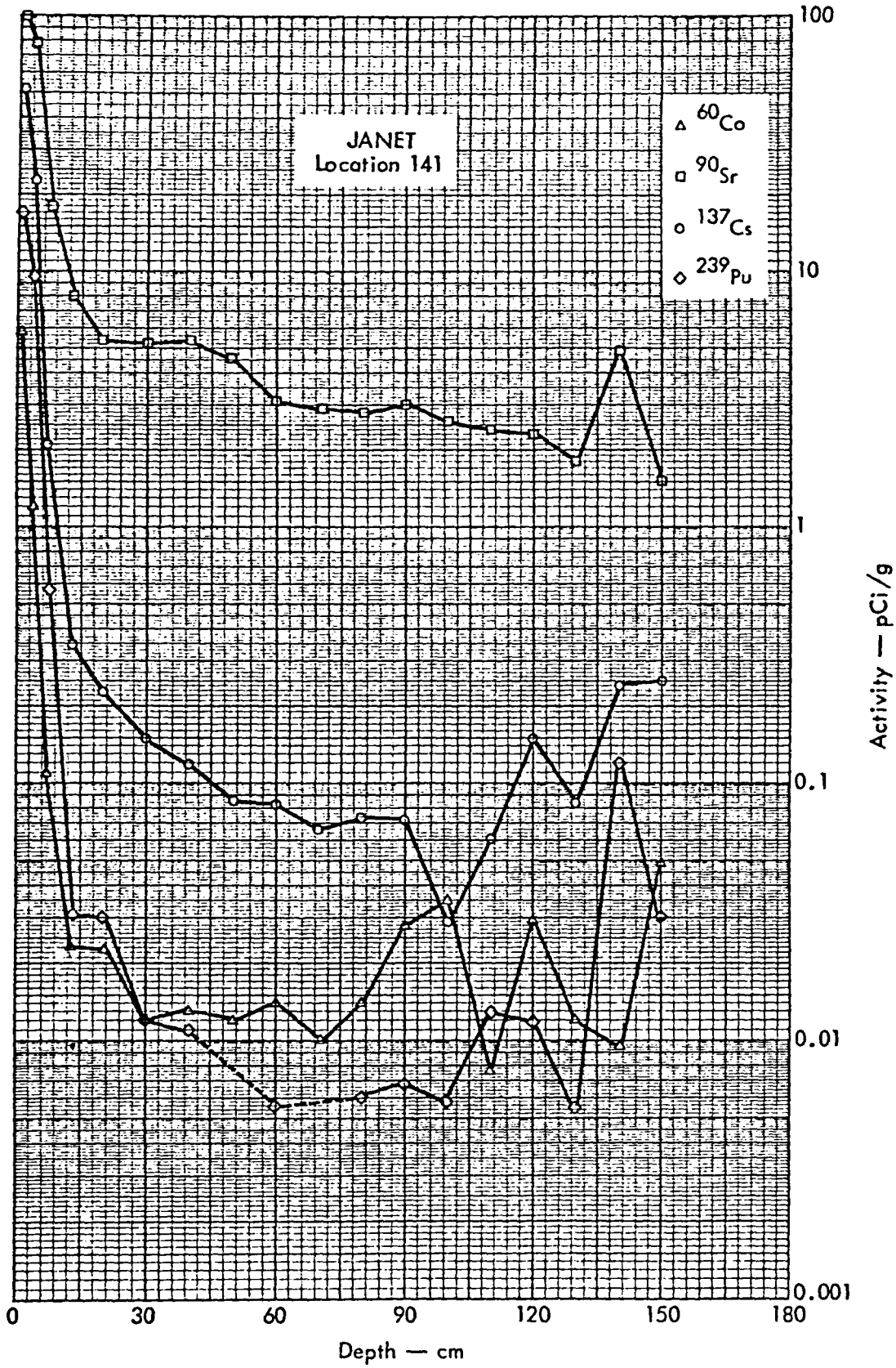


FIGURE 28. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

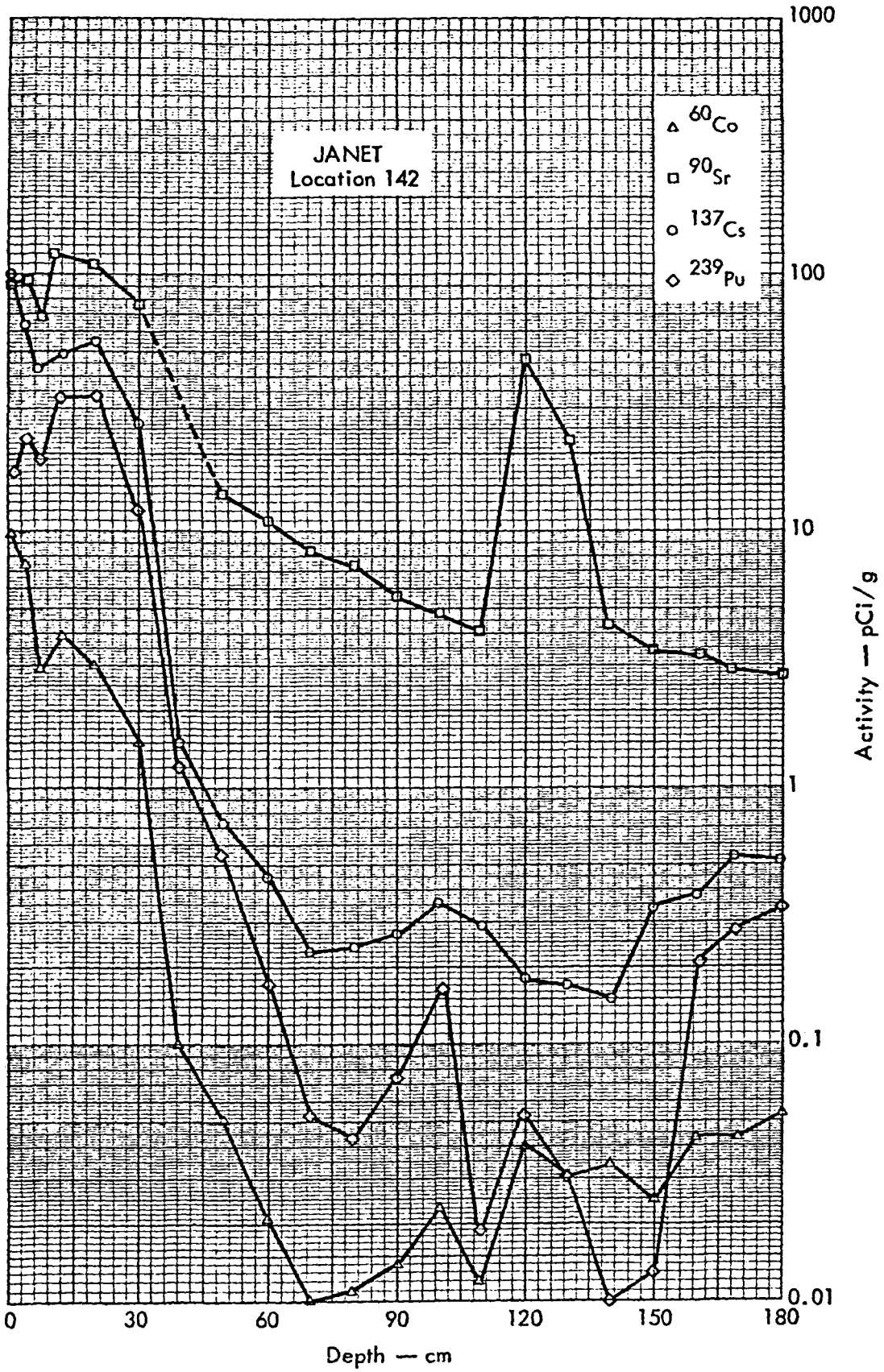


FIGURE 29. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

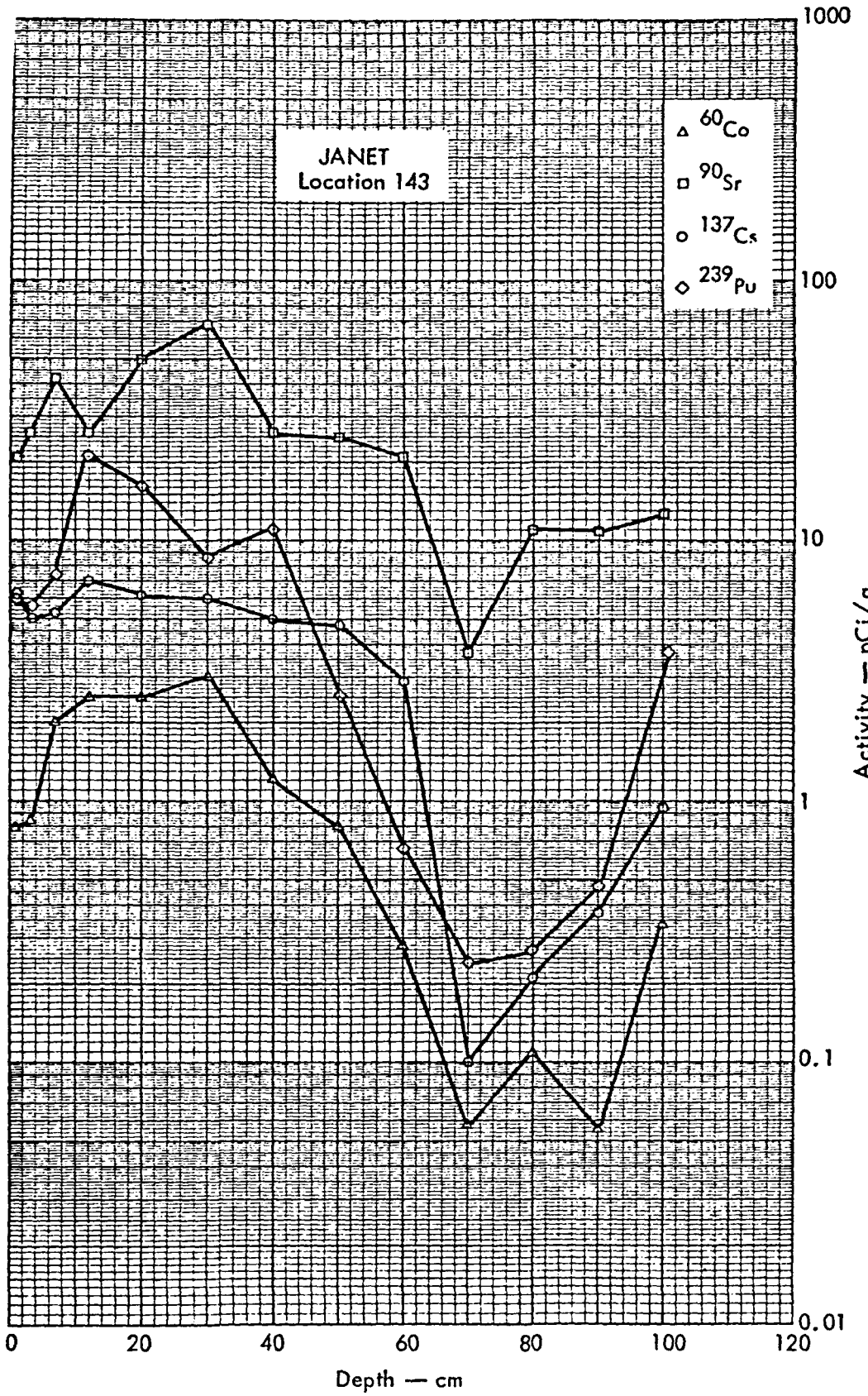


FIGURE 30. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

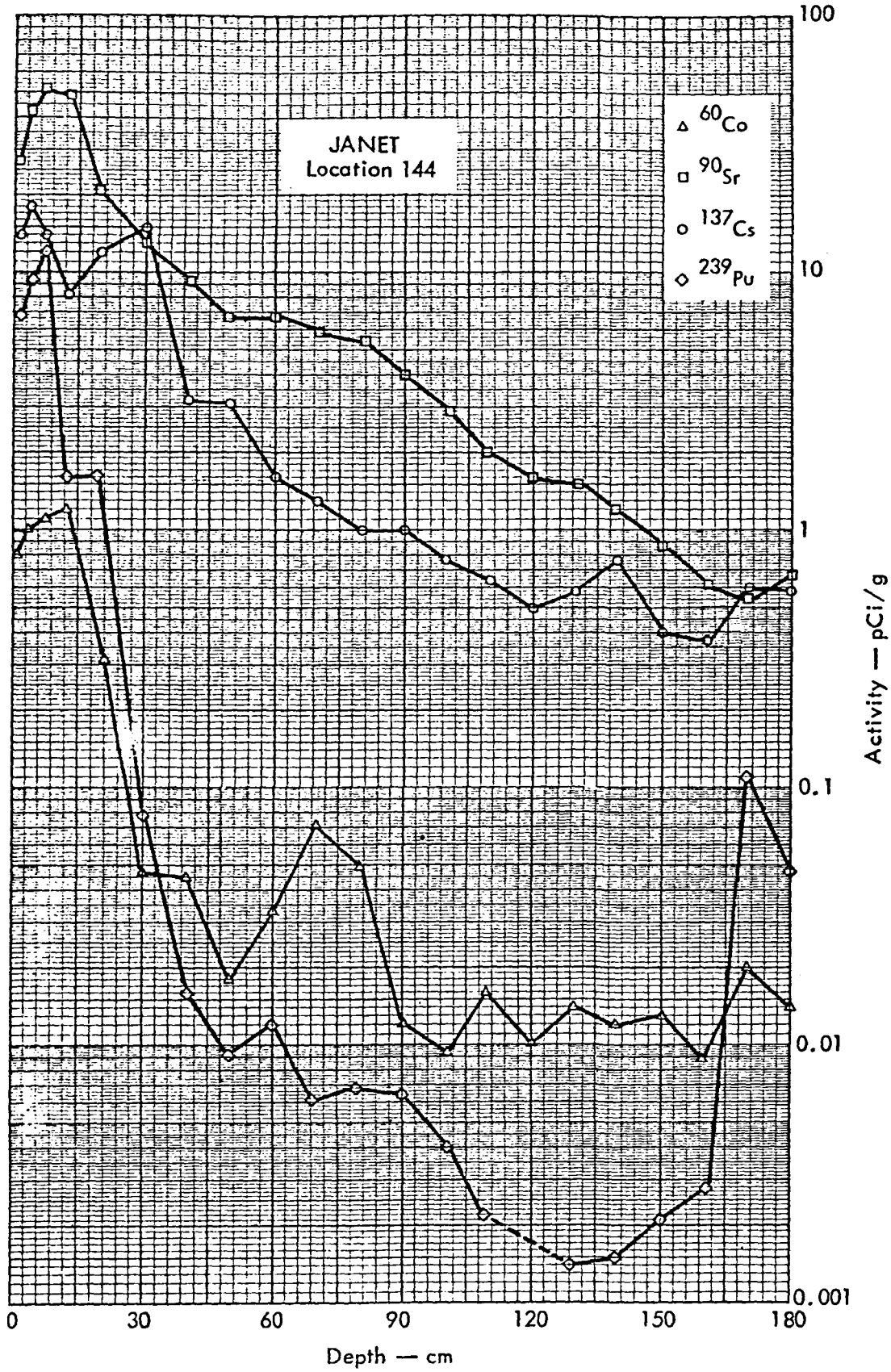


FIGURE 31. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

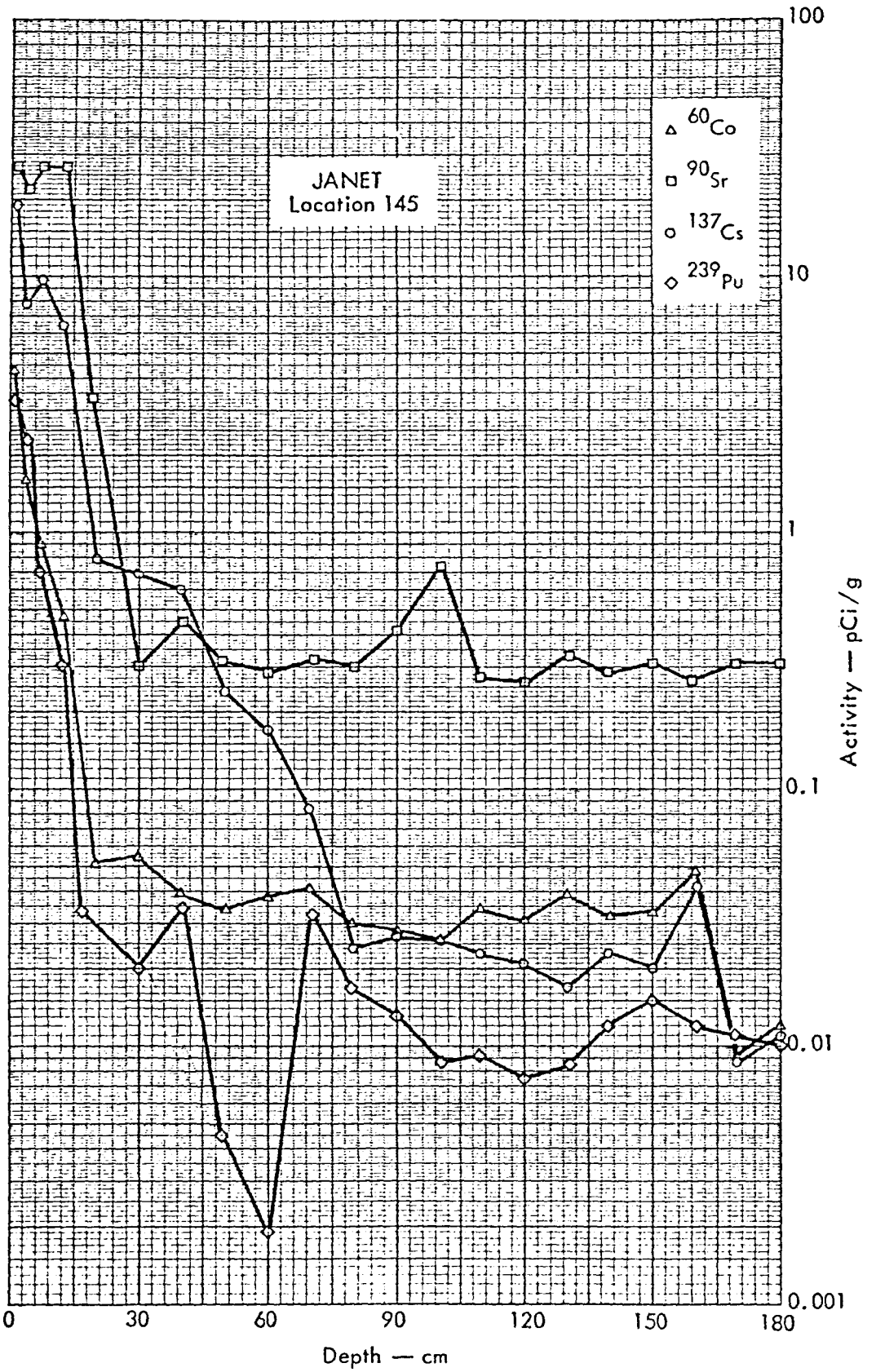


FIGURE 32. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

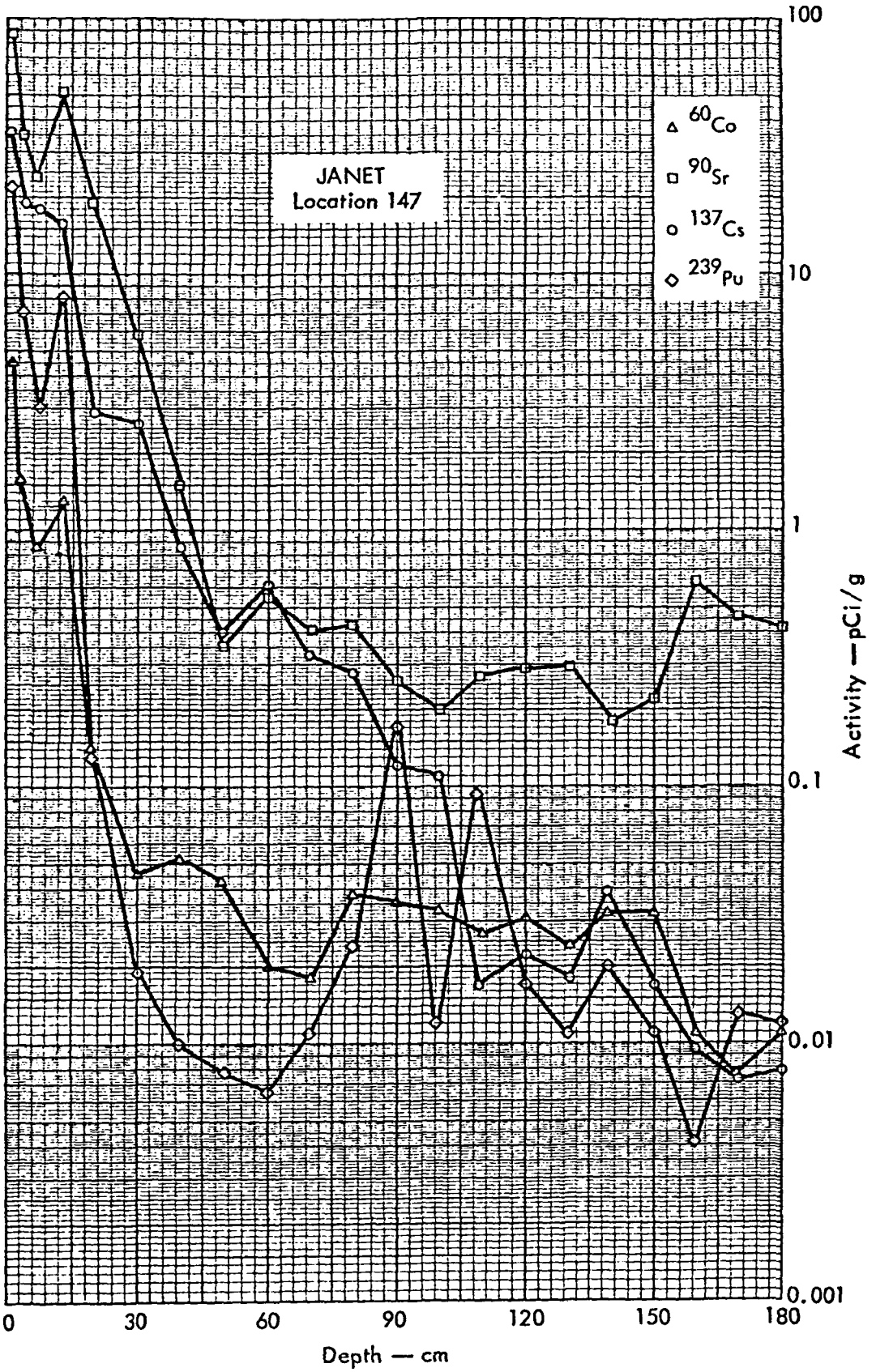


FIGURE 33. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

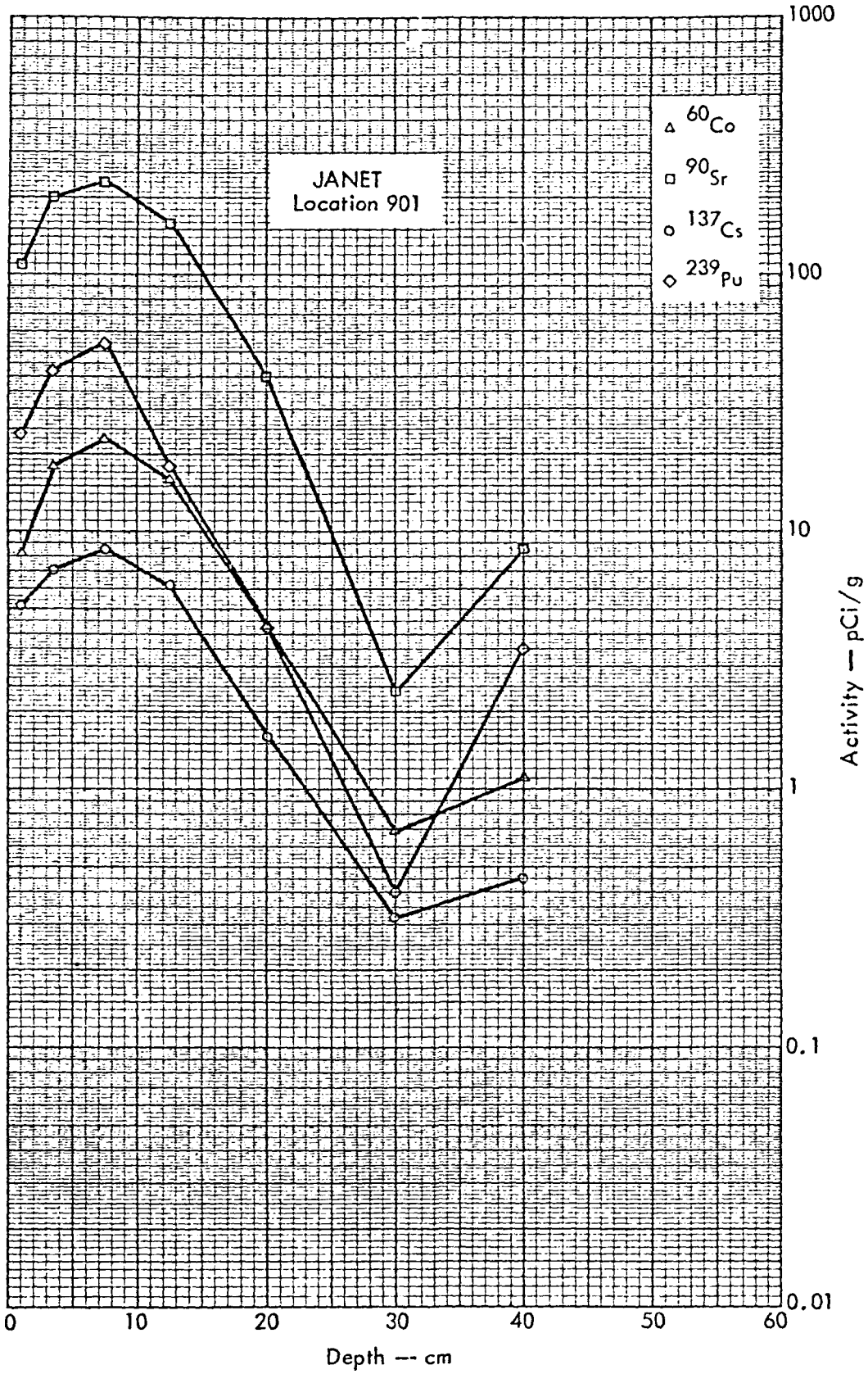


FIGURE 34. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

Site Name: KATE
Board of Geo.: MUJINKARIKKU
Marshallese: MIJIKADREK

KATE is located in the northern portion of Enewetak Atoll and has an area of about 16 acres (6.4 hectares). The island contains relatively open, sparsely vegetated areas over a large portion of its interior and along the lagoon and north sides. The remainder of the island is covered with dense vegetation.

KATE was used extensively for photographic purposes and effects on test structures during OPERATION GREENHOUSE (Figure 35). There is a considerable amount of metal debris and rubble on the island. No surface zeroes were located on KATE. The island ranks 15th of all the islands in the Atoll with 1,753 R/h accumulated H+1 hour exposure rate.

The results of analyses of surface soil samples as reported in NVO-140 are:

Radionuclide	Activity (pCi/g)	
	Mean	Range
Areas of sparse vegetation		
^{90}Sr	67	3.7 - 200
^{137}Cs	24	18 - 37
^{239}Pu	17	8.6 - 50
^{60}Co	2.7	1.6 - 5.8
Areas of dense vegetation		
^{90}Sr	11	1.6 - 49
^{137}Cs	4.8	1.8 - 16
^{239}Pu	2.3	0.17 - 14
^{60}Co	0.46	0.03 - 3.5

The depth distribution of activity compares to those obtained from more pristine areas; however, grading and construction took place on the island during the weapons testing program. Scientific stations for OPERATION IVY, for example, were constructed after three tower shots on adjoining JANET.

No known burials of radioactive material exist on KATE. Scrap material has been classified as not contaminated above the background level of the island.

CASE 3: BIRDS, EGGS, PICNIC, SUBSISTENCE & COMMERCIAL AGRICULTURE

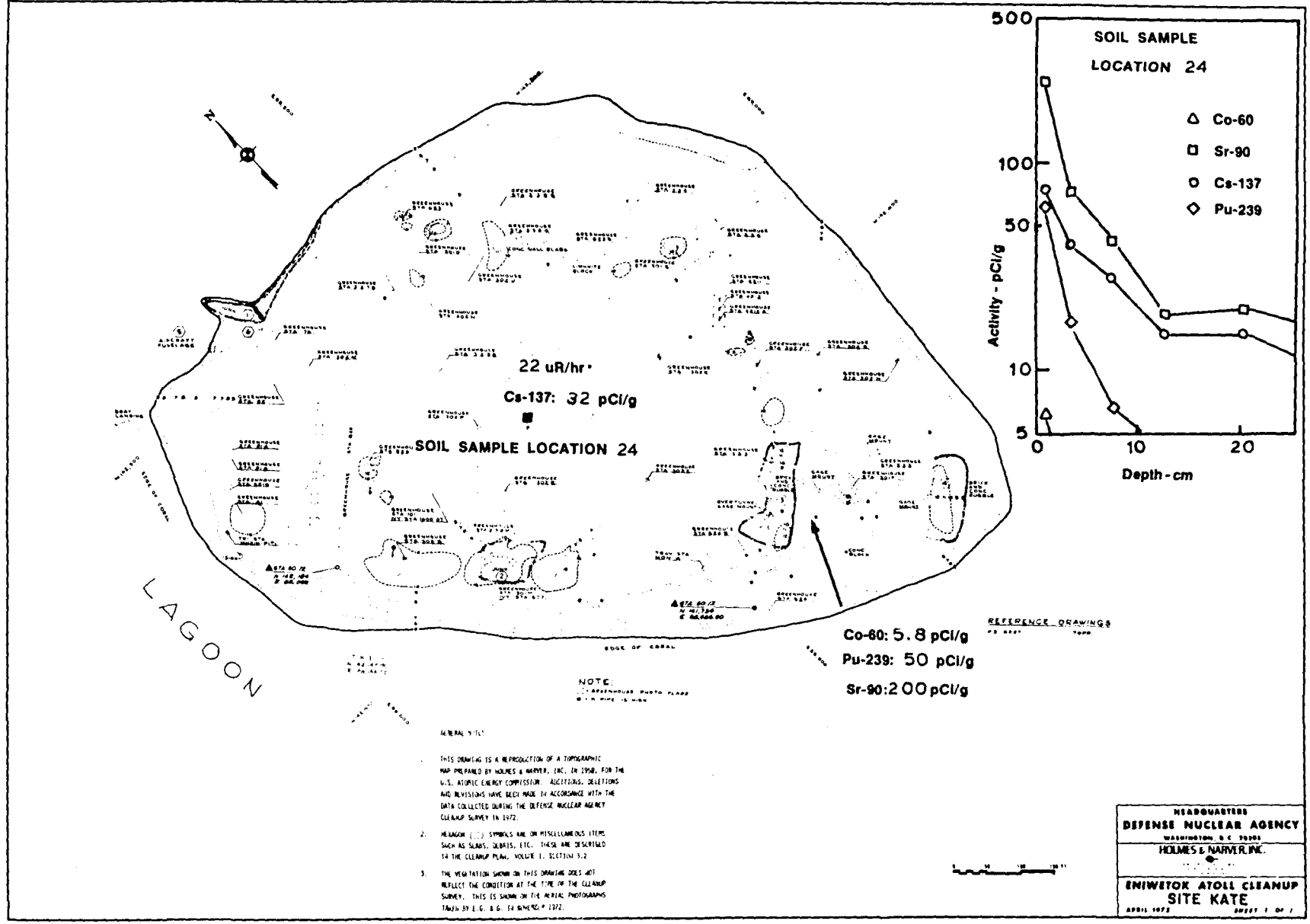


FIGURE 35. SITE KATE

Site Name: LUCY
Board of Geo.: BILLEE
Marshallese: KIDRINEN

LUCY is located in the northern portion of Enewetak Atoll and has an area of about 19 acres (7.9 hectares). The island is covered with dense vegetation except in the southeast quadrant where the cover is moderate.

This island was instrumented for biomedical studies and sampling during GREENHOUSE and held some instrumentation for IVY and HARDTACK. Most debris which remains is in small pieces.

LUCY has no surface zeroes. It ranks 14th of all the islands in the Atoll with 1,776 R/h accumulated H+1 hour exposure rate which was contributed by 10 events.

Only a few soil samples were collected from LUCY because of the dense vegetation cover. The mean and range of activities observed in the surface soil samples (23) collected were:

Radionuclide	Activity (pCi/g)	
	Mean	Range
^{90}Sr	32	10 - 83
^{137}Cs	11	2.2 - 25
^{239}Pu	7.7	2.4 - 22
^{60}Co	1.5	0.26 - 3.8

Profile sampling results indicate that higher concentrations exist in surface samples of less than the standard 15 cm depth.

The profiles generally reflect a sharp decrease in activity in the top 10 cm (relaxation lengths of about 5 cm) and a leveling off below this depth (Figure 36). Because of the relatively small number of soil samples, the data was considered as a single population; however, the isoexposure contours developed from the aerial survey measurements reflect lower exposure rates over the less dense vegetation, i.e., the southeast end.

No radioactive material burial sites are known to exist on LUCY. Scrap and debris has not been classified as contaminated.

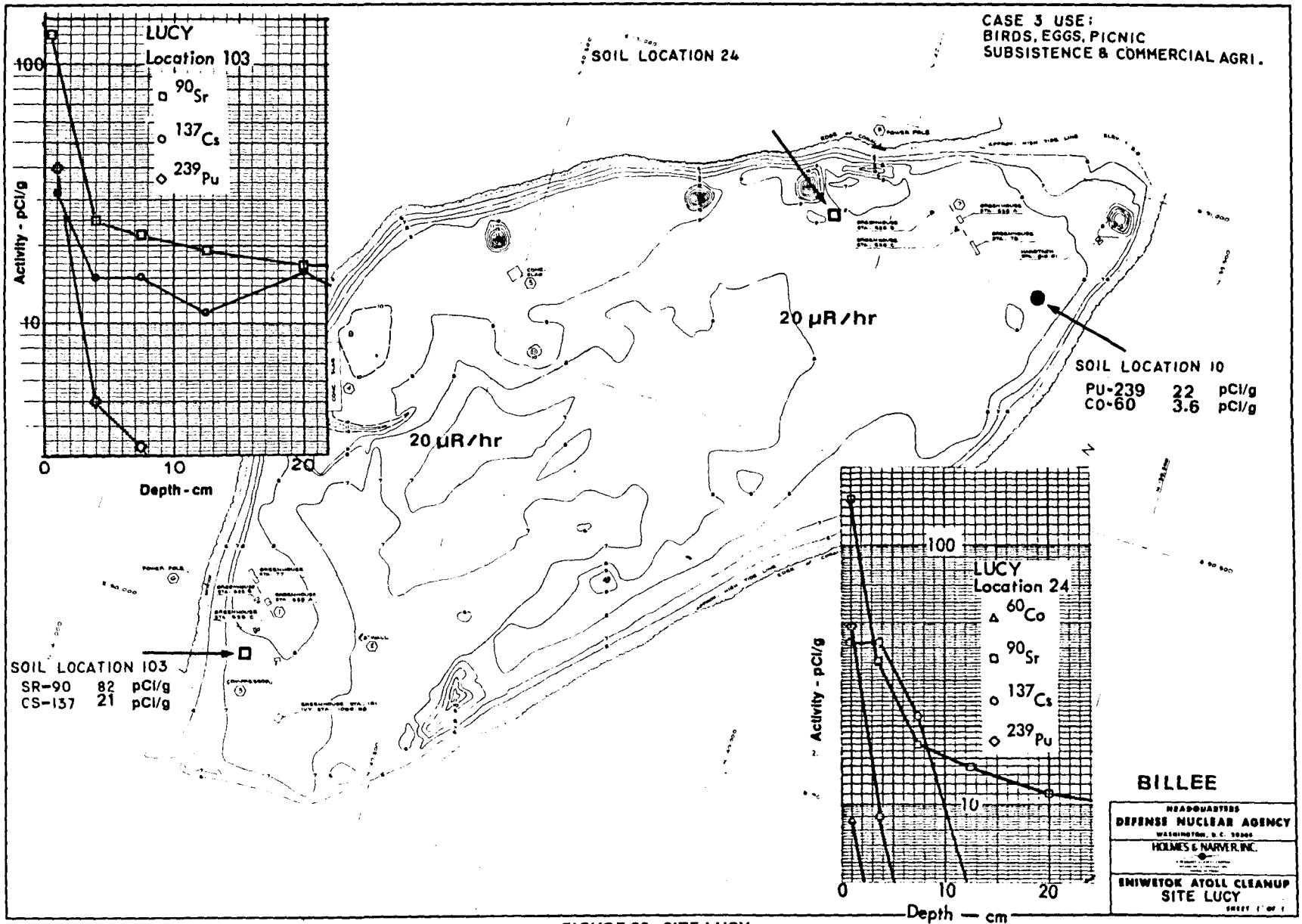


FIGURE 36. SITE LUCY

Site Name: MARY
Board of Geo.: BOKONARAPPU
Marshallese: BOKENELAB

MARY is located in the northern portion of Enewetak Atoll and has an area of about 12 acres (4.7 hectares). Vegetation on the island ranges from sparse to moderate.

MARY was used for instrumentation during OPERATIONS GREENHOUSE, IVY and HARDTACK (Figure 37). Structures of poor condition remain from those operations. MARY has no surface zeroes but ranks 12th of all islands in the Atoll with 2,785 R/h accumulated H+1 hour exposure rate.

The distribution of radioactivity is fairly homogeneously distributed throughout the island, with no significant correlation between activity levels and the degree of vegetation in the vicinity of the sampling locations. The mean and range of activities observed over the entire island, excluding the beaches, are:

Radionuclide	Activity (pCi/g)	
	Mean	Range
^{90}Sr	29	11 - 140
^{137}Cs	9.9	5.6 - 26
^{239}Pu	8.0	2.0 - 35
^{60}Co	1.5	0.74 - 4.8

Some construction activity occurred on the island during the testing operations which may be reflected in the dissimilar results of soil profile sample results.

No radioactive material burials are known to exist on MARY.

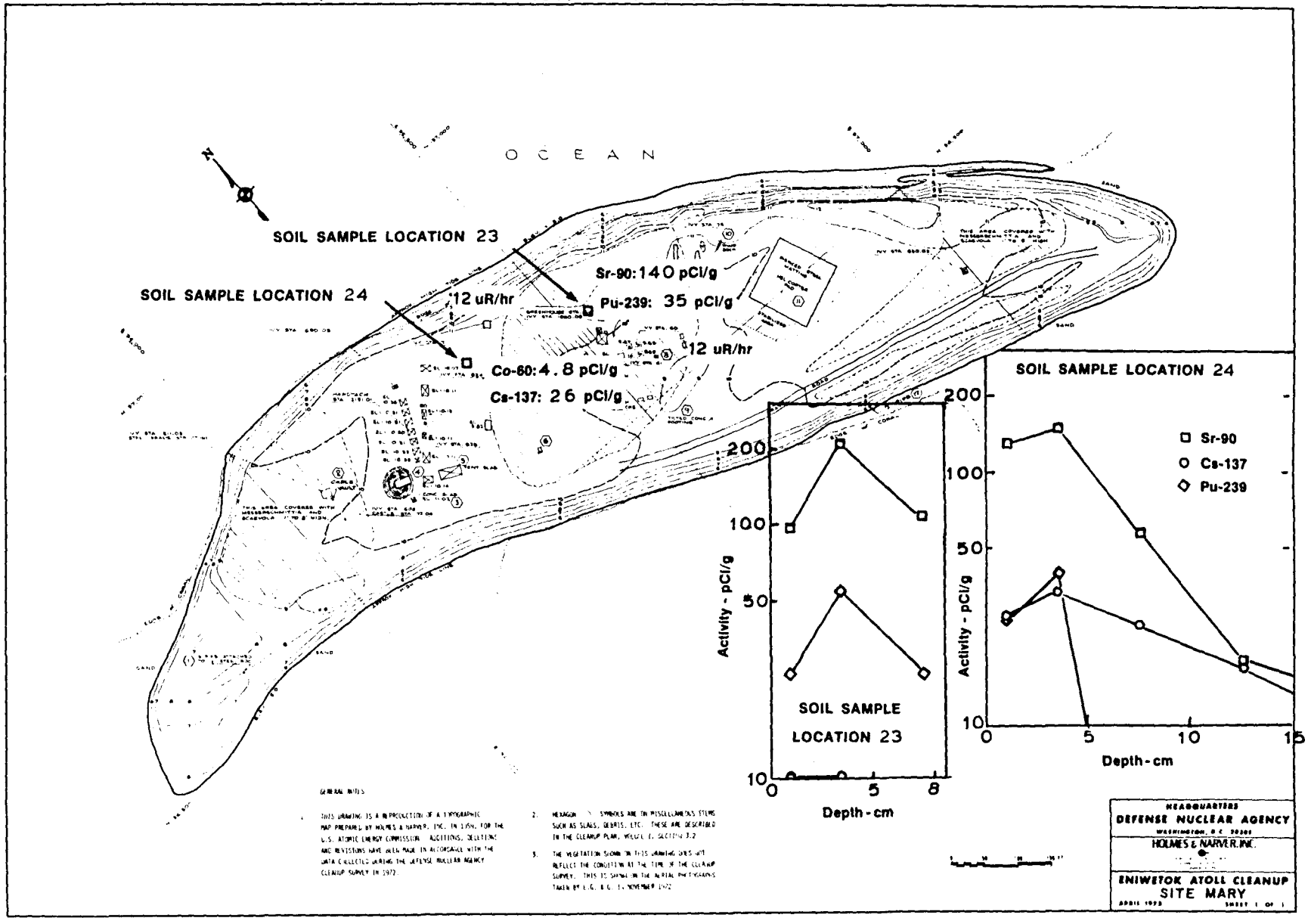


FIGURE 37. SITE MARY

Site Name: NANCY
Board of Geo.: YIERI
Marshallese: ELLE

NANCY is located in the northern portion of Enewetak Atoll and has an area of about 11 acres (4.5 hectares). The island (Figure 38) is completely covered with dense vegetation.

NANCY has no surface zeroes and ranks 17th of all islands in the Atoll with 1,251 R/h accumulated H+1 hour exposure rate. Seven shots contributed this exposure. The island is reported to be clear of debris from testing.

The radioactivity is fairly homogenously distributed throughout the island. The activities of pertinent radionuclides reported in NVO-140 are:

Radionuclide	Activity (pCi/g)	
	Mean	Range
^{90}Sr	36	16 - 110
^{137}Cs	12	6.0 - 28
^{239}Pu	9.1	2.3 - 28
^{60}Co	1.6	0.56 - 5.3

The depth distributions of activity as measured in soil profiles display a rapid decrease of activity immediately below the surface (relaxation lengths of 3-5 cm) for locations sampled in the island's interior. A beach profile from the western end of the island shows more homogeneity. Plutoniom-239 was measured to be 42 pCi/g at 7.5 cm in this profile whereas the maximum of the interior profiles was 35 pCi/g at the surface.

No radioactive material burial sites are known to exist on NANCY.

CASE 3: BIRDS, EGGS, PICNIC

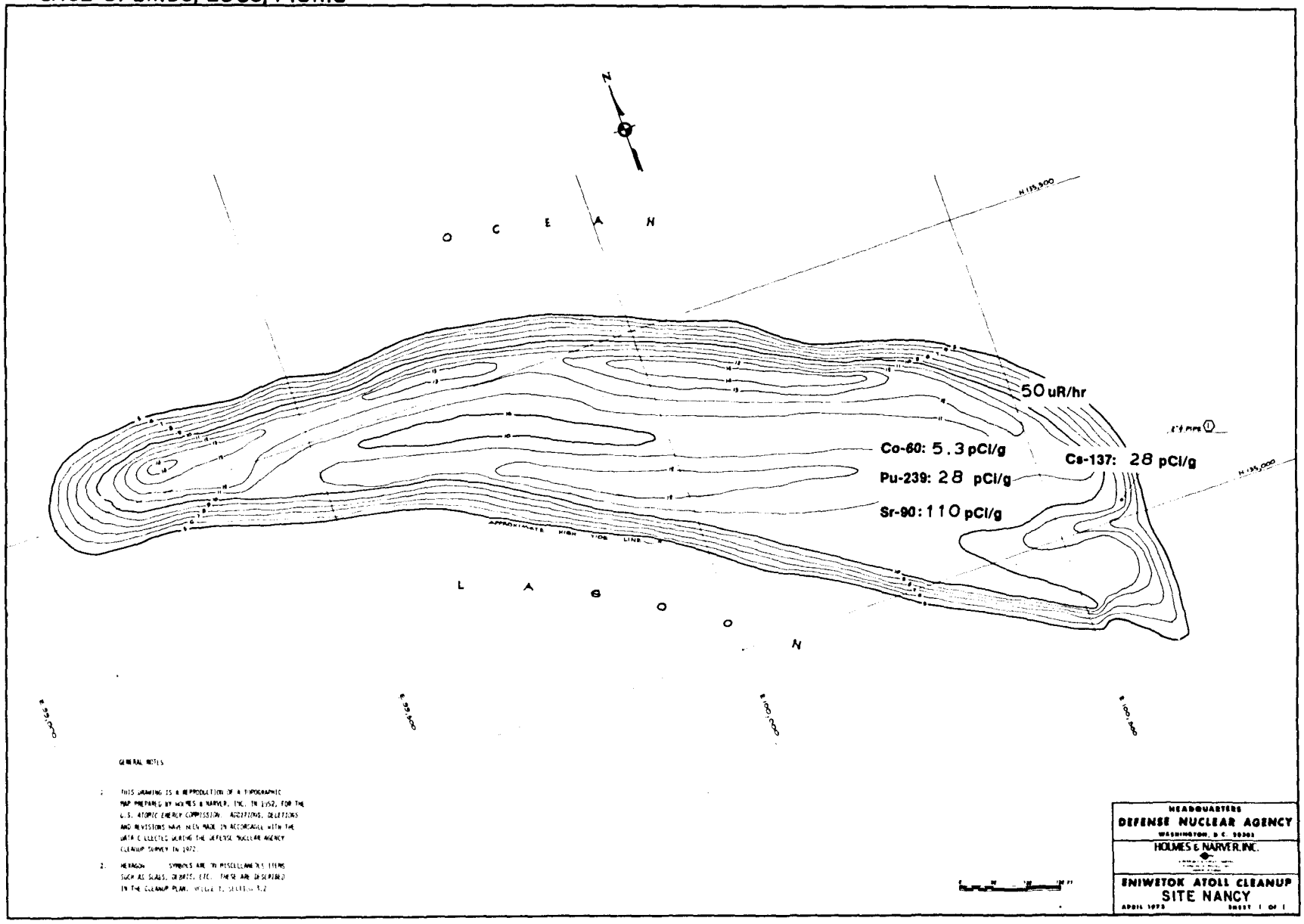


FIGURE 38. SITE NANCY

Site Name: OLIVE
Board of Geo.: AITSU
Marshallese: AEJ

OLIVE is located in the northern portion of Enewetak Atoll and has an area of about 40 acres (16 hectares). Vegetation on the island ranges from sparse to dense.

OLIVE has no surface zeroes and ranks 16th of all islands in the Atoll with 1,252 R/h accumulated H+1 hour exposure rate. Twelve events contributed to this exposure. Only one structure, a recording bunker for OPERATION CASTLE, exists on the island.

Soil sample results for OLIVE have been divided into areas where vegetation was sparse and more dense. The radionuclide concentrations reported in NVO-140 for these areas are:

Radionuclide	Activity (pCi/g)	
	Mean	Range
Areas of dense vegetation		
^{90}Sr	22	4.6 - 70
^{137}Cs	8.5	3.5 - 28
^{239}Pu	7.7	2.2 - 30
^{60}Co	1.5	0.65 - 4.1
Areas of sparse vegetation		
^{90}Sr	4.5	2.0 - 11
^{137}Cs	0.16	0.07 - 11
^{239}Pu	2.8	1.9 - 4.1
^{60}Co	0.11	0.05 - 0.31

The unusually large difference in the mean values of the two groups of data is probably due to the fact that samples collected on or near the edge of sparsely vegetated areas reflect the lower activities on the beach, and that a significant portion of the samples representing the densely vegetated interior were collected in an area somewhat toward the ocean side. Aerial measurements show this area had a slightly higher radiation level than the rest of the island. The depth distributions (Figure 39) obtained within the interior of the island are quite similar with relaxation lengths of about 5 cm.

No radioactive burials are known to exist on OLIVE.

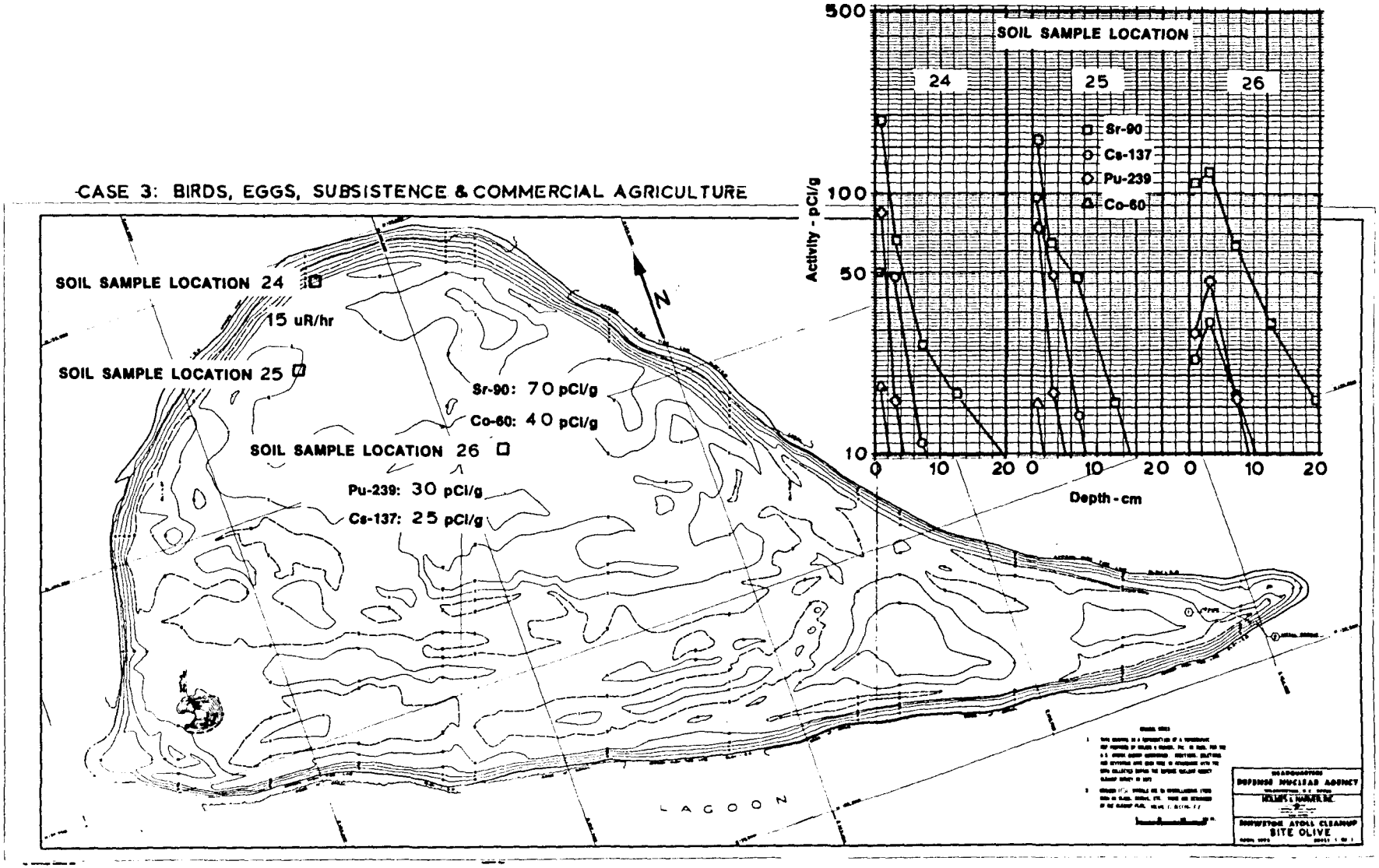


FIGURE 39. SITE OLIVE

Site Name: PEARL
Board of Geo.: RUJIYORU
Marshallese: LUJOR

PEARL is located in the northern portion of Enewetak Atoll and has an area of about 54 acres (22 hectares). The island is moderately vegetated.

PEARL was the location of the INCA EVENT of OPERATION REDWING. PEARL ranks 6th of the islands in the Atoll with 4,329 R/h accumulated H+1 hour exposure rate. This exposure was the result of INCA plus 12 other shots. INCA was conducted on June 21, 1956, and produced heavy local contamination on the shot island, however, did not delay preparations for the MOHAWK EVENT on adjoining island RUBY. Four concrete anchor blocks are located on the northwest end (Figure 40) around the INCA ground zero. Some debris from testing is located toward the southeast end of the island (Figure 41).

The NVO-140 radiological evaluation was based on soil activities without regard to the degree of vegetation. That evaluation divided the island data into a hot spot represented by five locations and the remainder of the island. The mean and range of activities for soil samples from these samples are:

Radionuclide	Activity (pCi/g)	
	Mean	Range
Hot Spot		
^{90}Sr	62	35 - 140
^{137}Cs	19	7.4 - 55
^{239}Pu	51	15 - 530
^{60}Co	12	3.6 - 70
Remainder of Island		
^{90}Sr	17	3.2 - 61
^{137}Cs	7.6	1.2 - 34
^{239}Pu	11	0.85 - 100
^{60}Co	4.1	0.49 - 49

NVO-140 shows that the samples which are used to define the "hot spot" are closely grouped and no samples were collected north toward the ocean beach nor within a hundred meters east or west (Figure 42).

The depth distributions of these nuclides measured at various locations throughout the island show relaxation lengths of the order of 5 cm except one location near the southeast end where the soil activities are more homogenous with depth. The maximum value for ^{239}Pu at this location is 24 pCi/g at 7.5 cm in depth. The graphs for the only two profiles with ^{239}Pu greater than 40 pCi/g appear in Figures 43 and 44. Thirteen surface (0-15cm) soil samples showed ^{239}Pu concentrations of greater than 40 pCi/g as may be noted on Figure 42 (NVO-140 Figure B15.1.i.).

Gamma intensities, hand-held survey as well as aerial ^{60}Co, were highest in the area of the INCA ground zero. Four hundred (400) uR/h was the highest rate recorded using the hand-held meter measurement method.

No radioactive material burial sites are known to exist on PEARL; however as a surface zero exists there it may be assumed that some activity took place during post-shot operations which may have covered radioactivity to prevent personnel exposure or to aid recovery operations.

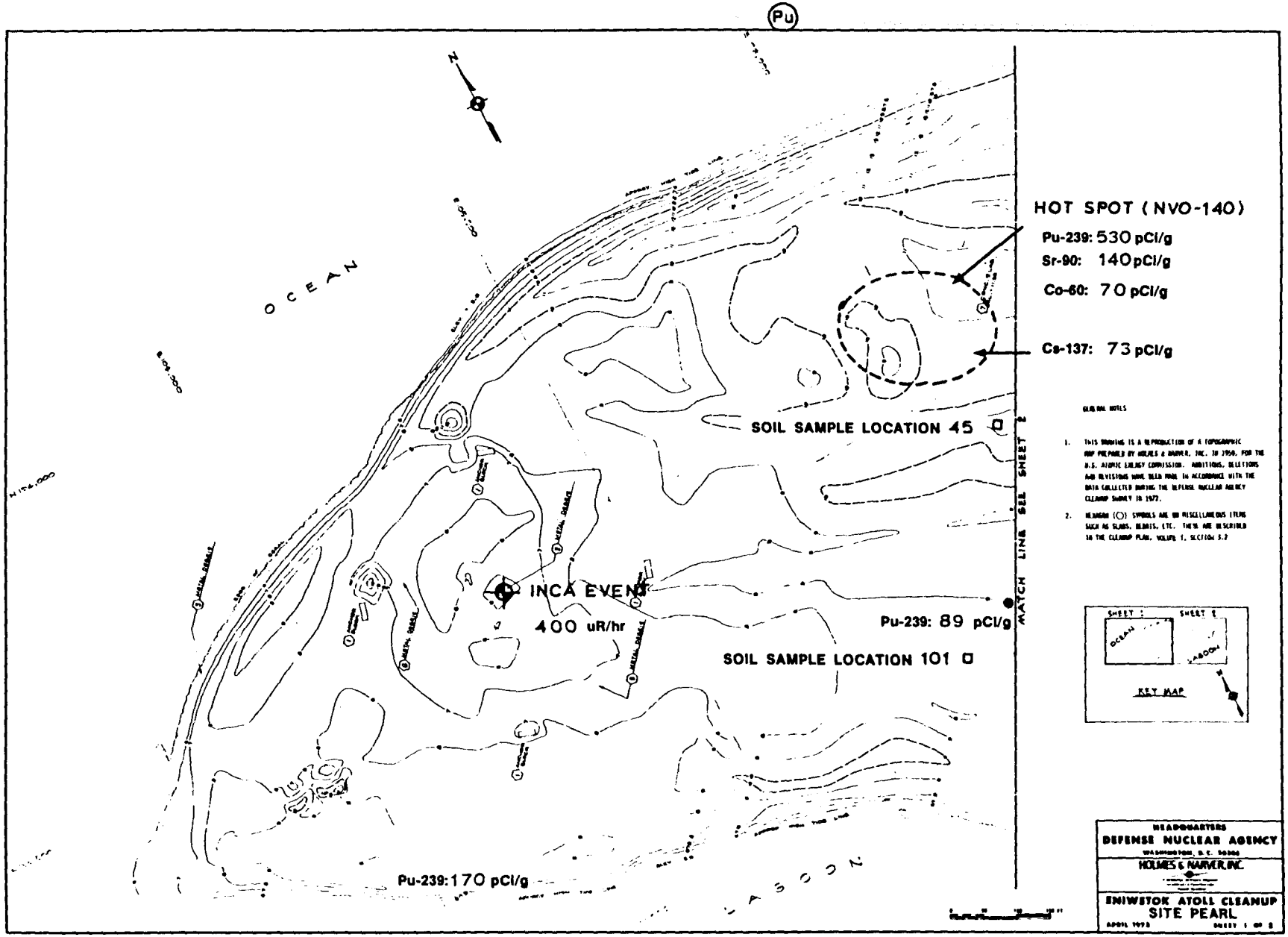


FIGURE 40. SITE PEARL, SHEET 1 OF 2

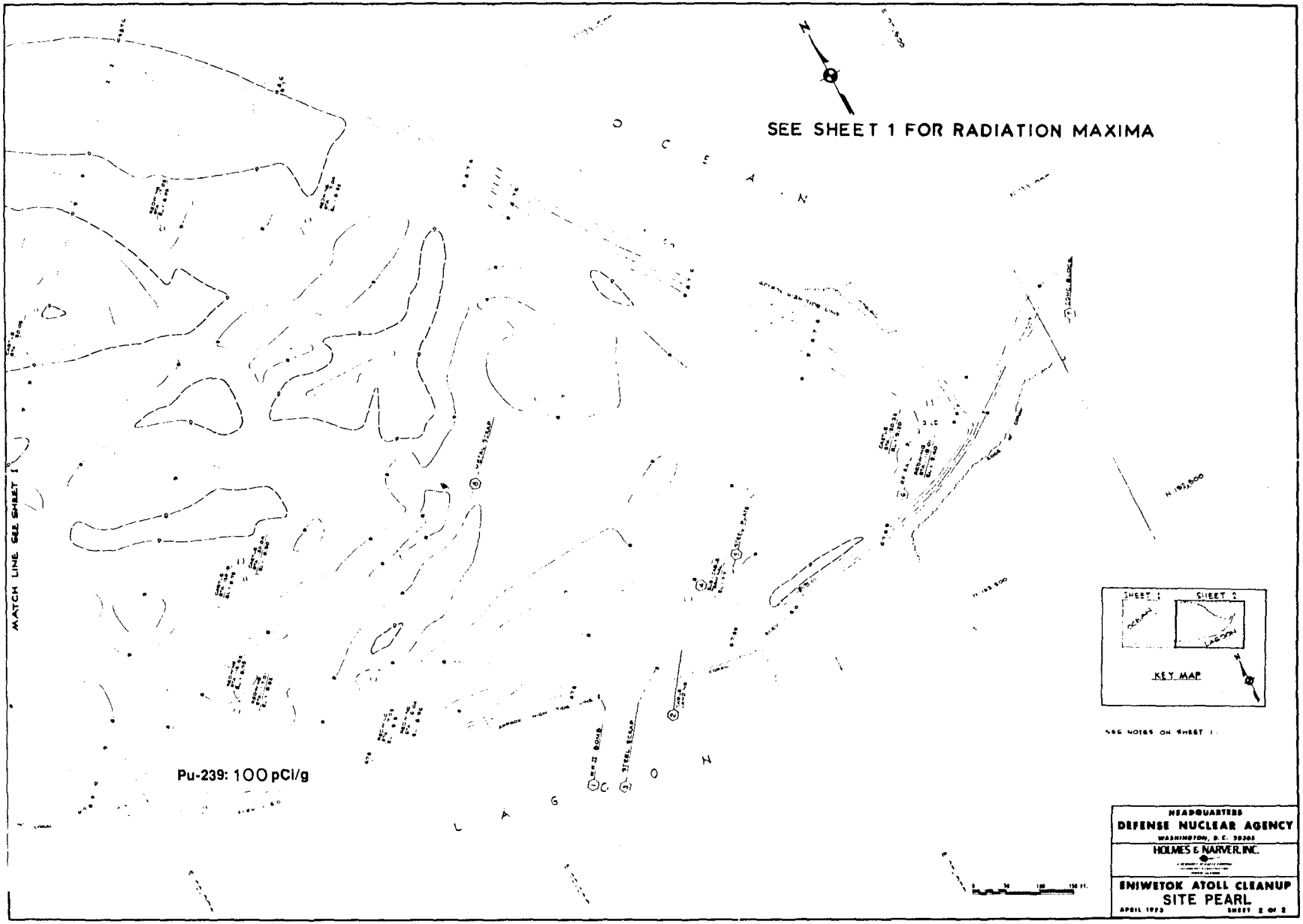


FIGURE 41. SITE PEARL, SHEET 2 OF 2

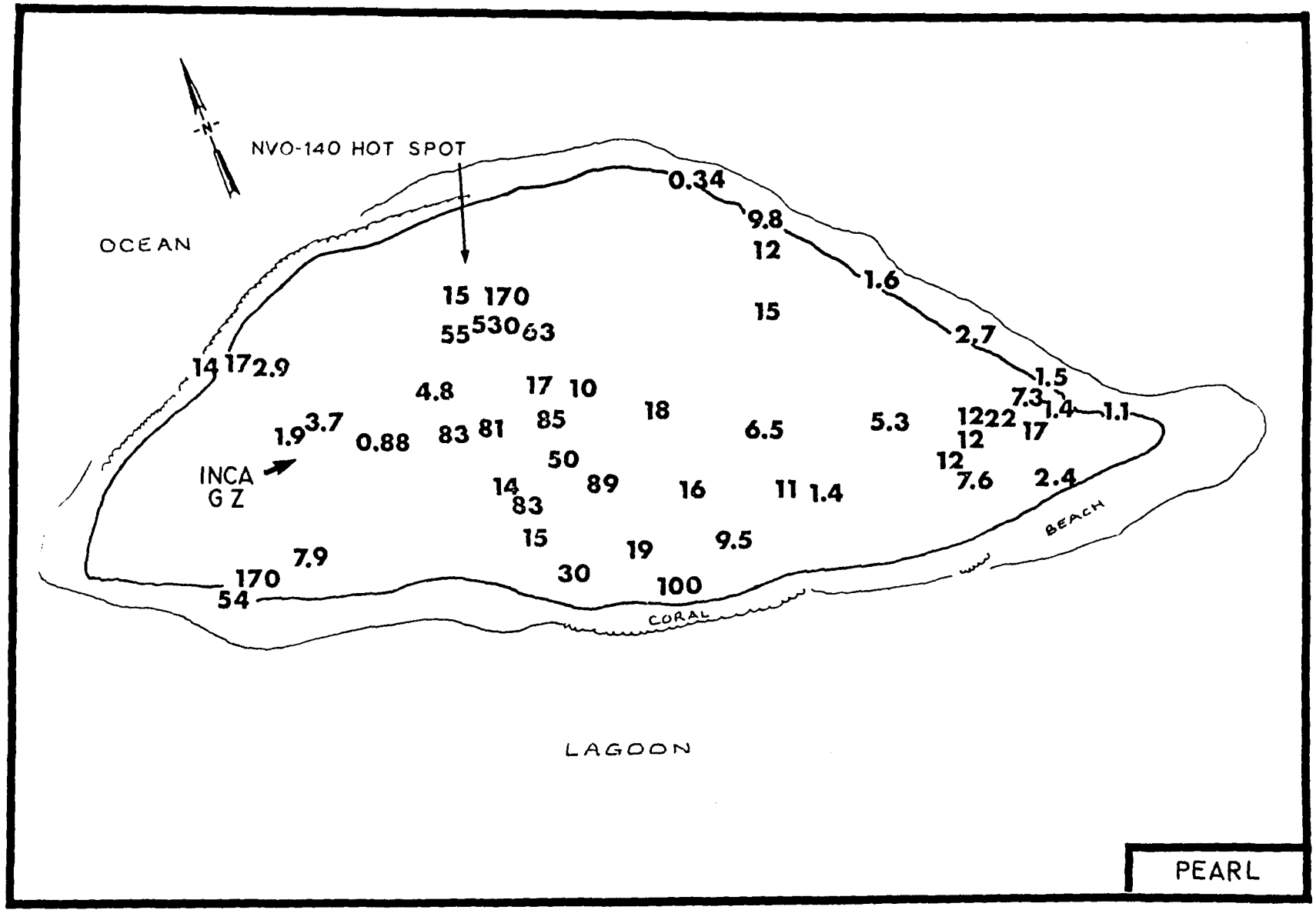


FIGURE 42. THE AVERAGE ^{239}Pu ACTIVITIES (pCi/gm) IN SOIL SAMPLES COLLECTED TO A DEPTH OF 15 CM

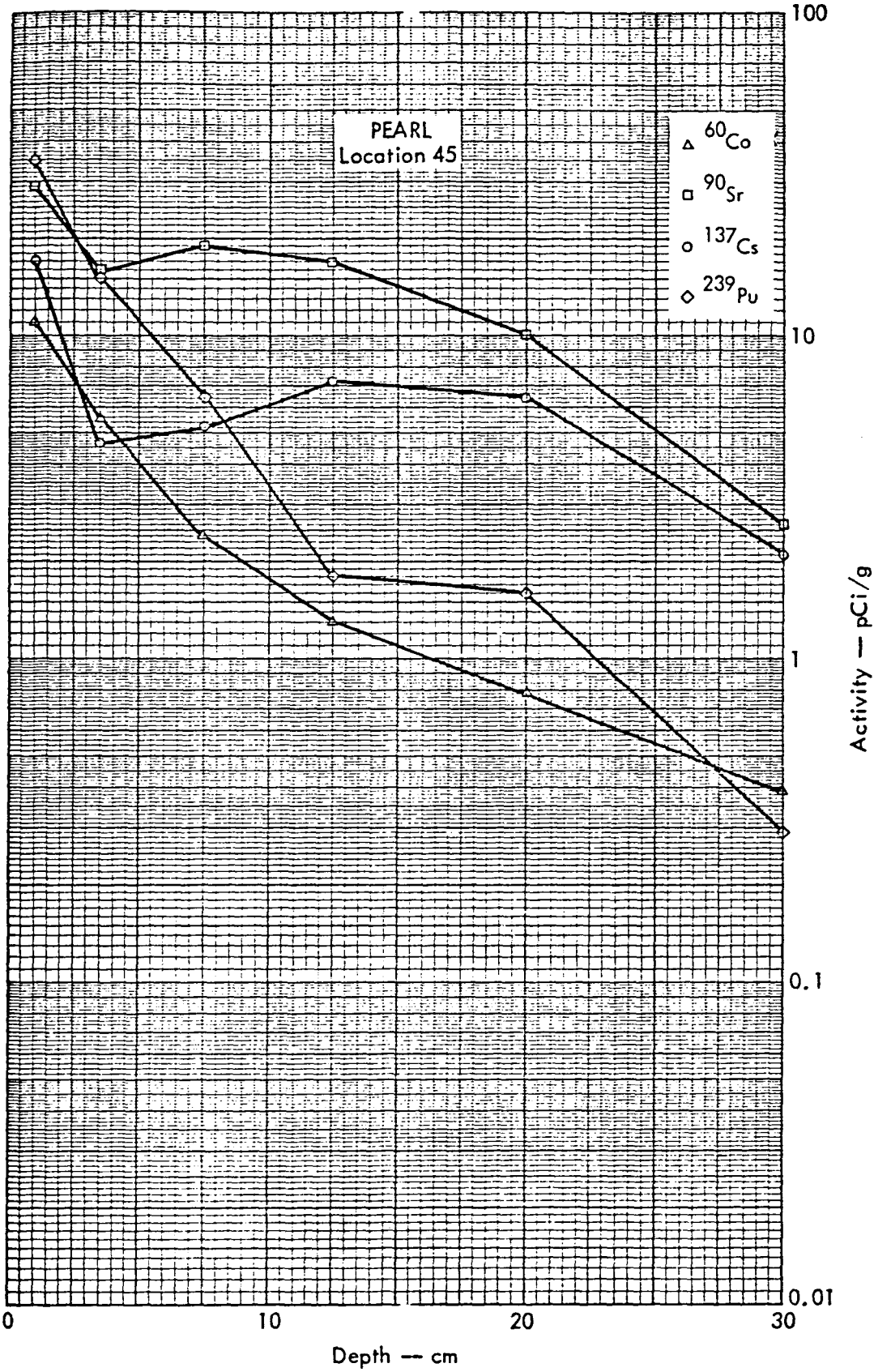


FIGURE 43. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

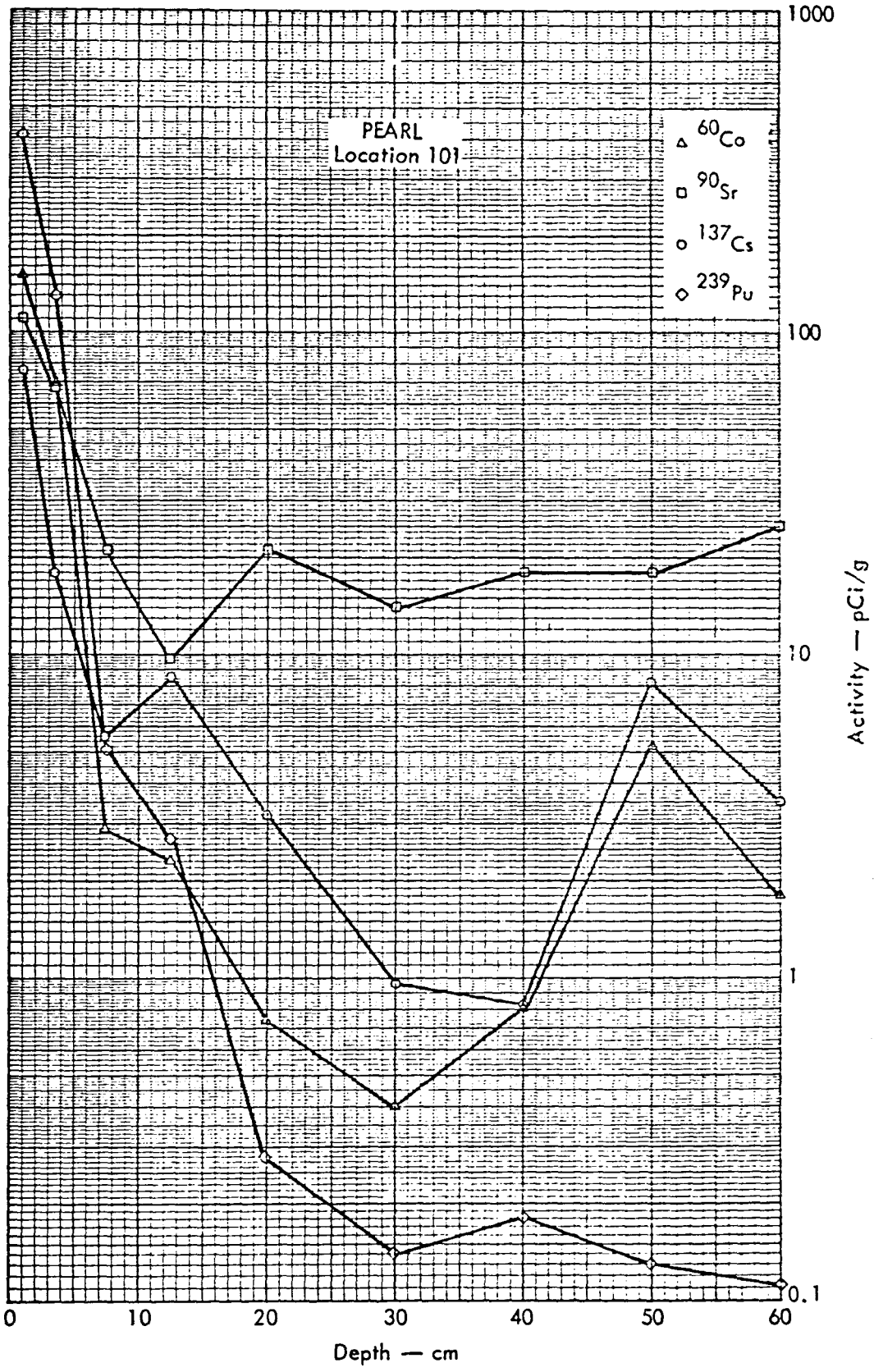


FIGURE 44. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

Site Name: PERCY
Marshallese: TAIWEL

PERCY is located in the northern portion of Enewetak Atoll between LUCY and MARY. It has an area of about 5 acres (1.9 hectares) and consists of a sandbar supported by coral shoals with little or no vegetation (Figure 45).

The only structure on the island is an overturned submarine cable terminal box.

Results from soil samples collected at six locations sampled show the following activities:

Radionuclide	Activity (pCi/g)	
	Mean	Range
^{90}Sr	13	3.6 - 73
^{137}Cs	0.94	0.12 - 17
^{239}Pu	3.5	1.5 - 23
^{60}Co	0.47	0.08 - 2.9

The depth distribution obtained from a single profile indicates that the maximum activity is situated 3-8 cm below the surface with a rapid decrease from 8-20 cm. Plutonium-239 was measured to be 90 pCi/g at 7.5 cm in depth.

No radioactive material burials are known to exist on PERCY.

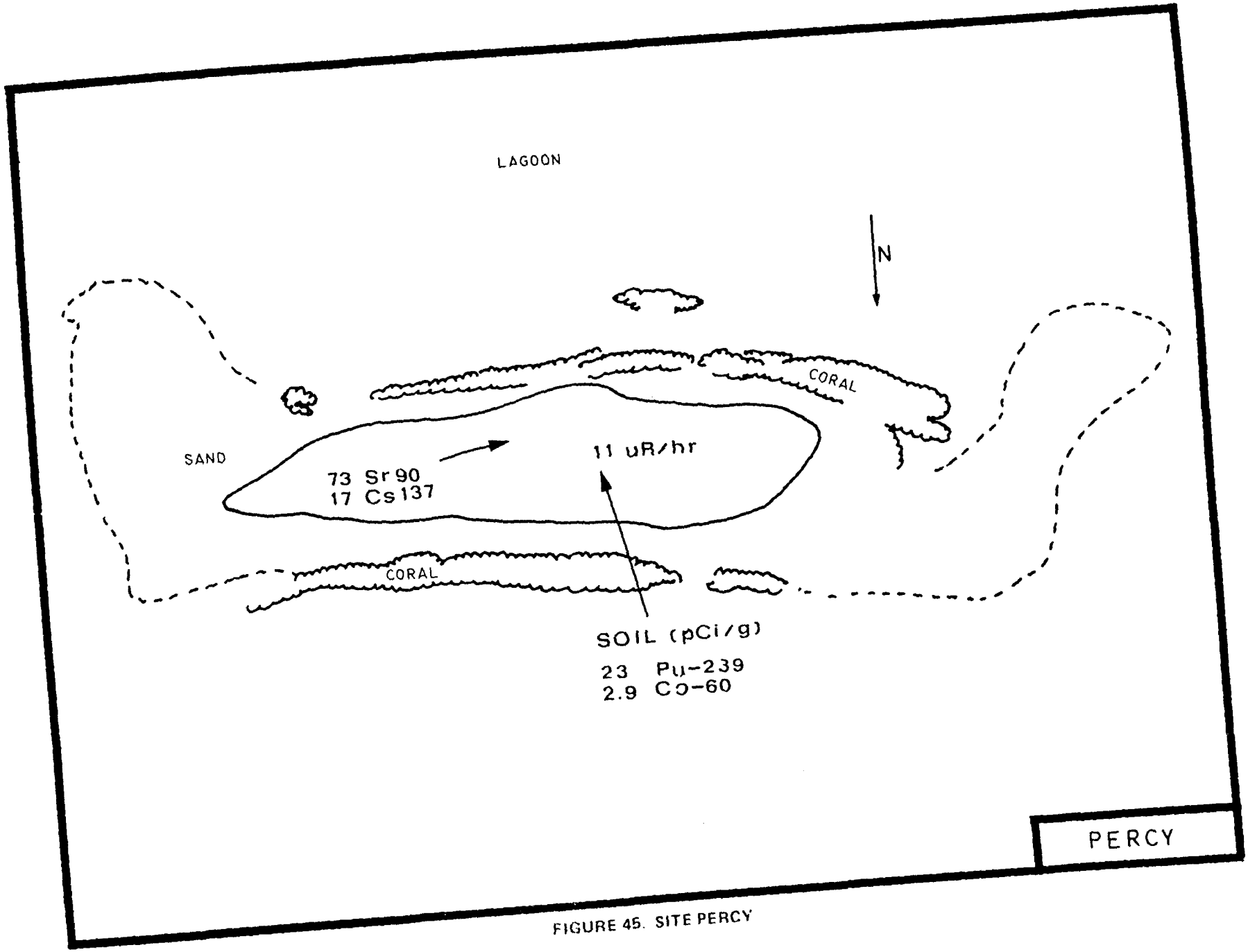


FIGURE 45. SITE PERCY

Site Name: RUBY
Board of Geo.: EBERIRU
Marshallese: ELELERON

RUBY was an island located in the northeastern portion of Enewetak Atoll. The original island has been nearly destroyed as a result of nuclear testing. As a result two small islets exist. The islet farthest from Site SALLY was identified as RUBY in NVO-140 and the islet at the end of the north causeway from SALLY was included with SALLY. The Pacific Cratering Experiments (PACE) of early 1972 contributed to this misnaming perhaps by grading SALLY and filling the area (an old borrow area) south of the RUBY-SALLY causeway. Figure 46 shows the original land areas of RUBY and the SALLY-TILDA-URSULA complex.

RUBY was the site of two nuclear events:

Name	Date GCT	Type & Height (ft) of Burst
GREENHOUSE, GEORGE	5/8/51	Tower, 200
REDWING, MOHAWK	7/2/56	Tower, 300

GEORGE resulted in a large shallow, water-filled crater on RUBY. MOHAWK was detonated about 450 feet west of the GEORGE zero point and destroyed a major portion of the remaining island.

The remainder of this report will address RUBY as described in NVO-140. Readers acquainted with the island's history may wish to refer to the Site SALLY report which covers the RUBY islet and causeway still connected to SALLY.

Fallout from 16 events ranks RUBY 2nd of all islands in the Atoll in H+1 hour accumulated exposure rate received with 10,643 R/h. Most of the land mass receiving this exposure has been blasted or eroded away.

The islet sampled in the radiological survey (NVO-140) showed radionuclide concentrations in soil to be:

Radionuclide	Activity (pCi/g)	
	Mean	Range
^{90}Sr	12	7.1 - 63
^{137}Cs	1.4	0.71 - 7.2
^{239}Pu	7.3	3.0 - 24
^{60}Co	0.93	0.29 - 16

In each case the maximum concentration occurred near the lagoon side of the island. The one profile sampling displayed a homogeneous distribution with depth illustrative of hydraulic influences on the small land mass. Soil concentrations are below remedial action levels.

Aerial photographs show some debris remains from testing and, although not so identified by NVO-140, may be contaminated. That report designates RUBY as a burial site because two zero points existed there. As water now covers these points, burial should not be assumed in the general sense; however, a shallow water survey may reveal debris which may be contaminated.

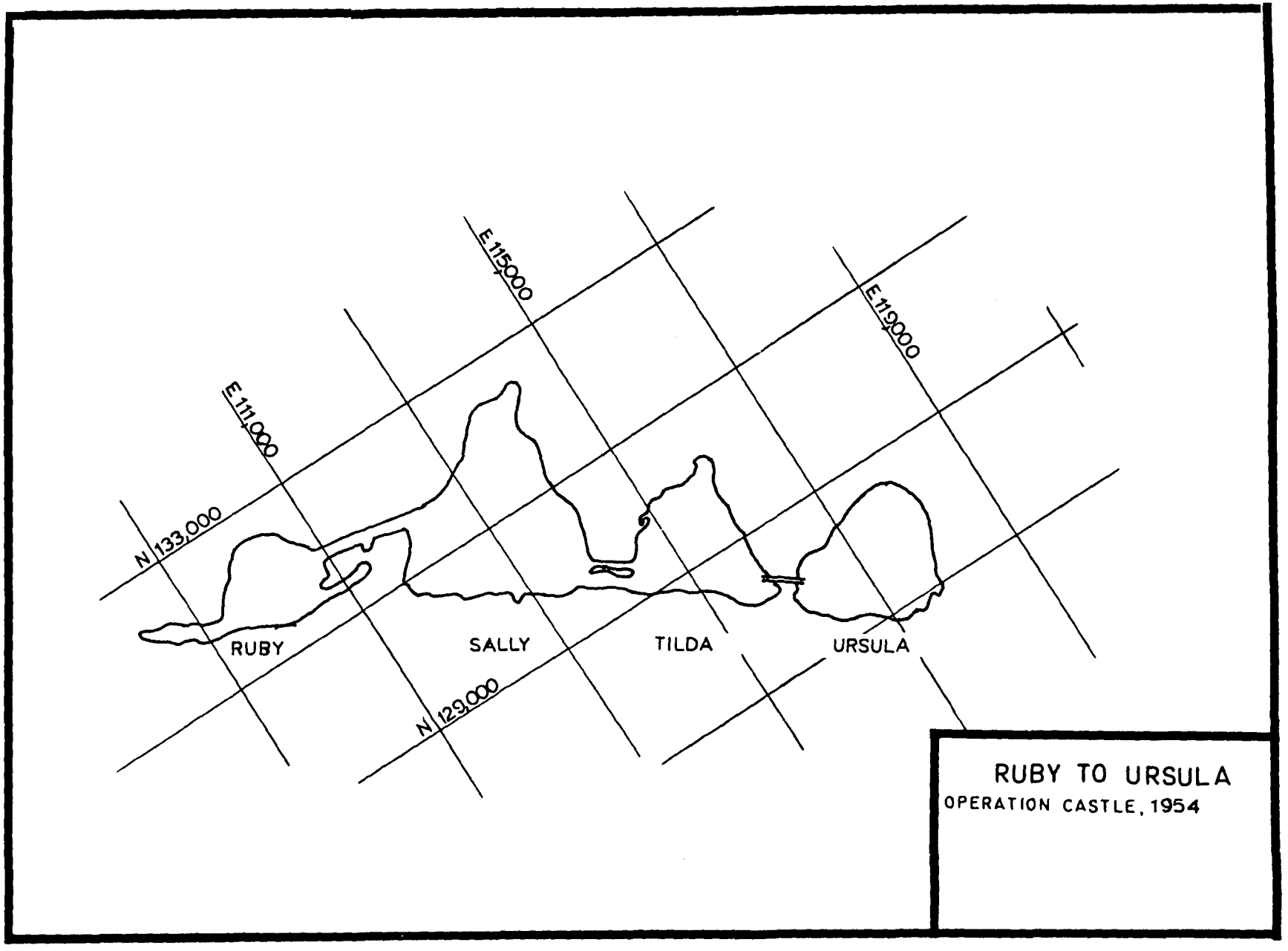


FIGURE 46. SITES RUBY TO URSULA

Site Name: SALLY (ALSO SALLY'S CHILD)
Board of Geo.: AOMAN
Marshallese: AOMON

Site SALLY is located in the northeastern portion of Enewetak Atoll and has an area of about 99 acres (40 hectares). SALLY is the northern island of the AOMAN-BIIJIRI, or AOMAN-BIIJIRI-LOJUA complex as it was known by many during testing operations. SALLY was connected to RUBY (EBERIRU) and TILDA (BIIJIRI) by causeways as shown in Figure 46. RUBY is also referred to as Eleleron or Aleleron, a second Marshallese name. The user of this report should acquaint himself with the preceding report for Site RUBY. The portion of RUBY shown on the figures from NVO-140 and the topographic drawings used herein, (Figures 47-49) was subject to the two shots conducted on RUBY, i.e., GREENHOUSE GEORGE and REDWING MOHAWK.

SALLY'S CHILD, included in this report, is a small islet on the reef east of SALLY (Figure 50).

SALLY contains three surface zero points. These plus fallout from 13 other events cause SALLY to rank 13th of the islands in the Atoll for accumulated H+1 hour exposure rate received with 1,981 R/h. The events conducted on SALLY are:

Operation/Event Name	Date (GCT)	Type & Height (ft) of Burst	Yield
SANDSTONE / YOKE	4/30/48	Tower 200	49 KT
REDWING/ YUMA	5/27/56	Tower 200	-
KICKAPOO	6/13/56	Tower 300	-

SALLY was used for various types of instrumentation during other nuclear operations. It was also one of the sites used for the Pacific Cratering Experiments (PACE) Program in 1972 as evidenced by the defoliated areas and small craters present. This excavation undoubtedly altered the radiological conditions on SALLY; however, these activities were concluded prior to the radiological survey reported in NVO-140. As a result of the PACE, the topographic drawings used here do not show the appropriate roads, etc. for a large section of the island, nor do the drawings show the area filled between RUBY and SALLY west of the causeway. From the 1972 aerial photo in NVO-140, this area was apparently filled to a height greater than high water line and now has an established beach. Soil movement was approximately as outlined in Figure 50.

The soil survey conducted in 1972 did not include sampling the areas excavated for the PACE. These excavations included one and perhaps two ground zeros and their associated radioactive burial sites (standard assumption burial). An exception is the 2 or 3 samples collected from the beach of the filled area between RUBY and SALLY. The soil results below should therefore be regarded not as a definitive statement of the radiological conditions of the island, but as an indication of the activity levels which may be encountered. The radionuclide concentrations obtained from the samples collected from the undisturbed (by PACE) areas on SALLY and SALLY'S CHILD were:

Radionuclide	Activity (pCi/g)	
	Mean	Range
^{90}Sr	8.4	0.87 - 140
^{137}Cs	3.0	0.03 - 30
^{239}Pu	4.3	0.21 - 130
^{60}Co	0.54	0.05 - 69

The highest Pu concentration on SALLY proper was 52 pCi/g near a suspected burial area. The 130 pCi/g sample was collected from the islet originally part of RUBY. Levels as high as 78 pCi/g of ^{239}Pu were measured on SALLY'S CHILD.

Correspondingly, the maximum background gamma rate (uR/h) at 1 meter was 10 for SALLY and SALLY'S CHILD, while 110 was measured on the RUBY islet.

All the maximum activities in the above table were obtained from a single and only location sampled on the northern tip of SALLY, the RUBY islet. This area should receive special attention during cleanup surveys to assure representative assessment.

Profile samples collected at Locations 34 and 35 on Figure 51, near GREENHOUSE Stations 12 and 132a&b, respectively, indicate increasing activities to a depth of 60 - 150 cm below the surface, while the distribution at Location 200, a less disturbed area 75 m south of 35, is essentially homogenous to a depth of 40 cm. These unusual distributions may have resulted from mechanical mixing of the soil due to construction activities during nuclear testing or the PACE program. Most likely, the former for Location 34 and the latter for 35. The maximum ^{239}Pu encountered was 40 pCi/g at 123 cm depth at Location 35. Location 35 is 20-30 meters south of the YOKE GZ and the activity there may be associated with YOKE post shot operations. Typically, paving material around the SANDSTONE GZ's was pushed into the crater and covered. Presence of this paving would indicate association with the YOKE shot.

The depth distributions measured at the remaining sites (Figures 52-56) throughout SALLY and SALLY'S CHILD show the more conventional rapid decrease in activity with depth through the first 10 - 20 cm and leveling off in the rate of decrease below 20 cm. A thin surface layer exceeded 40 pCi/g ^{239}Pu at Location 36 and at Location 46 (SALLY'S CHILD).

SALLY contains known plutonium burial sites as indicated on Figures 57-59. SALLY also contains many possible burial areas, some of which may have been disturbed by the PACE Program. As a result, cleanup surveys should include a careful assessment of the filled area between SALLY and RUBY and the western beach of SALLY. In the period between the dates of the enclosed topographic drawings and the aerial photos of NVO-140, the western beach has moved inland about 15 meters which places YUMA SGZ near the intersection of the beach and the vegetated island.

The most obvious burial is the alpha disposal site located between the manmade and natural causeways which connect SALLY to Site TILDA, the island adjacent to the south. The site is marked near its center with a concrete monument which states: "Contains plutonium contaminated material and sand which is covered with two feet of earth fill." Each corner of the site is marked by a 6-inch square concrete post. Each post is marked with its coordinates which are also shown on the center monument. The quantity or activity of radioactive material contained in the burial is not known.

Two other marked sources are known to occur at the KICKAPOO and YUMA SGZ's. These sources are not likely burials or crypts by literal translation, but are more likely plutonium contaminated concrete blocks which have been covered with 3 inches of uncontaminated concrete. Plaques are affixed to these sources which state: "This three inch thick slab covers plutonium contaminated concrete debris." Conversely it has been said that the "crypts" at KICKAPOO have broken open and contaminated debris is exposed. Six such structures have been identified - 4 at the YUMA SGZ and 2 at the KICKAPOO SGZ. From discussions held with test-era participants concerning the KICKAPOO area, it is apparent that other debris in the area is also contaminated with plutonium.

NVO-140 reports a large suspected burial site which includes the YUMA SGZ and extends north along the island's edge for over 100 meters. If this burial is found, it may be expected to contain plutonium. If soil sampling Location 200 is indicative of the burial, the levels are low. Exploration for definition of this suspected burial should continue from Location 200 to the YUMA SGZ.

Operational activities during the nuclear test period may have created other burials, and the PACE fill previously mentioned may be a sort of burial as well. Roll-up of the SANDSTONE Operations included obliterating the visible effects of bomb damage to an extent which would prohibit disclosure of classified test information. This included some bulldozing and blasting but no intentional burial. In preparation for Operation GREENHOUSE, decontamination of the SANDSTONE YOKE crater area was accomplished. The area around the crater was scraped, the material deposited in the crater, and thereafter covered with uncontaminated material. Other decontamination included removal of the steel stumps and foundation of the YOKE tower and gathering and dumping all debris remaining on the island. Metal fragments found within 1000 feet of the old zero point were found to be highly contaminated so were removed by picking up pieces individually and ultimately dumping them at sea. The standard assumption of burial around a SGZ can be applied to all three on the island. There were also a number of coaxial cable runs on SALLY which could have resulted in the burial of surface contamination. The locations of these and some of their dimensions are included on Figures 47-49. PACE excavations may have erased evidence of the cable runs shown; however, similar runs were made for the KICKAPOO event.

Preceding the MOHAWK event on adjoining RUBY, cables anchoring the remnants of the towers for shots KICKAPOO and YUMA were cut and the towers were blown down by the blast from MOHAWK. The final disposition of the tower material is not known. It may be found near the GZ's and if so, may be contaminated with plutonium. Logically, the YUMA tower debris would be along the beach southeast of GZ and the KICKAPOO tower debris would be strewn on the reef east of that GZ.

CASE 3: BIRDS, EGG, SUBSISTENCE & COMMERCIAL AGRICULTURE (Pu)

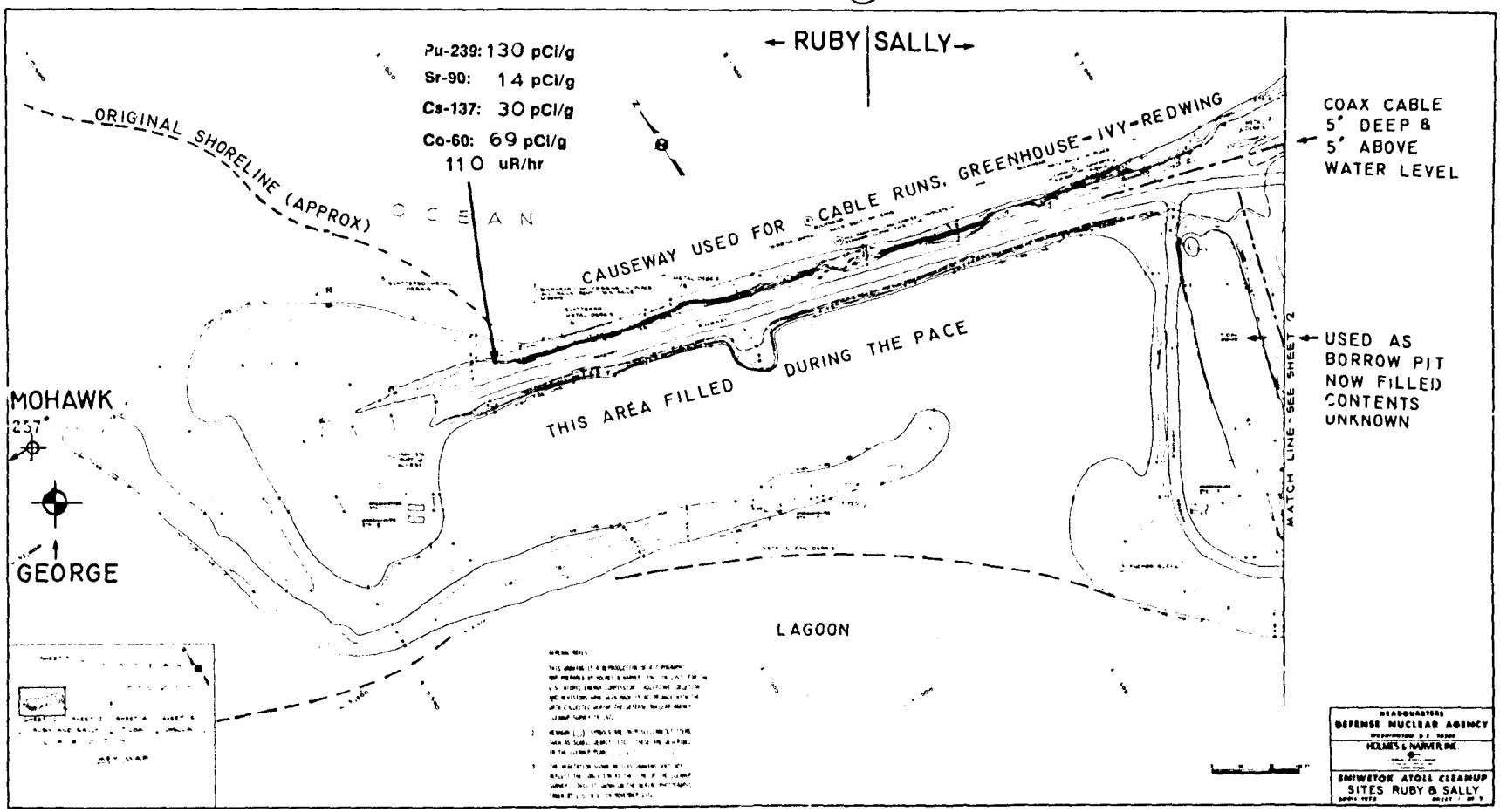


FIGURE 47. SITES RUBY AND SALLY, SHEET 1 OF 5

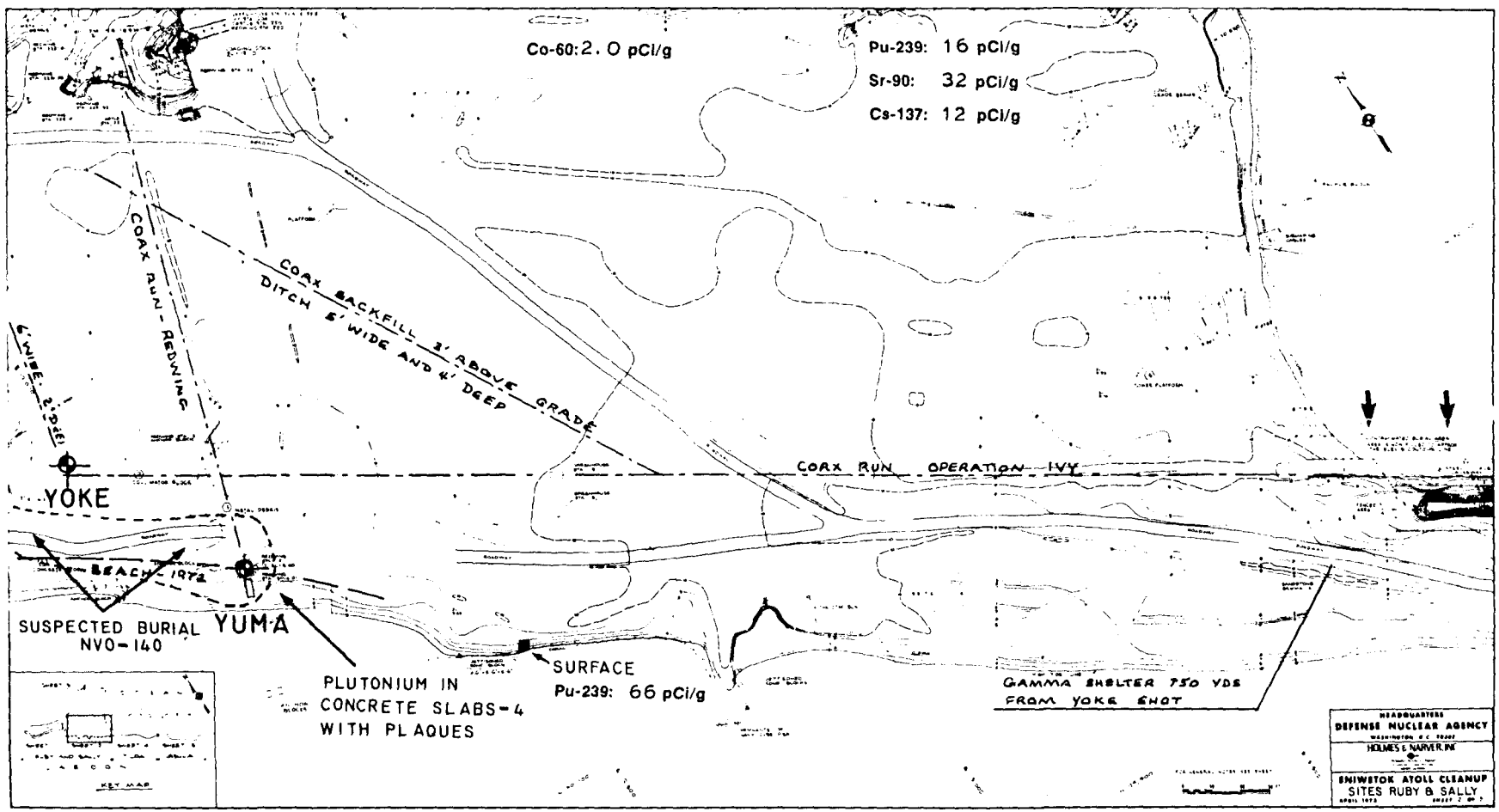


FIGURE 48. SITES RUBY AND SALLY, SHEET 2 OF 5

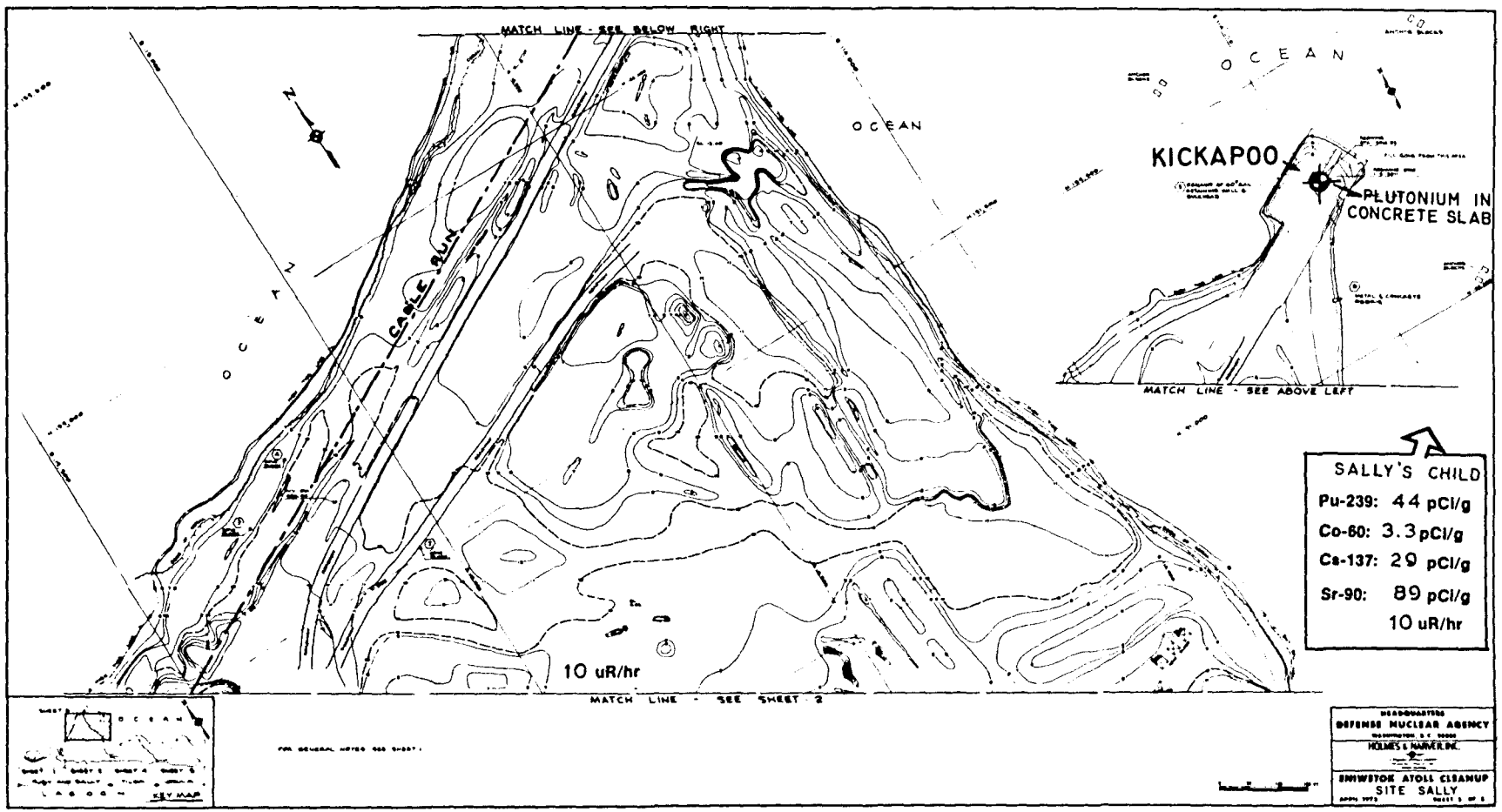


FIGURE 49. SITE SALLY, SHEET 3 OF 5

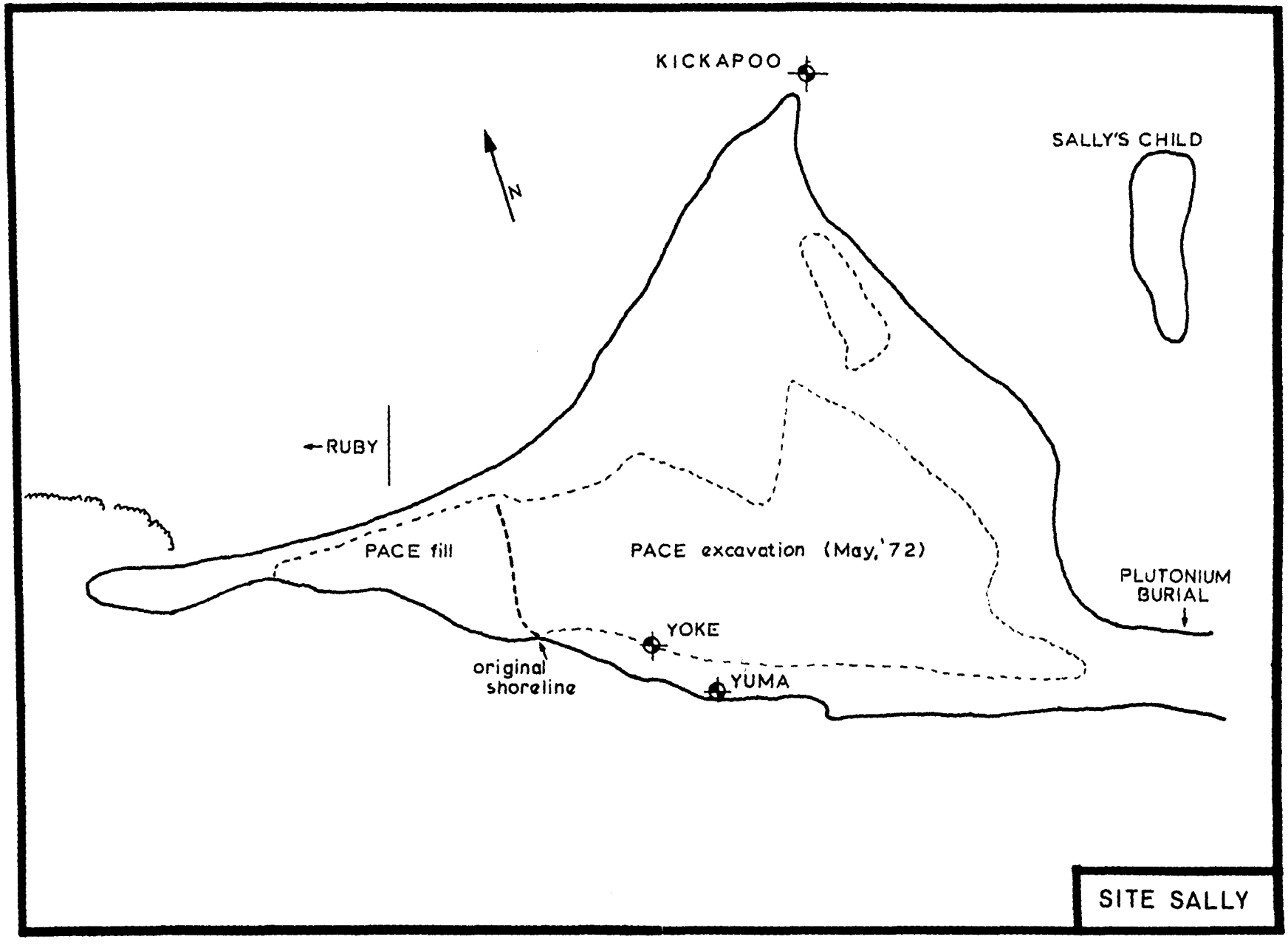


FIGURE 50. SITE SALLY, PRINCIPAL FEATURES

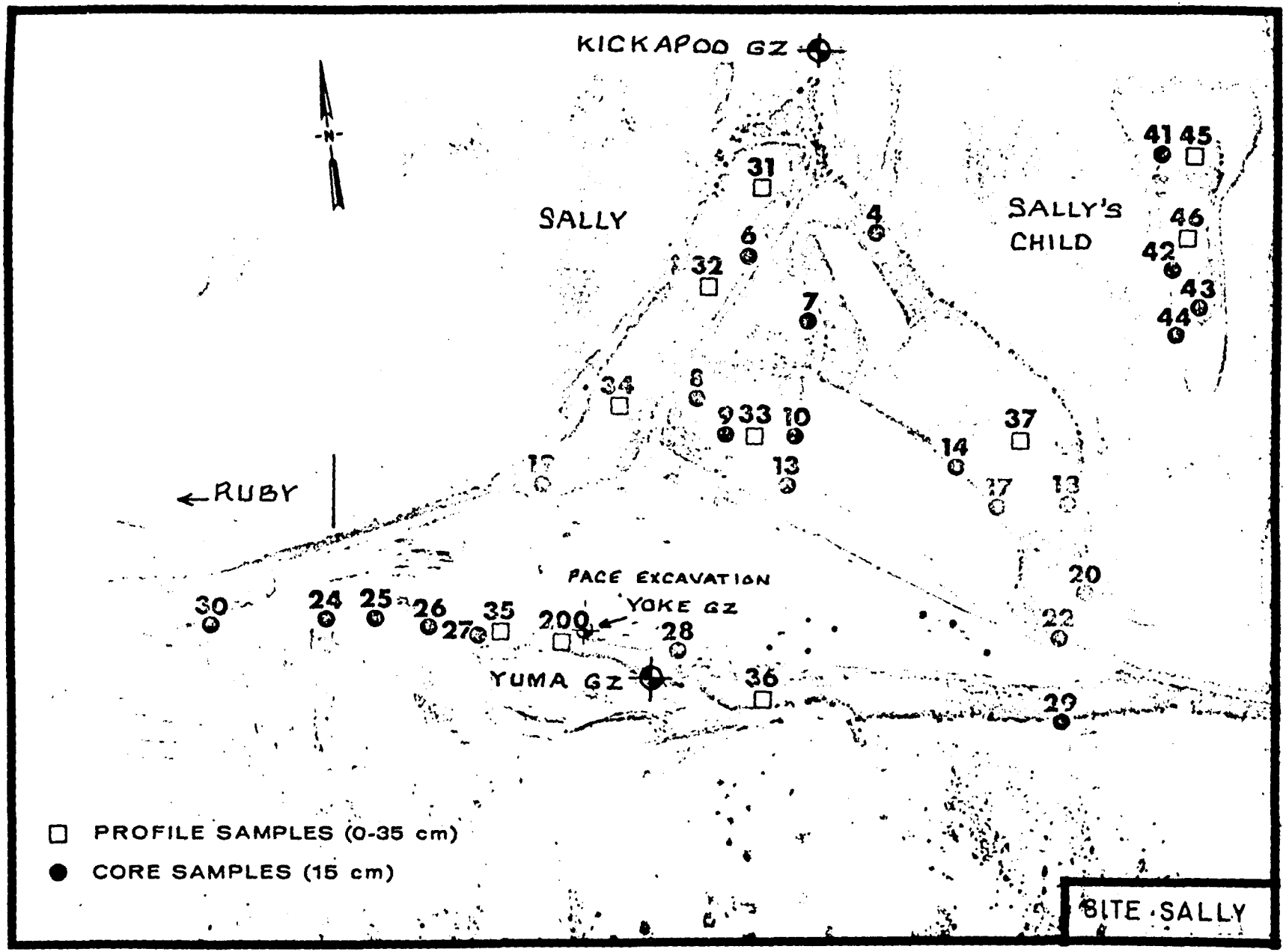


FIGURE 51. SOIL SAMPLE LOCATIONS

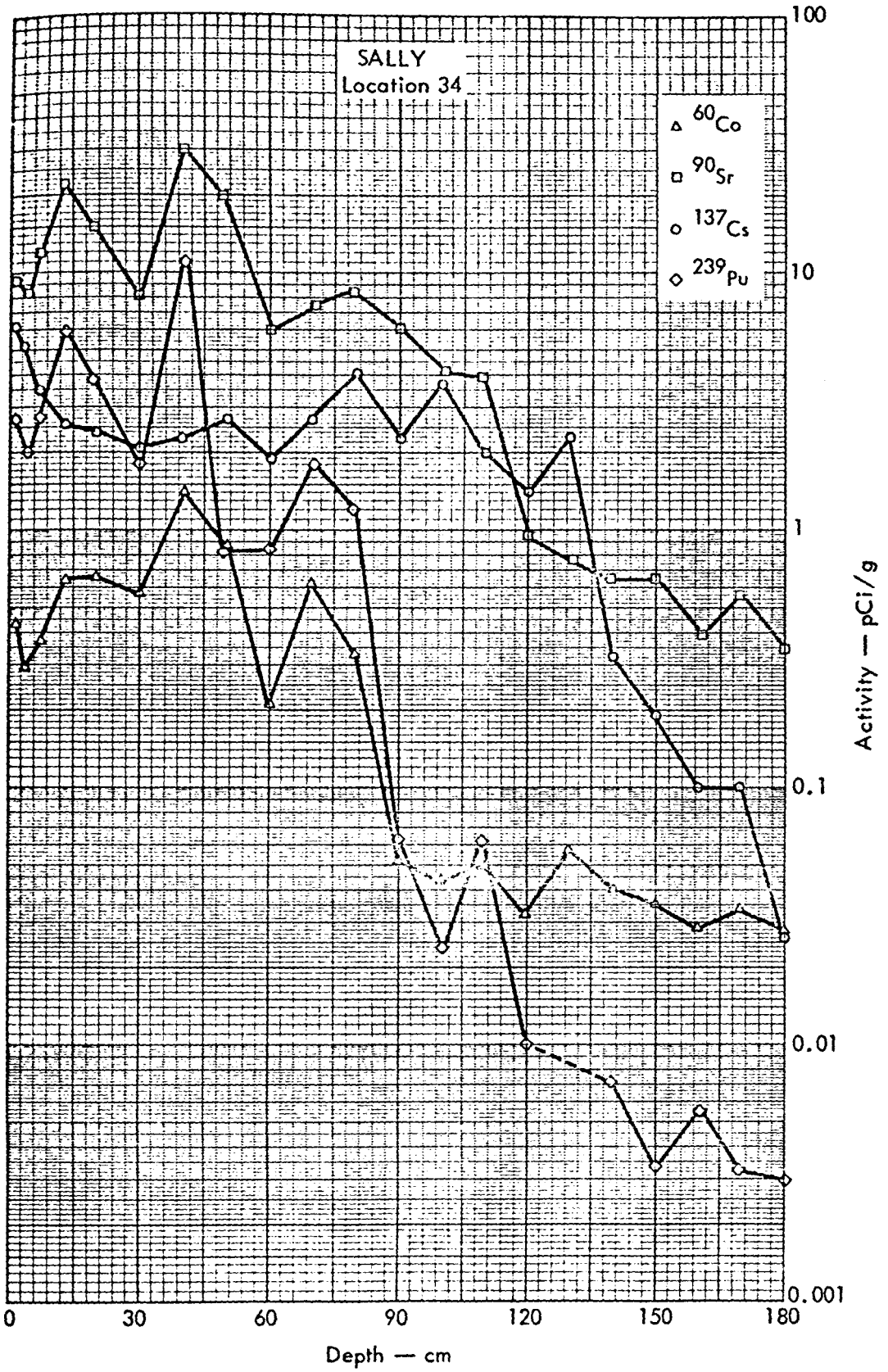


FIGURE 52. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

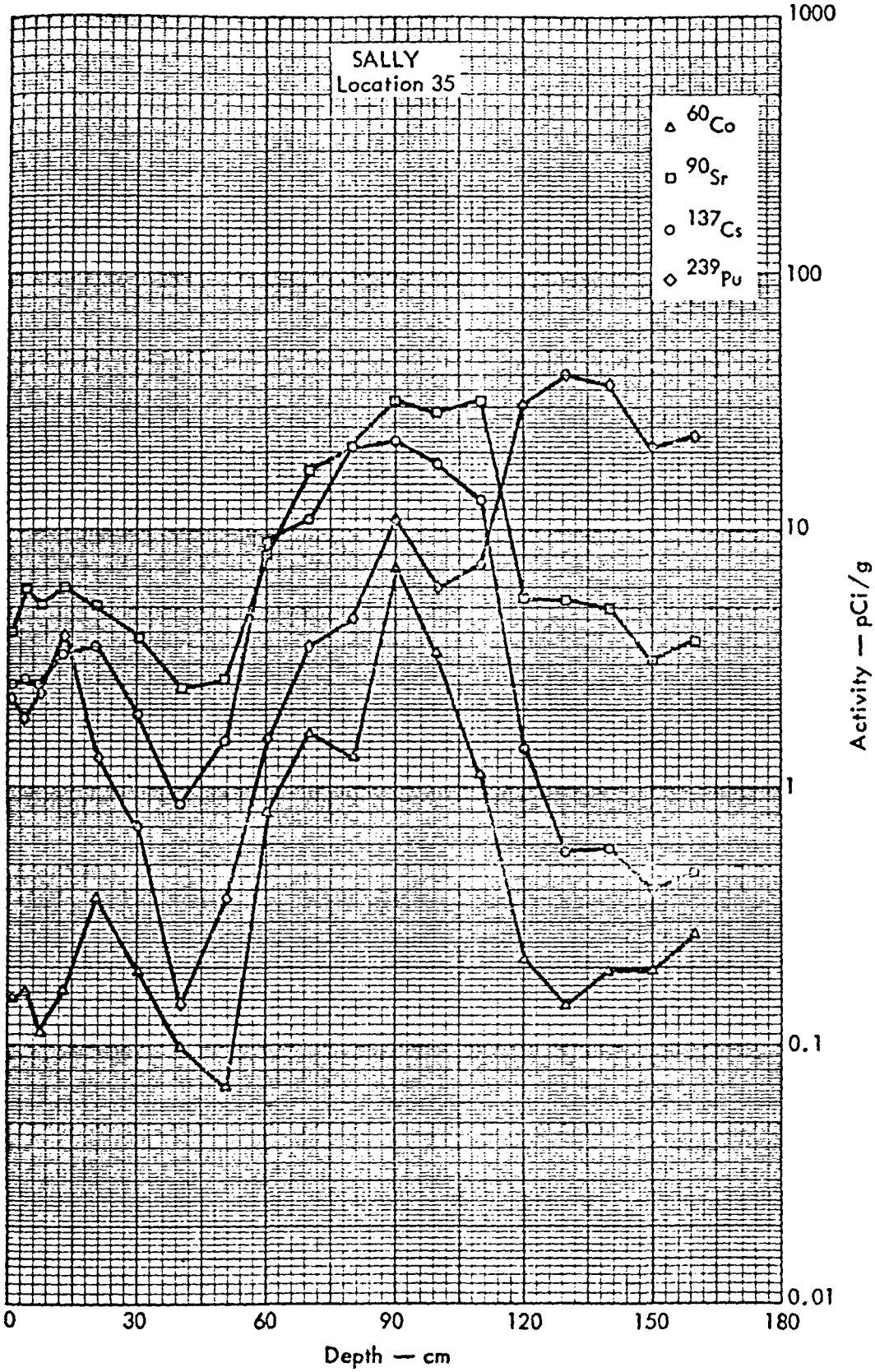


FIGURE 53. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

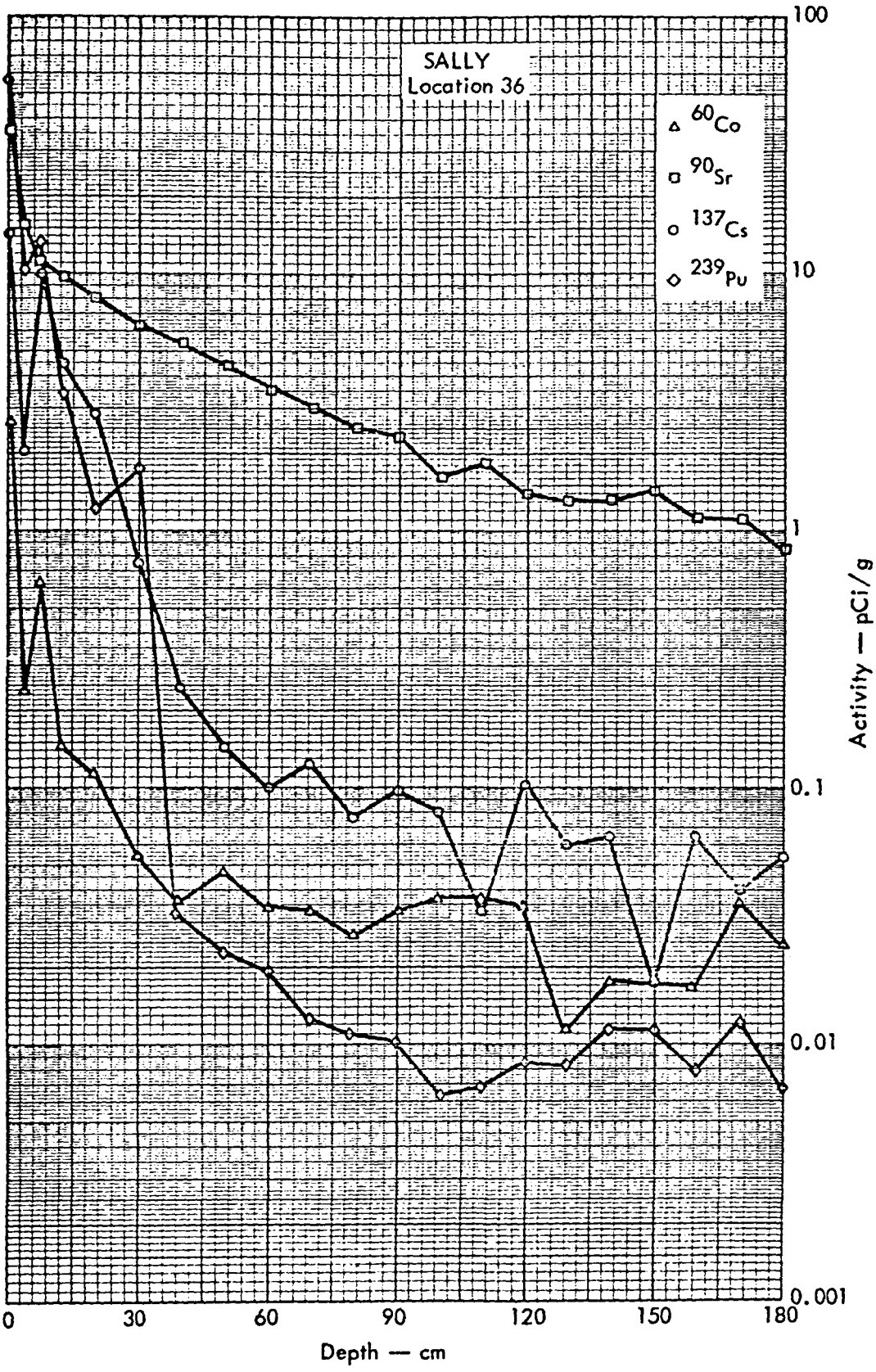


FIGURE 54. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

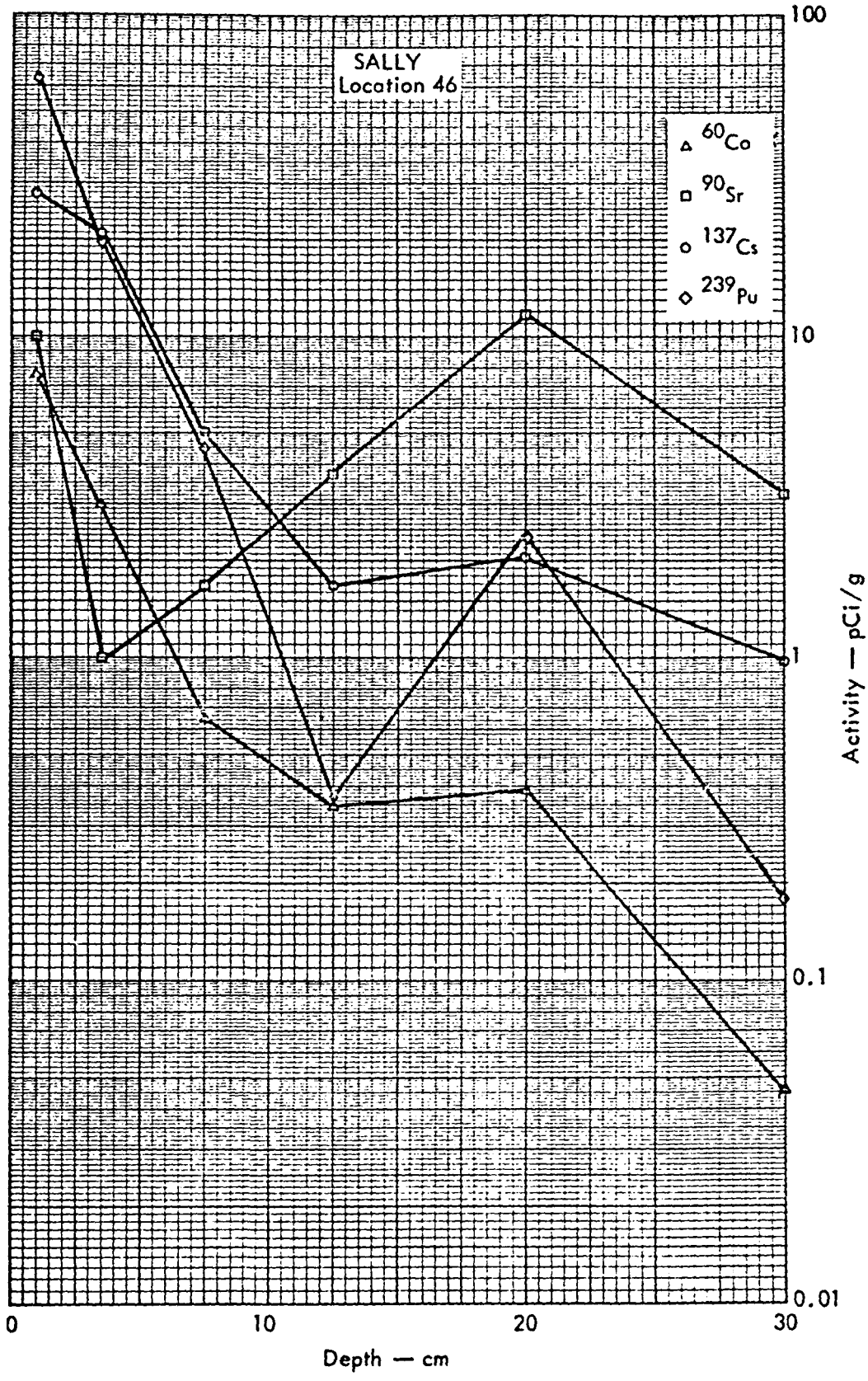


FIGURE 55. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

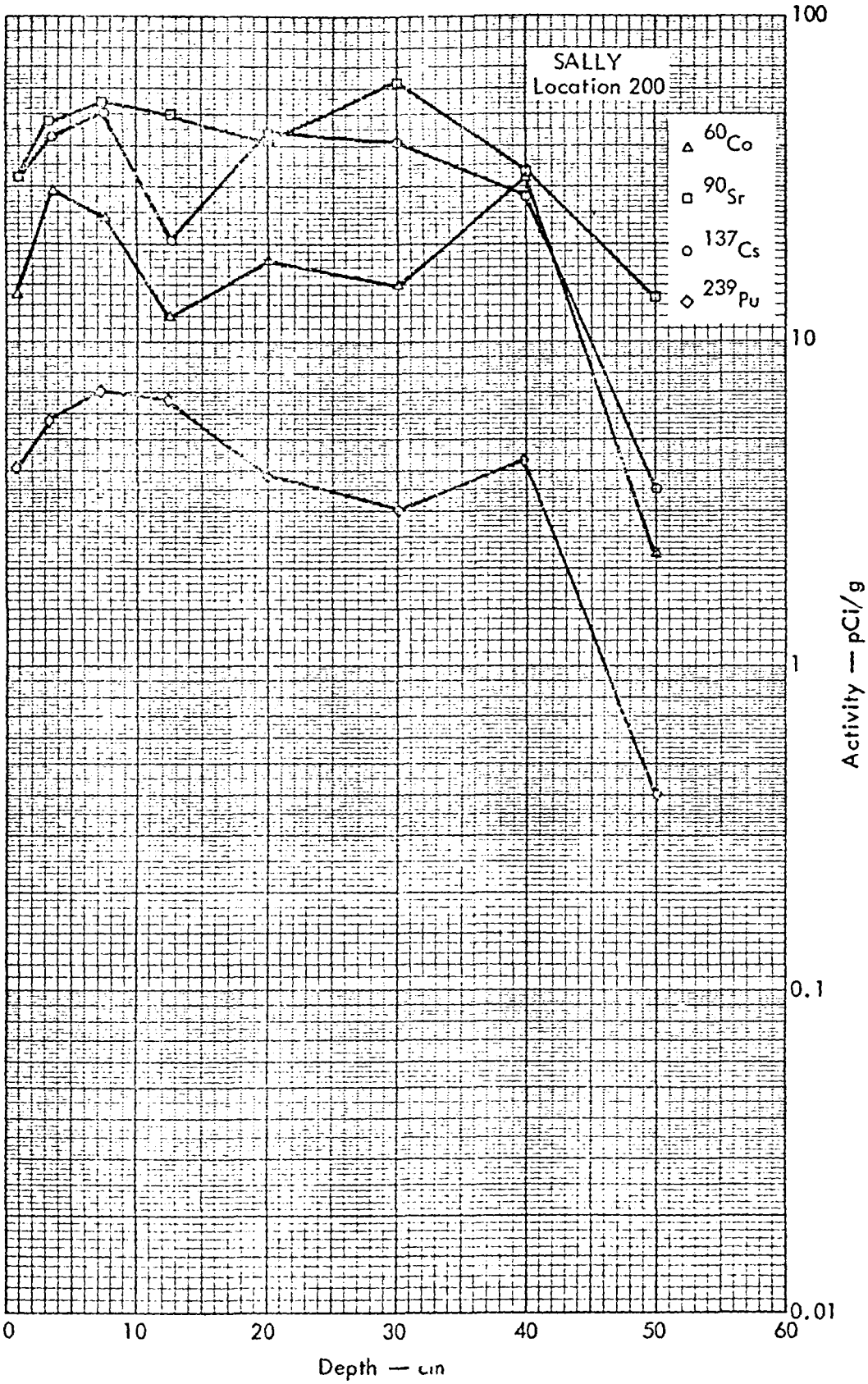


FIGURE 56. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

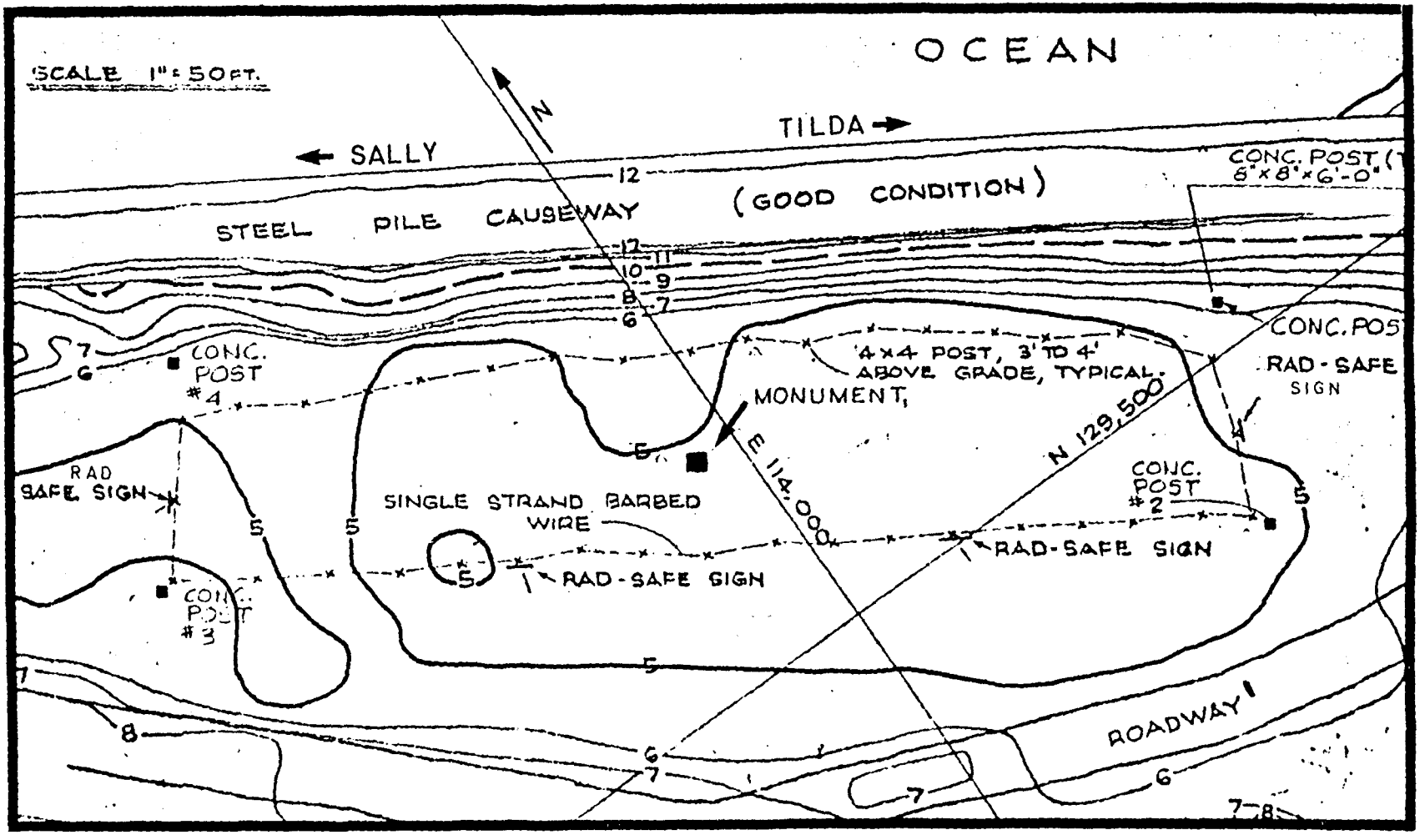


FIGURE 57. SITE SALLY ALPHA DISPOSAL SITE

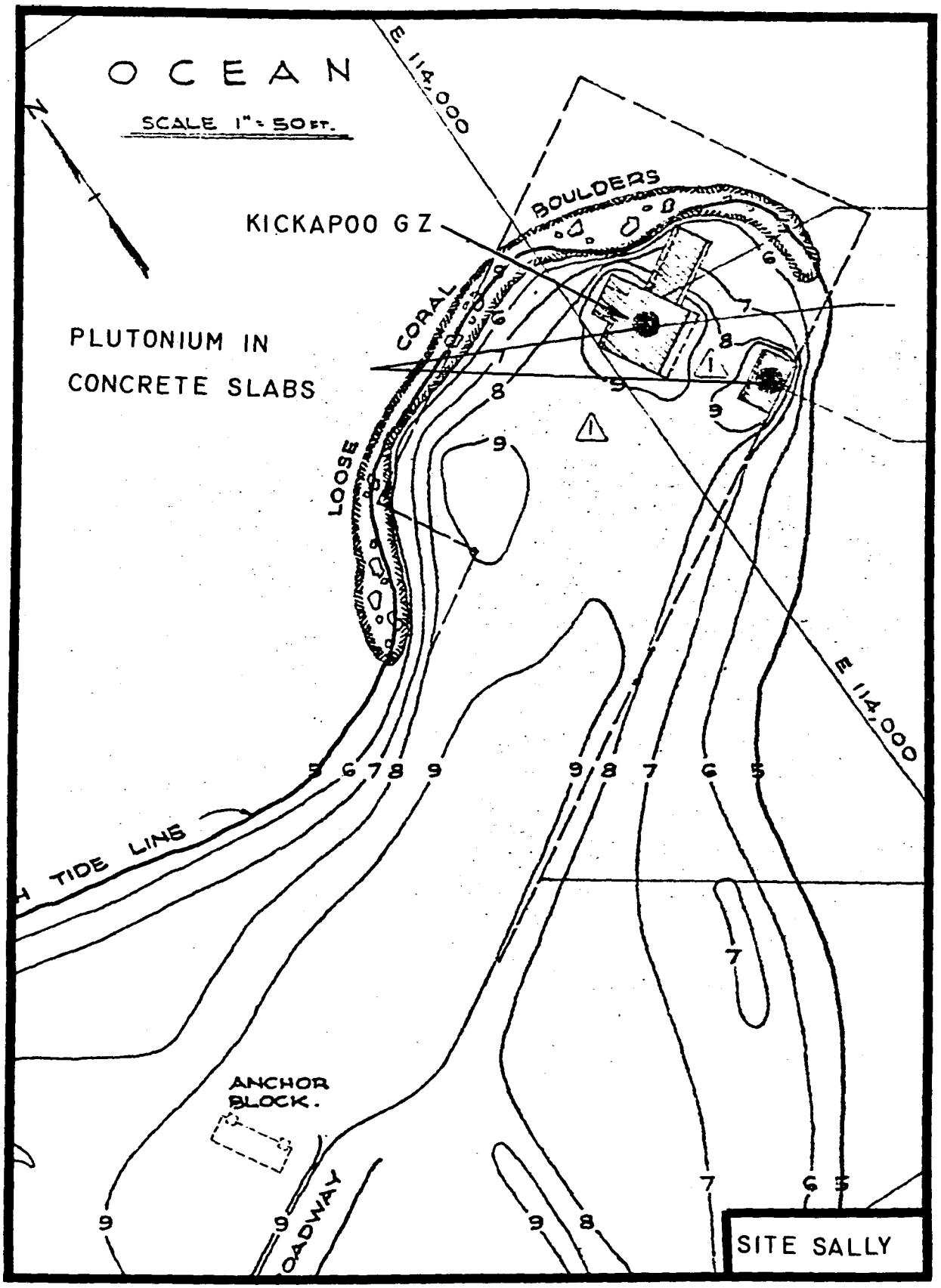


FIGURE 58. SITE SALLY, VICINITY OF KICKAPOO GZ

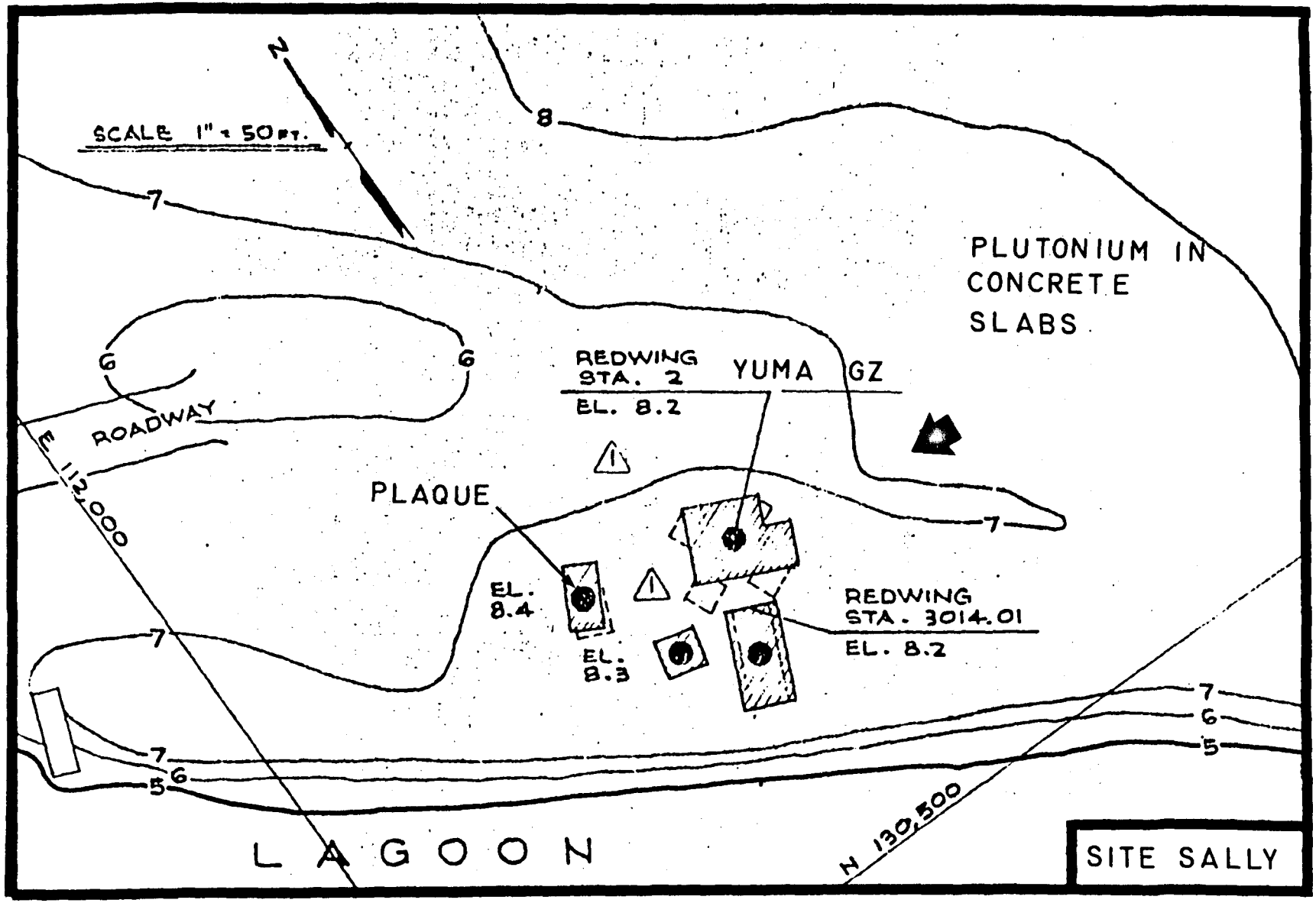


FIGURE 59. SITE SALLY, VICINITY OF YUMA GZ

Site Name: TILDA
Board of Geo.: BIIJIRI
Marshallese: BIJIRE

TILDA is located in the northern portion of Enewetak Atoll and has an area of about 52 acres (21 hectares). TILDA is vegetated from moderately to densely.

TILDA is the location of numerous structures remaining from nuclear test operations. TILDA was widely used as it connects by causeways to SALLY and RUBY, both of which were sites of nuclear tests, and to URSULA, which was a forward area campsite. TILDA has no surface zeroes and ranks 18th of the islands in the Atoll with 774 R/h accumulated H+1 hour exposure rate.

The radioactivity that is distributed throughout the island resulted primarily from devices detonated on SALLY, the adjacent island to the north. The activity is fairly homogeneously distributed throughout the island; however, a direct correlation may be made with the density of vegetation present. The island is divided by an airstrip. The area north of the airstrip (Figure 60) and on the lagoon (west) side of the north-south road is much less densely vegetated than the remainder of the island. The following activities for soil reflect this difference in vegetation:

Radionuclide	Activity (pCi/g)	
	Mean	Range
Areas of dense vegetation		
^{90}Sr	27	17 - 54
^{137}Cs	8.4	3.5 - 20
^{239}Pu	7.6	1.4 - 17
^{60}Co	1.2	0.61 - 1.9
Areas of sparse vegetation		
^{90}Sr	8.7	2.2 - 47
^{137}Cs	1.0	0.04 - 5.3
^{239}Pu	2.5	1.1 - 34
^{60}Co	0.37	0.21 - 1.7

The mean values vary by factors of nearly three or more between these two areas. This variation was also observed in the aerial survey measurements. The depth distributions of activity vary considerably throughout the island. In no case, surface or profile sampling, was the ^{239}Pu concentration greater than 40 pCi/g.

No radioactive material burial sites are known to exist on TILDA. An alpha disposal site exists between the manmade and natural causeways which connect TILDA to SALLY. That site is described in the previous report for Site SALLY. Considerable construction activity has occurred on TILDA which may have caused burial, mechanical or natural, or low level contamination, e.g., coaxial cable burials and the erosion of soil into old borrow pits.

CASE 3: BIRDS, EGGS, SUBSISTENCE & COMMERCIAL AGRICULTURE

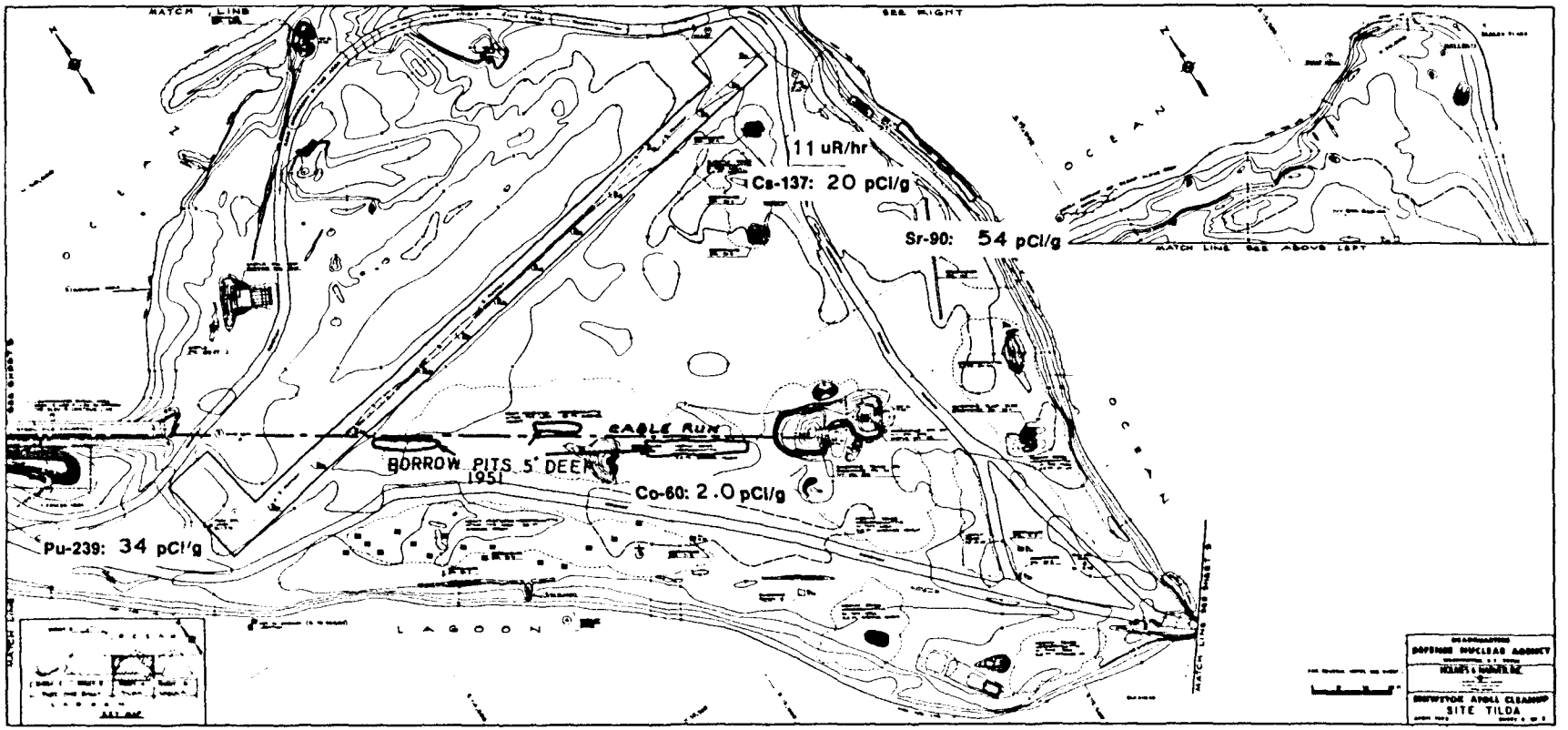


FIGURE 60. SITE TILDA

Site Name: URSULA
Board of Geo.: ROJOA
Marshallese: LOJWA

URSULA is located in the northeast quadrant of Enewetak Atoll and has an area of about 40.5 acres (16.4 hectares). Vegetation on the island ranges from moderate to dense.

URSULA was used as the shot camp site for the AOMON-BIJIRE-LOJWA (SALLY-TILDA-URSULA) complex and much evidence of testing activities remains (Figure 61). By D+150 days of the cleanup (approx. November 15, 1977), the island will house the forward base camp for supporting cleanup teams B and C. URSULA has no surface zeroes, but received fallout from 12 events which rank it 19th in total H+1 hour exposure rate received with 651 R/h.

The activities of radionuclides measured in soil (NVO-140) were quite low compared to those measured on the more northern islands. The mean and range of activities measured in surface samples collected over the entire island are:

Radionuclide	Activity (pCi/g)	
	Mean	Range
^{90}Sr	6.8	2.0 - 19
^{137}Cs	1.7	0.13 - 7.8
^{239}Pu	1.3	0.26 - 7.3
^{60}Co	0.31	0.05 - 1.7

Although cleanup shall consist only of removing physical hazards, URSULA has received significant contamination as a result of testing. The LACROSSE EVENT on YVONNE contaminated the SALLY-URSULA complex to the extent that roads were scraped to reduce exposure of personnel in transit to work sites. The H+4 hour exposure rate on URSULA was 8 R/hr. No record of where the scraped material was disposed of is available. The MOHAWK EVENT on RUBY produced contamination which delayed recovery operations on the SALLY-URSULA complex for several days.

No radioactive material burial sites are known to exist on URSULA. Decontamination procedures may have created accumulations of soil which would now show relatively low levels of radioactivity.

Some decontamination facilities will be operated on URSULA in support of cleanup operations.

CASE 3: BIRDS, EGGS, SUBSISTENCE & COMMERCIAL AGRICULTURE

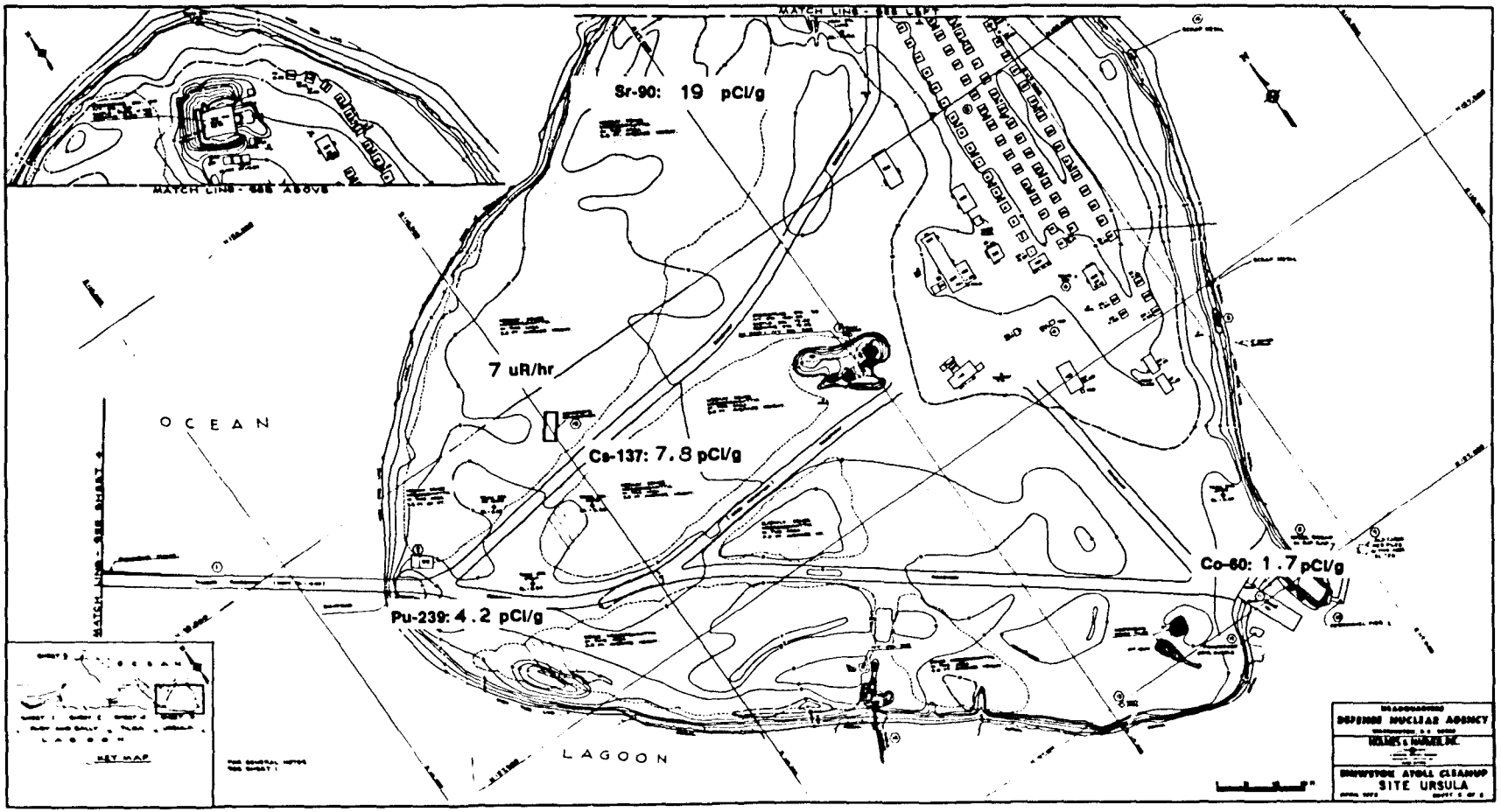


FIGURE 61. SITE URSULA

July 28, 1977

Site Name: VERA
Board of Geo.: ARAMBIRU
Marshallese: ALEMBEL

VERA is located in the northeast portion of Enewetak Atoll and has an area of about 38 acres (15 hectares). The island, densely vegetated, is outlined in Figures 62 and 63.

A small amount of debris remains from testing. A scientific station which housed animals for medical research during OPERATION GREENHOUSE remains and is in poor condition. VERA has no surface zeroes and ranks 22nd of all islands in the Atoll with 270 R/h accumulated H+1 hour exposure rate.

The radiological contamination of this island from nuclear weapons tests is relatively minor (NVO-140). The activities measured in soil are relatively low as follows:

Radionuclide	Activity (pCi/g)	
	Mean	Range
^{90}Sr	6.3	1.1 - 68
^{137}Cs	2.0	0.03 - 12
^{239}Pu	2.5	0.60 - 25
^{60}Co	0.30	0.02 - 2.2

The highest ^{239}Pu values found were 35 pCi/g in thin layers from profile sampling. The depth distributions of activity in soil show relaxation lengths of 2-5 cm near the northwest beach to 10-15 cm in the island's interior.

No radioactive material burial sites are known to exist on VERA.

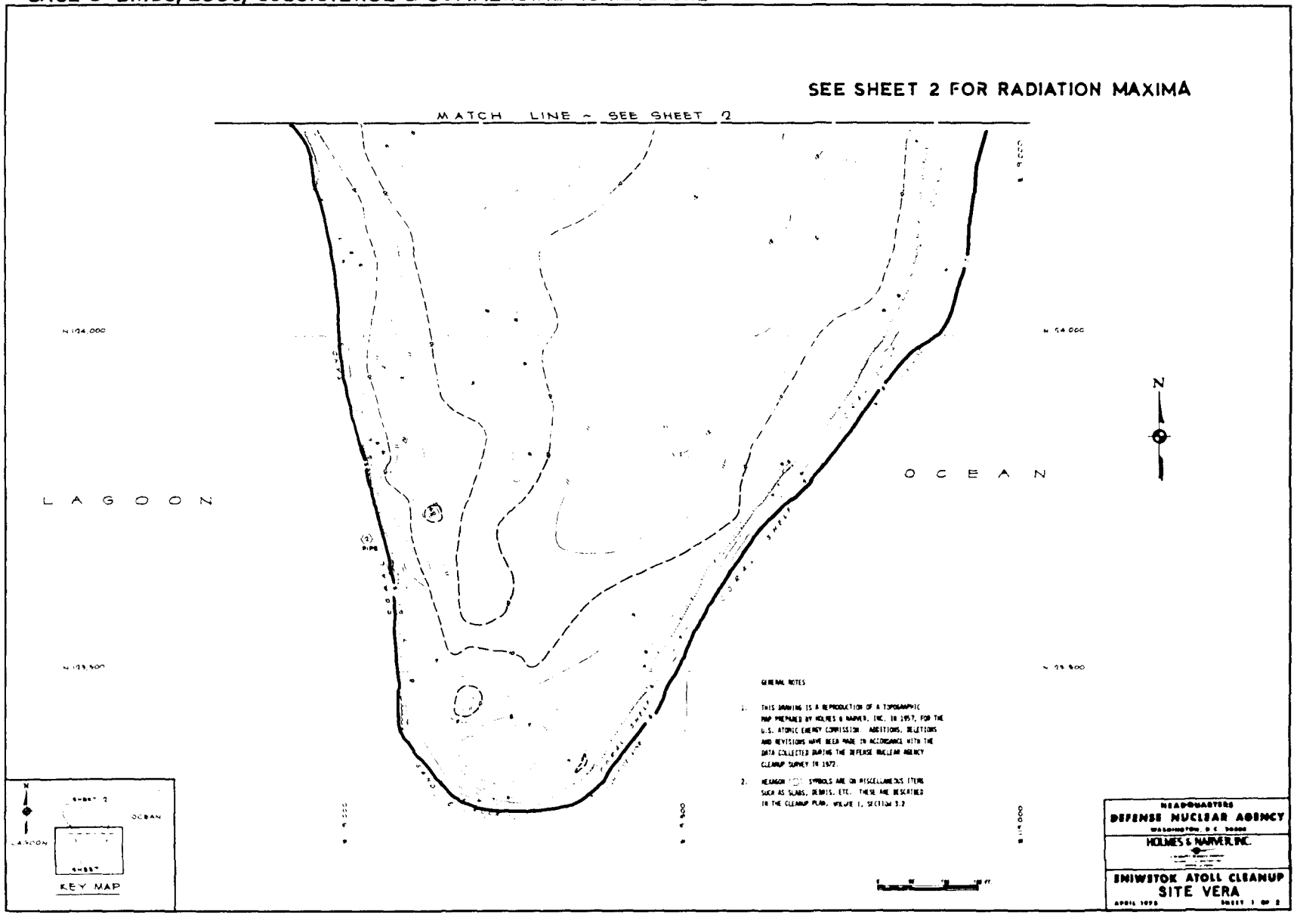


FIGURE 62. SITE VERA, SHEET 1 OF 2

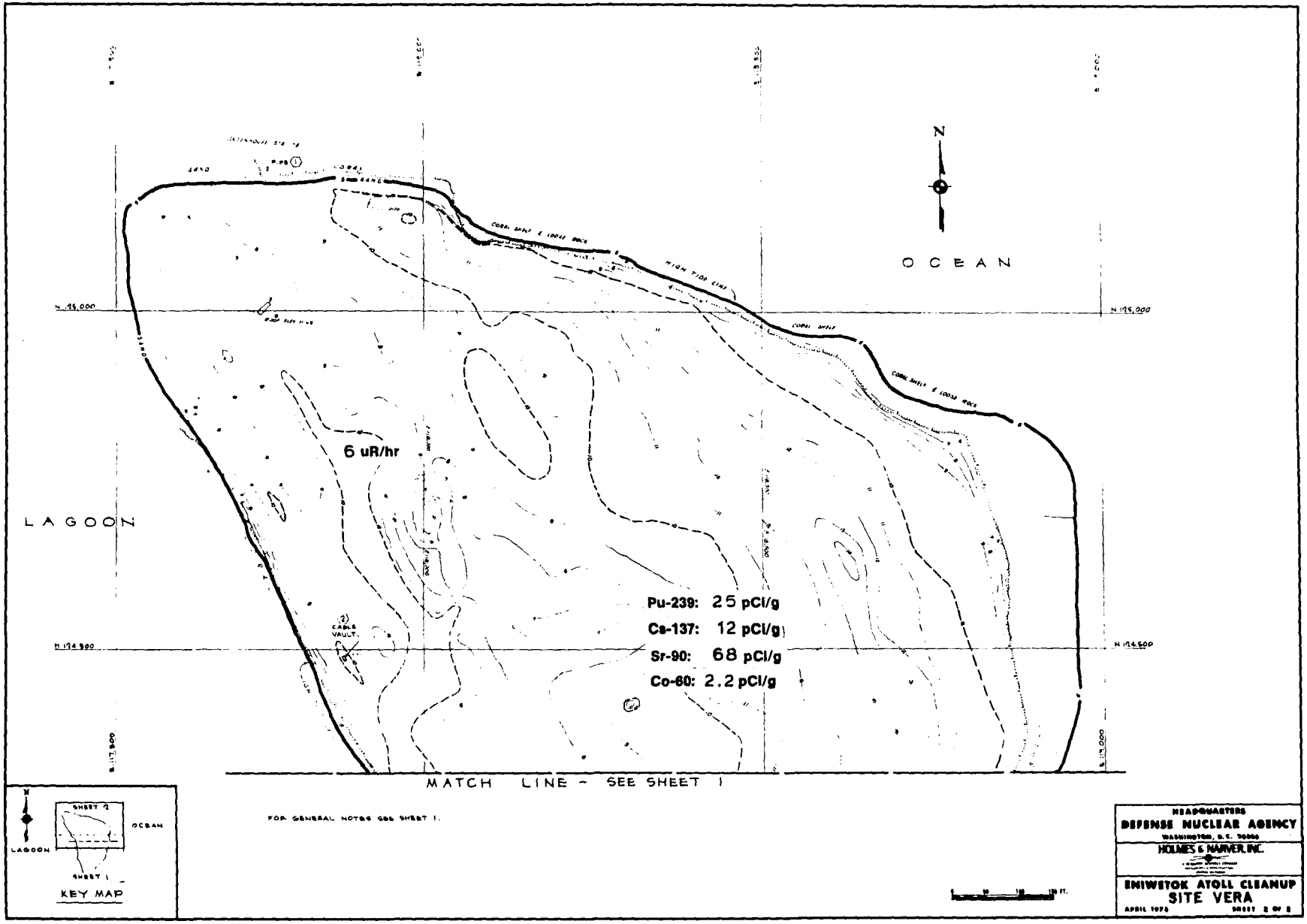


FIGURE 63. SITE VERA, SHEET 2 OF 2

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July 28, 1977

Site Name: WILMA
Board of Geo.: PIIRAI
Marshallese: BILLAE

WILMA is located in the northeast portion of Enewetak Atoll and has an area of about 16 acres (6.4 hectares). The island is densely vegetated.

Eight scientific stations with a moderate amount of debris remain on WILMA (Figure 64). WILMA has no surface zeroes and ranks 21st among islands of the Atoll with 294 R/h accumulated H+1 hour exposure rate.

The radiological contamination of the island is similar to neighboring VERA. The following data were obtained from surface soil samples collected.

Radionuclide	Activity (pCi/g)	
	Mean	Range
^{90}Sr	3.3	0.26 - 13
^{137}Cs	1.3	0.31 - 7.2
^{239}Pu	1.1	0.1 - 5.3
^{60}Co	0.12	0.01 - 0.7

The profile samples collected at several sites throughout the island display similar depth distributions with relaxation lengths of 10 - 15 cm. No ^{239}Pu concentrations exceeded 8 pCi/g.

No radioactive material burial sites are known to exist on WILMA.

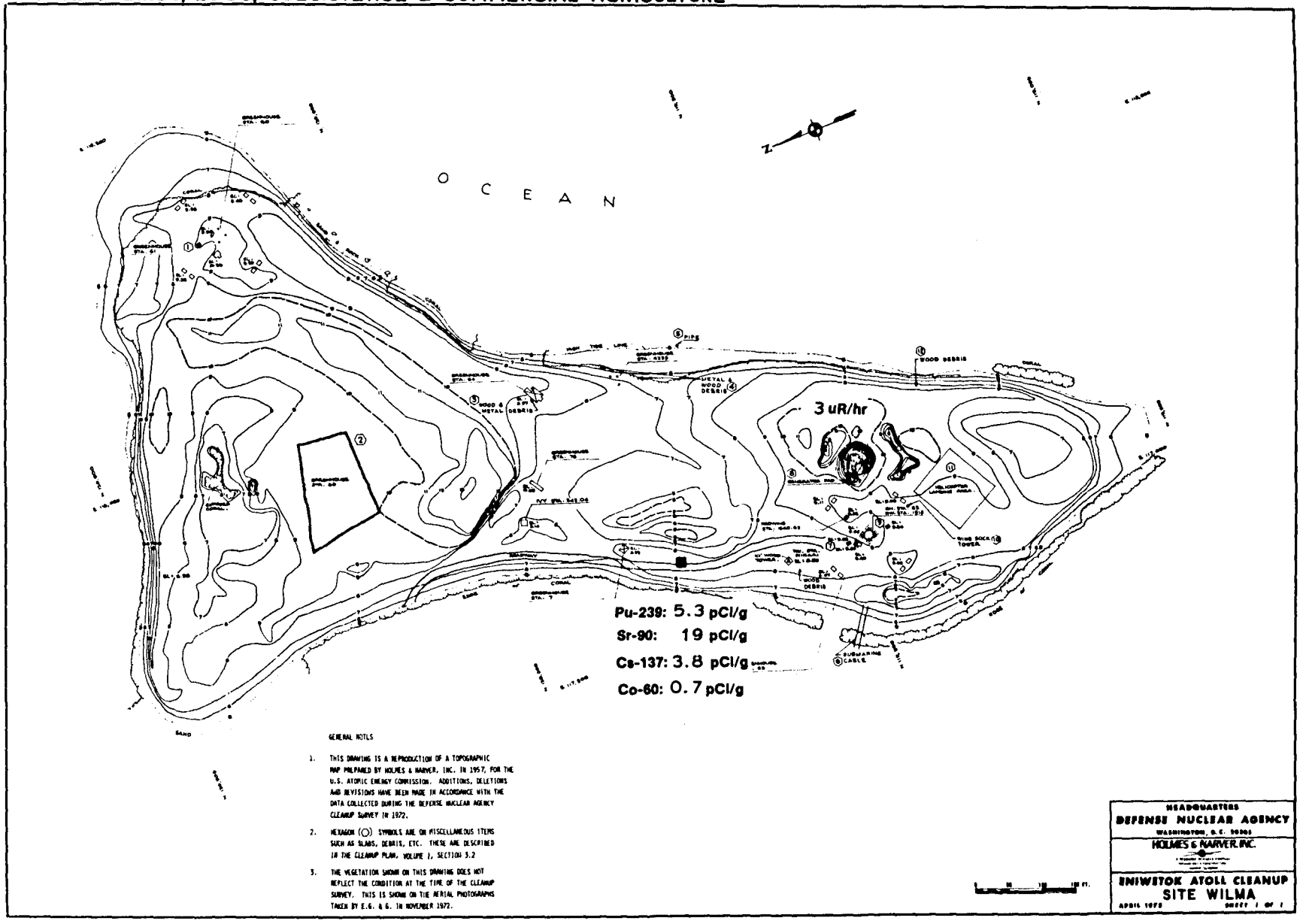

FIGURE 64. SITE WILMA

Site Name: YVONNE, SOUTH
Board of Geo.: RUNIT
Marshallese: RUNIT

Site YVONNE is reported in two sections. Information in this section applies to the portion of the island south of the cleanup hotline to be established at Station 1310, REDWING and HARDTACK. This portion will be called SOUTHERN YVONNE.

YVONNE has an area of 91 acres (37 hectares). Less than half of the island is south of Station 1310.

SOUTHERN YVONNE was the location of one nuclear experiment, ERIE, detonated May 30, 1956, on a 300-foot tower north of the aircraft runway. The OSAGE event of June 16, 1956, was airdropped and detonated approximately 670 feet over Station 1310 (Figure 65). Seven barge events were conducted in the lagoon near YVONNE and five surface shots were executed on NORTHERN YVONNE.

YVONNE received the most severe radiological dose of any island within the Atoll — 62,849 R/h accumulated H+1 hour exposure rate. The greatest insult occurred to the northern portion. Radioactivity measured in soil samples collected from SOUTHERN YVONNE (Figures 65-67) indicate that the geographical distribution of activity within the top 15 cm is rather uniform; however, somewhat higher values appear preferentially within the area immediately north of the runway. The geometric mean and the range of selected radionuclides measured within the top 15-cm layer are:

Radionuclide	Activity (pCi/g)	
	Mean	Range
^{90}Sr	1.7	0.09 - 20
^{137}Cs	0.40	0.02 - 3.6
^{239}Pu	3.2	0.02 - 50
^{60}Co	0.64	0.01 - 20

Plutonium is generally homogenous and low-level or decreases quite rapidly with depth with an exception in the ERIE GZ area. Soil sampling location 61 may have been situated in a highly disturbed area as explained below.

The ERIE device produced heavy contamination on YVONNE. The behavior of the device was such that much debris remained in the GZ area. Also ERIE was heavily instrumented to evaluate weapons effects on missile structures and materials. Six arrays of test specimens were arranged west of the air zero at 45 degrees from horizontal and below air zero such that the specimens would impact west of ground zero. Specimens were recovered as far as 450 feet from ground zero and generally from northwest through southwest and at depths of up to five feet. It is reported that earth was excavated up to six to eight feet deep and that 100,000 cubic yards of earth was moved in the recovery operations. Not all specimens were recovered; however, should any be found during cleanup, no significant radiological hazard would be expected. The recovery procedure involved making 6-inch cuts with a "carry-all" and spreading the earth in 2-inch layers. The earth was removed from the impact area and spread in a pattern about 300 feet long and three swaths wide (about 24 feet) northwest of GZ. The soil was piled along the ocean side of the island. The pile was later returned to the impact area and the area graded (1957). The exact boundaries of the excavation are unknown and core sampling may be necessary to fix its location. The missile impact area is noted on Figure 66.

Other than the two items below, no burials specifically for disposing of radioactive debris are known to exist on SOUTHERN YVONNE. It may be assumed that debris was buried in the immediate GZ area during post-shot operations.

A jar containing sand contaminated with high activity plutonium may be found buried at the left side of the south entrance to Station 1310.

A small (15 x 15-ft) fenced area immediately north of the approach end of the runway may be found to contain a box which contains some contaminated material. This material includes activated metal, contaminated sand in a jar, a small disk with high alpha activity and a small disk with an exposure rate of 100 mR/h. A large portion of the scrap metal and debris between Station 1310 and the runway is contaminated. The highest exposure rate (60 mR/h) reported in NVO-140 is for the pile of rubble on the reef north of the runway and the ERIE GZ.

Early cleanup operations to occur on SOUTHERN YVONNE should be initiated carefully and with the knowledge that 40 pCi/g plutonium levels exist in soil near the east end of the proposed hotline, in the ERIE GZ area, and that any debris, surface or unearthed, may present a radiological hazard.

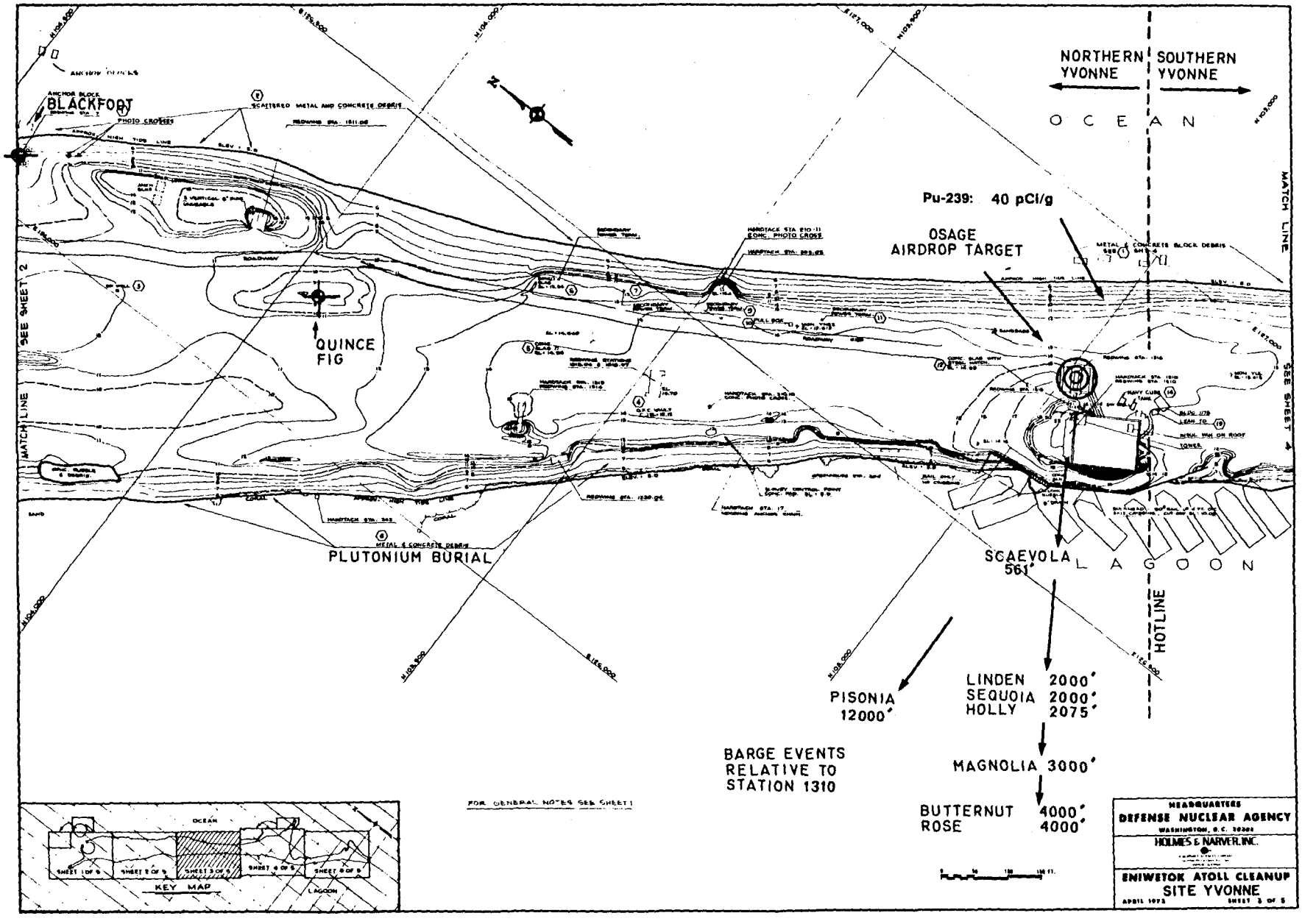

FIGURE 65. SITE YVONNE, SHEET 3 OF 5, SOUTH END

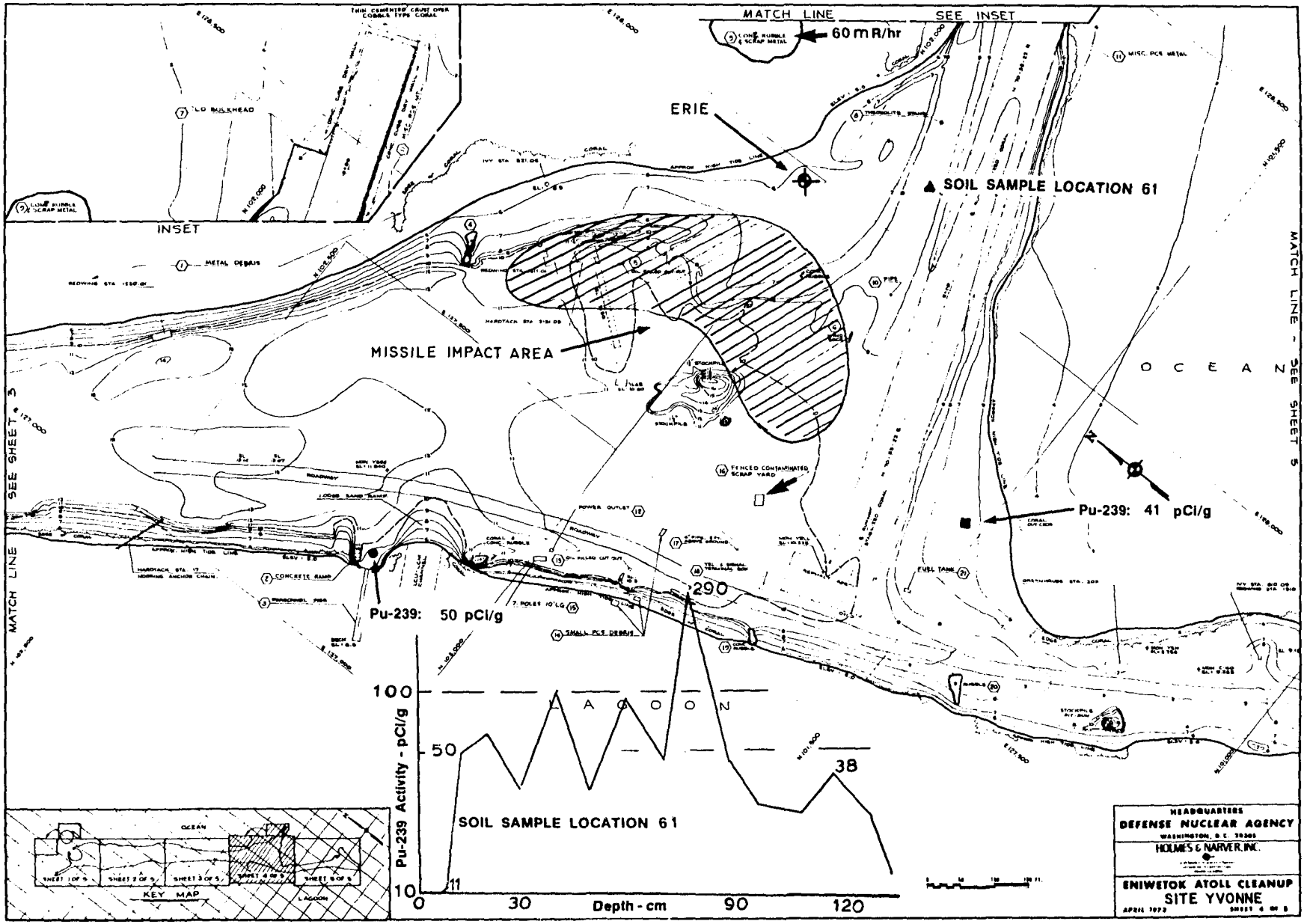

FIGURE 66. SITE YVONNE, SHEET 4 OF 5

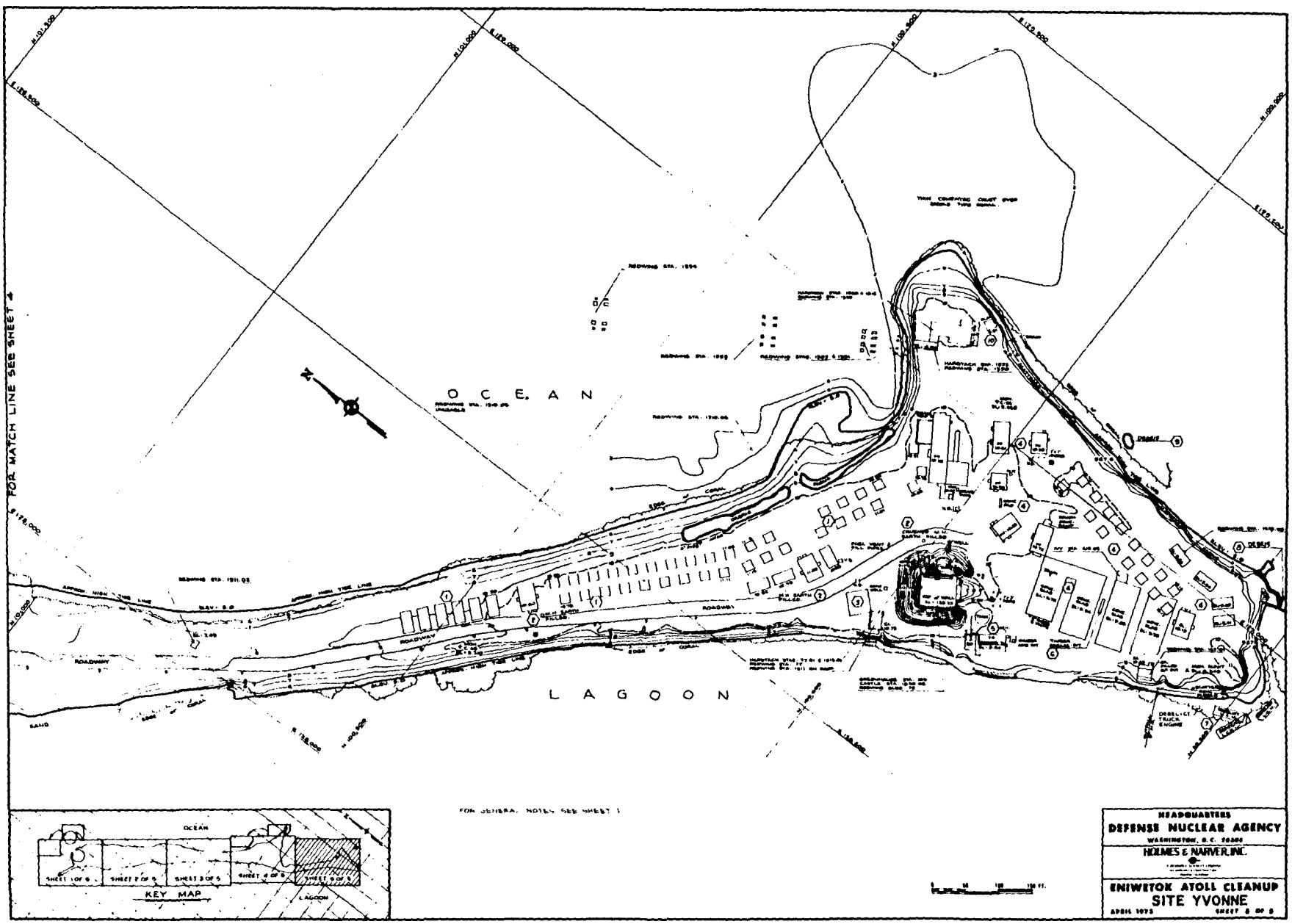

FIGURE 67. SITE YVONNE, SHEET 5 OF 5

July 18, 1977

Site Name: YVONNE, NORTH
Board of Geo.: RUNIT
Marshallese: RUNIT

Site YVONNE is reported in two sections. Information in this section applies to the portion of the island north of the cleanup hotline to be established at Station 1310, REDWING and HARDTACK. This portion will be called NORTHERN YVONNE.

YVONNE has a area of 91 acres (37 hectares). About two-thirds of the island is north of Station 1310 (Figures 68-70).

YVONNE received the most radiological dose of any island within the Atoll — 62,849 R/h accumulated H+1 hour exposure rate. This total results from 24 events. Eleven events with direct influence on YVONNE are listed below.

Operation/Event Name	Date (GCT)	Type & Height (ft) of Burst	Yield	Location
SANDSTONE/ZEBRA	5/14/48	Tower 200	18 KT	north end
GREENHOUSE/DOG	4/7/51	Tower 300	-	north end
IVY/KING	11/15/52	Airdrop 1500	500KT	reef, north of
REDWING/LACROSSE	5/4/56	Surface	40 KT	reef, north end
ERIE	5/30/56	Tower 300	-	near airstrip
BLACKFOOT	6/11/56	Tower 200	-	middle, ocean side
OSAGE	6/16/56	Airdrop 670	-	over Sta. 1310
HARDTACK, PHASE I				
CACTUS	5/5/58	Surface	18 KT	north end
SCAEVOLA	7/14/58	Barge	-	560'SW of 1310
QUINCE	8/6/58	Surface	-	middle
FIG	8/18/58	Surface	-	middle

Seven additional barge shots were conducted in the lagoon near YVONNE as shown on Figure 70.

This fallout history plus construction and decontamination activities conducted during and after the testing periods have produced a complex heterogenous radiological situation on the island.

Events ZEBRA and DOG were typical tower shots for which instrumentation constuction and blast damage contributed the most disturbance to the island. IVY, KING was detonated 2000 feet north and 1500 feet above the island and was not a major source of radiological insult. The LACROSSE event was detonated on a man-made island on the reef at the north end of the island. A very large array of instrumentation was used which is still evident as rubble on the reef. Large amounts of fill were used for construction which are now gone. Fallout from LACROSSE traveled northwest and resulted in significant amounts of contamination on all islands north of YVONNE. The ERIE event conducted on SOUTHERN YVONNE produced heavy contamination on the shot island. Bulldozing operations were carried out in the BLACKFOOT tower area to reduce exposures to an acceptable level for personnel requiring access to this area. BLACKFOOT also produced heavy contamination on YVONNE but was limited primarily to the shot island and the Mack photo tower located about 6.5 miles west of YVONNE in the lagoon. The OSAGE event produced no significant contamination on YVONNE. The CACTUS event created a large crater which remains. The highest gamma exposure rates from contaminated soil for the Atoll are found on the CACTUS crater lip. Large piles of ejecta remain as evidence of the physical disturbance resulting from the shot. The SCAEVOLA event was conducted on a barge 560 feet southwest of Station 1310. Heavy contamination resulted to the areas near the barge. The barge was towed to sea and sunk following the event.

Most notable in having created the alpha (plutonium) contamination on YVONNE is the QUINCE event. QUINCE had no nuclear yield which resulted in the plutonium in the device being spread by the high explosives. As the zero point was to be used for the following event, radiation controls and decontamination procedures were effected. A full Radex area was established between Stations 1310 and 1610 with a checkpoint at the personnel pier. An access road was bladed with a road grader from the checkpoint to GZ including a 25 x 75-ft parking area on the ocean size of GZ. Three to five inches of topsoil were removed with a skip loader and transported to the lagoon side of the island. A sixty-foot square area at GZ was graded to 3-inch depth and the soil transported to the lagoon disposal site. Contaminated equipment and debris was also disposed of at this site. Other areas were roped off to prohibit access. The GZ was then used for the FIG shot. FIG resulted in an elliptical crater 48 feet by 54 feet which was 9.7 feet below grade and had a lip of 3.6 feet above grade. A depression should remain from the crater.

In addition to the above, it has been reported that SANDSTONE roll-up included bulldozing materials in the vicinity of the blast hut into the lagoon. In preparation for GREENHOUSE, contamination was pushed into the SANDSTONE ZEBRA crater and covered with clean soil, and (by private communication), bulldozers and front loaders were used to push the top 6 inches of topsoil into the ocean — probably onto the reef. A stratum of contaminated soil 65 feet long and three inches thick has been reported to exist on the ocean side of YVONNE from the QUINCE/FIG GZ north. This layer was visible during visits in the early 1970's, however, recent visitors report it is not distinguishable from its surroundings. Excavation may reveal that contaminated soil was covered by plastic sheeting and clean soil to allow followup work in the area. The plastic was supposedly used as a barrier to alert persons digging in the area that contamination was present. Similar attention should be given to any area where plastic covering is encountered in cleanup operations.

The radiological condition of NORTHERN YVONNE as shown in NVO-140 has been reproduced and included in Figures 71 to 129. Exposure rates from rubble and scrap have been omitted as a precleanup resurvey is to be performed for disposal classification. Scrap exposure rates of up to 3 mR/h were measured in 1972. As plutonium is the radionuclide of most interest in cleanup, it will receive the most attention below. Except for the CACTUS crater area, the activities of ^{90}Sr, ^{137}Cs and ^{60}Co seem to be fairly evenly distributed throughout NORTHERN YVONNE. Generally the ^{90}Sr activities range between one and five pCi/g within the top 50 cm and less than one pCi/g below this depth. The activities of ^{137}Cs and ^{60}Co are similar in magnitude and usually range between 0.1 and 2 pCi/g. Within the CACTUS crater area, the mean surface activities of ^{90}Sr, ^{137}Cs and ^{60}Co are generally an order of magnitude greater than those measured throughout the remainder of NORTHERN YVONNE. Even though the geographical distributions of these radionuclides are highly variable (near CACTUS crater), they do show somewhat similar trends. For instance, if one proceeds outward on the two radials leading from Location 142 on the crater lip, one encounters an approximate tenfold increase in activity levels (averaged over 120 cm depth) in the vicinity of Locations 141 - 140 and Locations 143 - 144. These activities fall off, however, as one proceeds to Locations 139 and 145.

As explained above, the complexity of the radiological conditions on NORTHERN YVONNE was produced by several nuclear events; most notable of these being QUINCE. Radiation surveys reveal that the area is heterogenously contaminated with ^{239}Pu particles of various sizes up to milligram-size pieces of plutonium metal. The area wherein these hot spots have been found is shown on the enclosed figures. Hot spots found in the area were isolated using a FIDLER survey instrument which can react to attenuated high energy gamma rays as well as gamma rays from ^{241}Am which exists with plutonium. Thus, the "hot spots" found on YVONNE are local concentrations of radioactivity which, because of the history of the area, are probably, but not certainly, plutonium.

The soil sampling plan of the Enewetak Radiological Survey (NVO-140) is shown in Figures 71 and 79. The corresponding graphs present the radionuclide concentrations measured in the soil profile at each location. The plutonium profile data have been plotted in Figures 121-129, wherein the profiles represent a section either across the island or through a portion of its length with the locations presented in Figures 118-120. A significant portion of the activity is situated along the ocean side of the island between Locations 104 and 117. Within this area, the activities generally exceed 100 pCi/g to depths of 30 cm or more. These relatively high contamination levels appear to penetrate furthest inland along the Location 112 - 116 cross section, as evidenced by activity levels of greater than 100 pCi/g to depths of 50 cm at Location 113 and 10 cm at Location 114.

Elevated ^{239}Pu activities are also observed to a lesser extent along the lagoon side of the island. Activities exceeding 100 pCi/g were measured to depths of 20 cm within a narrow strip situated along Locations 111, 116, 120 and 125. An additional area of interest may be noted at depths of 60-90 cm beneath the surface within the island's interior. A strip, estimated to be as much as 100 - 200 feet wide, may be delineated at Location 110 and intersecting Locations 114 and 115. The ^{239}Pu activities generally exceed 10 pCi/g within the strip, with an observed maximum value of 70 pCi/g.

The ^{239}Pu activities measured in the samples collected along the line running up the center of the island to the CACTUS crater are significantly lower than those measured within the QUINCE area. For instance, activities exceeding 100 pCi/g were measured only on the surface at Location 134. Except for minor variations, the ^{239}Pu activities range from 5 to 30 pCi/g within the top 30 cm between Locations 132 and 142. Slightly higher activities, however, were measured at Locations 143, 144 and 146, along the CACTUS crater-to-lagoon cross section, where activities ranged between 10 and 150 pCi/g.

These data have been interpreted at the 40 pCi/g concentration level and included on Figures 118-120.

Author's Note:

> The above discussions conflict with information given in the section describing the events conducted on YVONNE. Formal reports specify that contaminated material was moved toward the lagoon. Informal sources as well as the above radiological survey information indicate that seaward transport may have also occurred.
>
> The only alternative is that the deep plutonium on the ocean side is a result of device material or mechanical disturbance from the FIG shot — suggestions of little credibility. The elevated levels of plutonium on the lagoon side would reflect the soil transport from the QUINCE GZ. (end author's note)

In general, not only did YVONNE receive the highest exposure of any island in the Atoll, but YVONNE was the site of the most shots and therefore the most physical alteration. It has been said that probably all of YVONNE was at one time or another excavated to within a couple of feet of the water level. As a further example, it can be seen in postshot damage reports that prior to the HARDTACK OPERATION, Station 1310 was protected by a seawall and an earthen cover. By the end of HARDTACK, the seawall was nearly gone and most of the earthen cover was missing. This is illustrative of the effects which will be evident throughout cleanup.

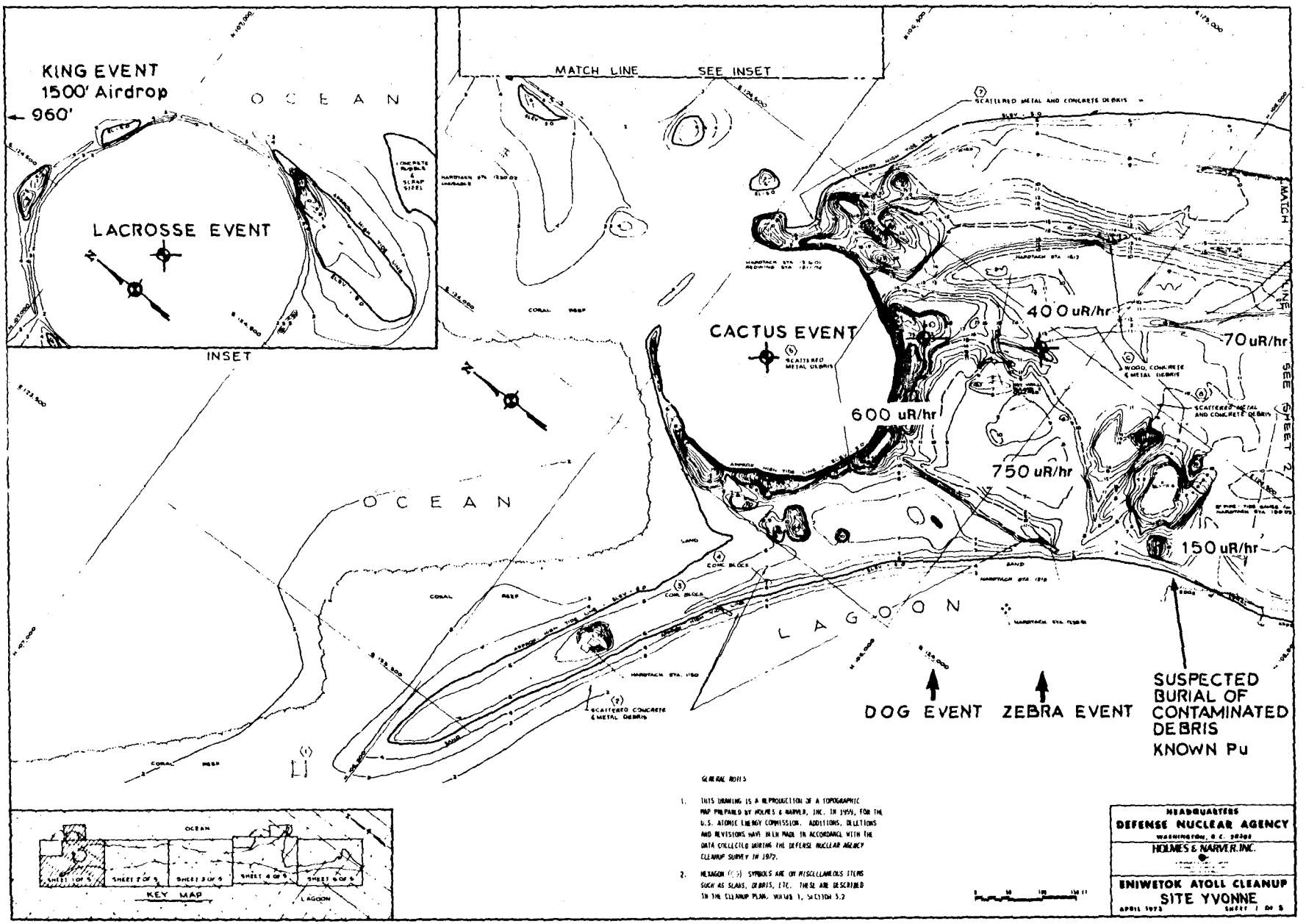

FIGURE 68. SITE YVONNE, SHEET 1 OF 5

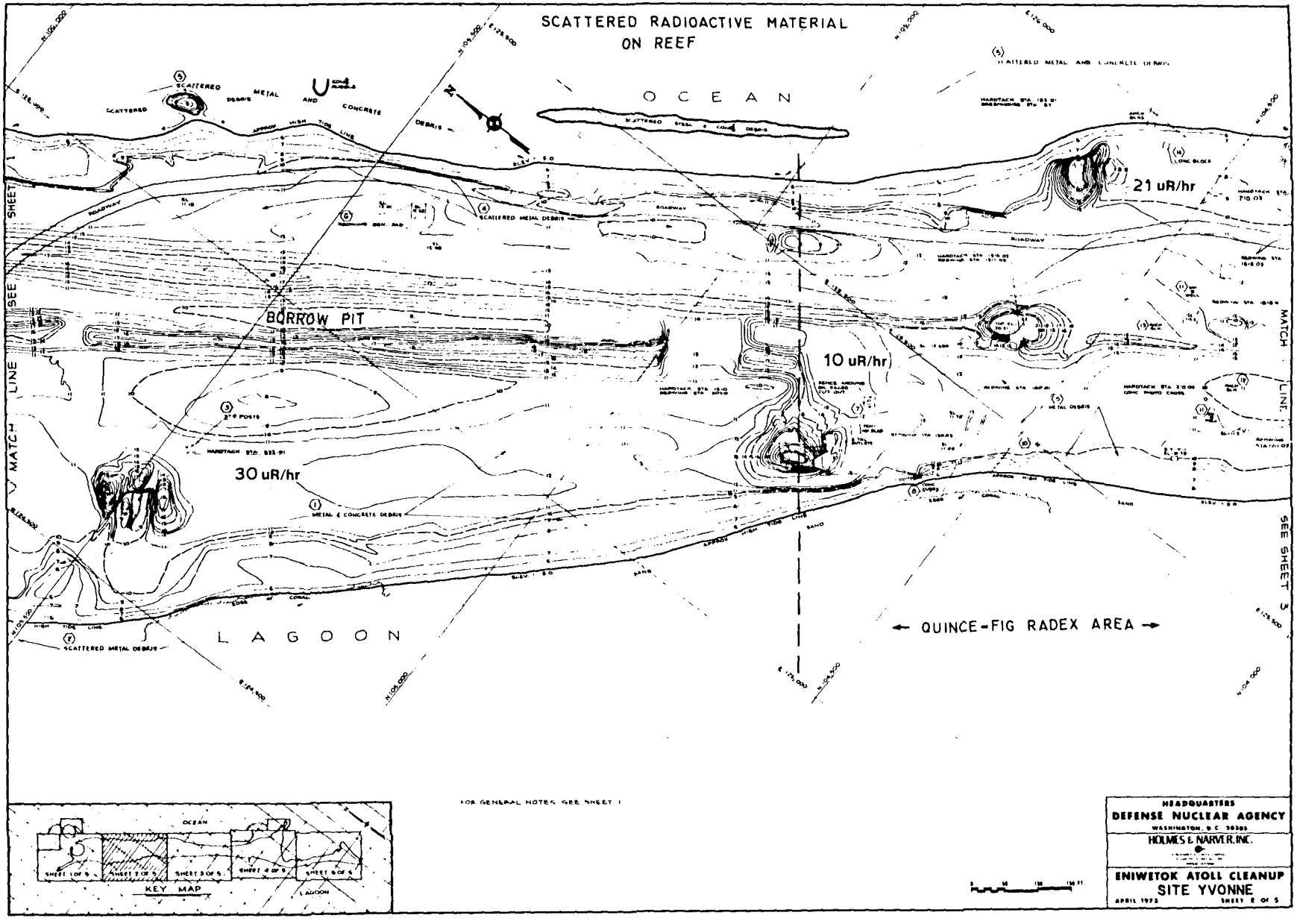

FIGURE 69. SITE YVONNE, SHEET 2 OF 5

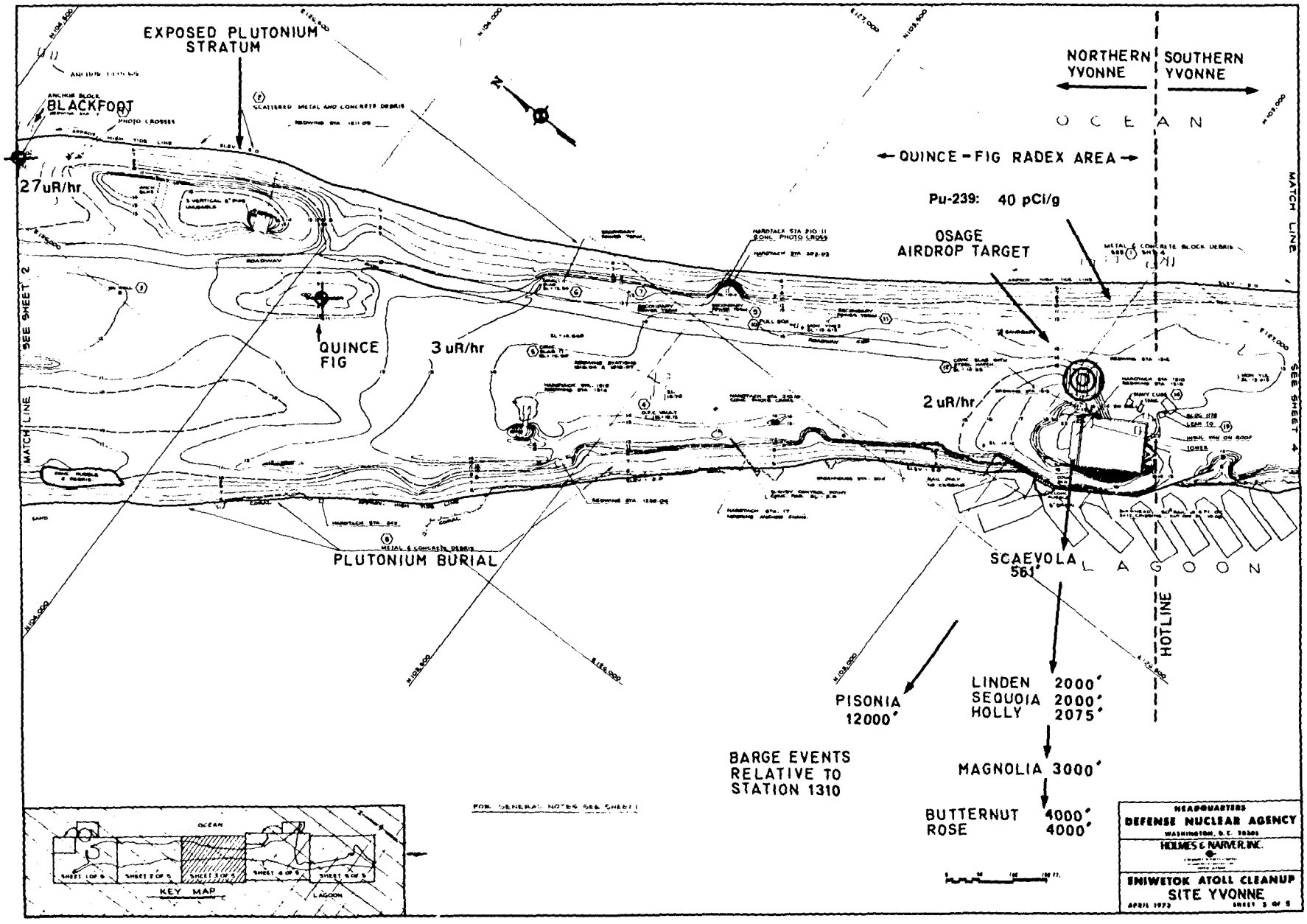

FIGURE 70. SITE YVONNE, SHEET 3 OF 5, NORTH END

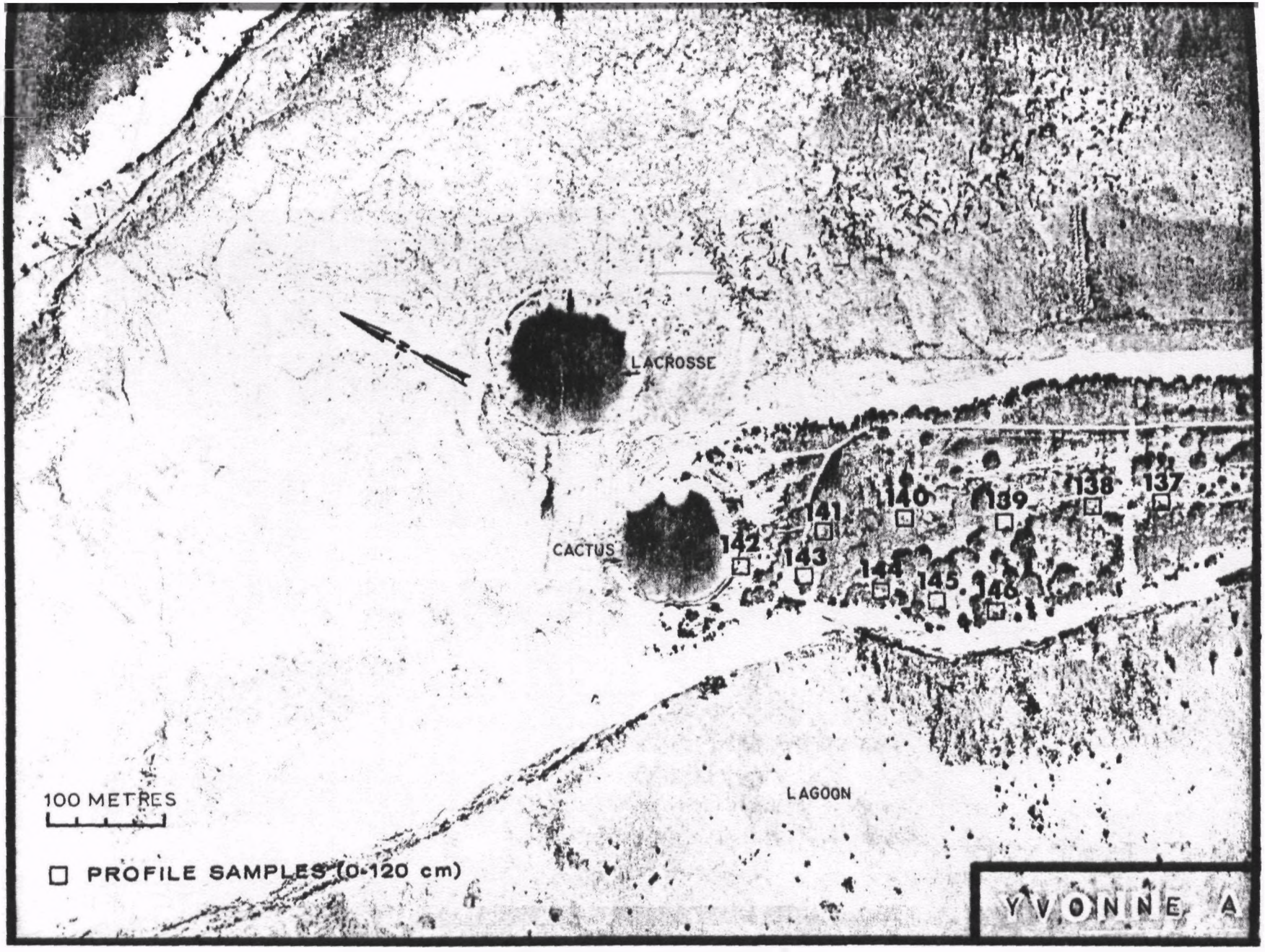

FIGURE 71. SOIL SAMPLE LOCATIONS

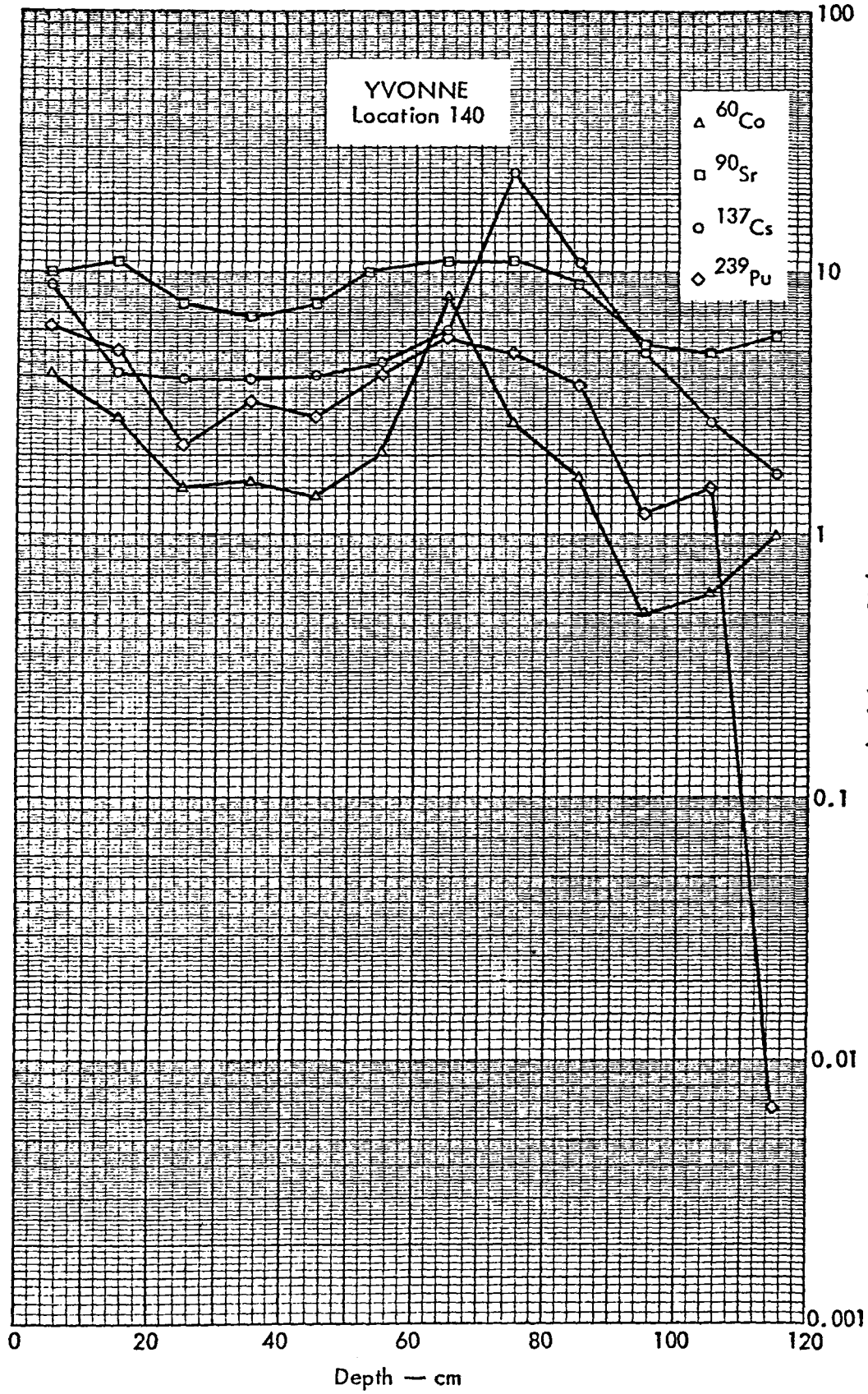

FIGURE 72. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

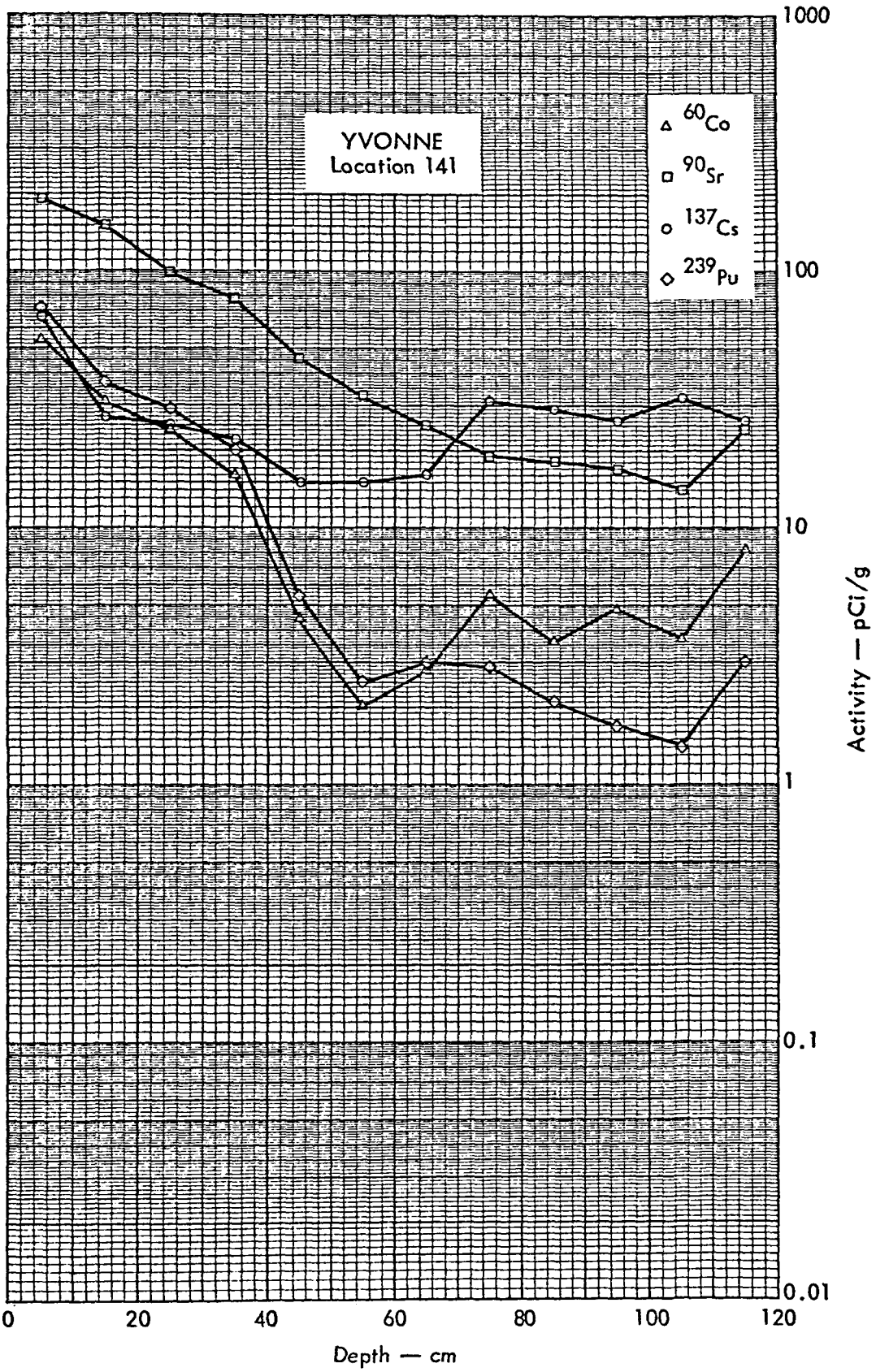

FIGURE 73. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

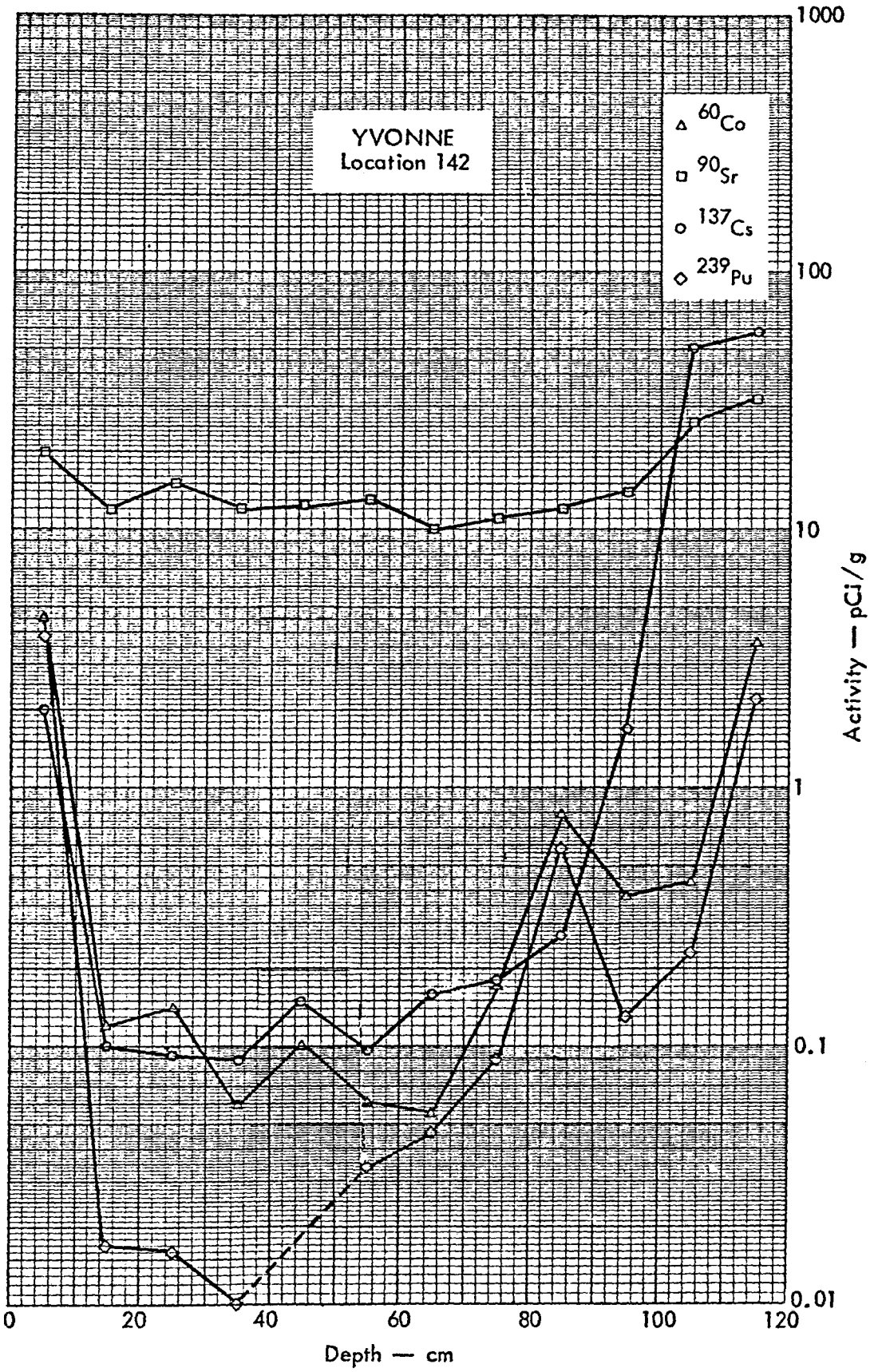

FIGURE 74. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

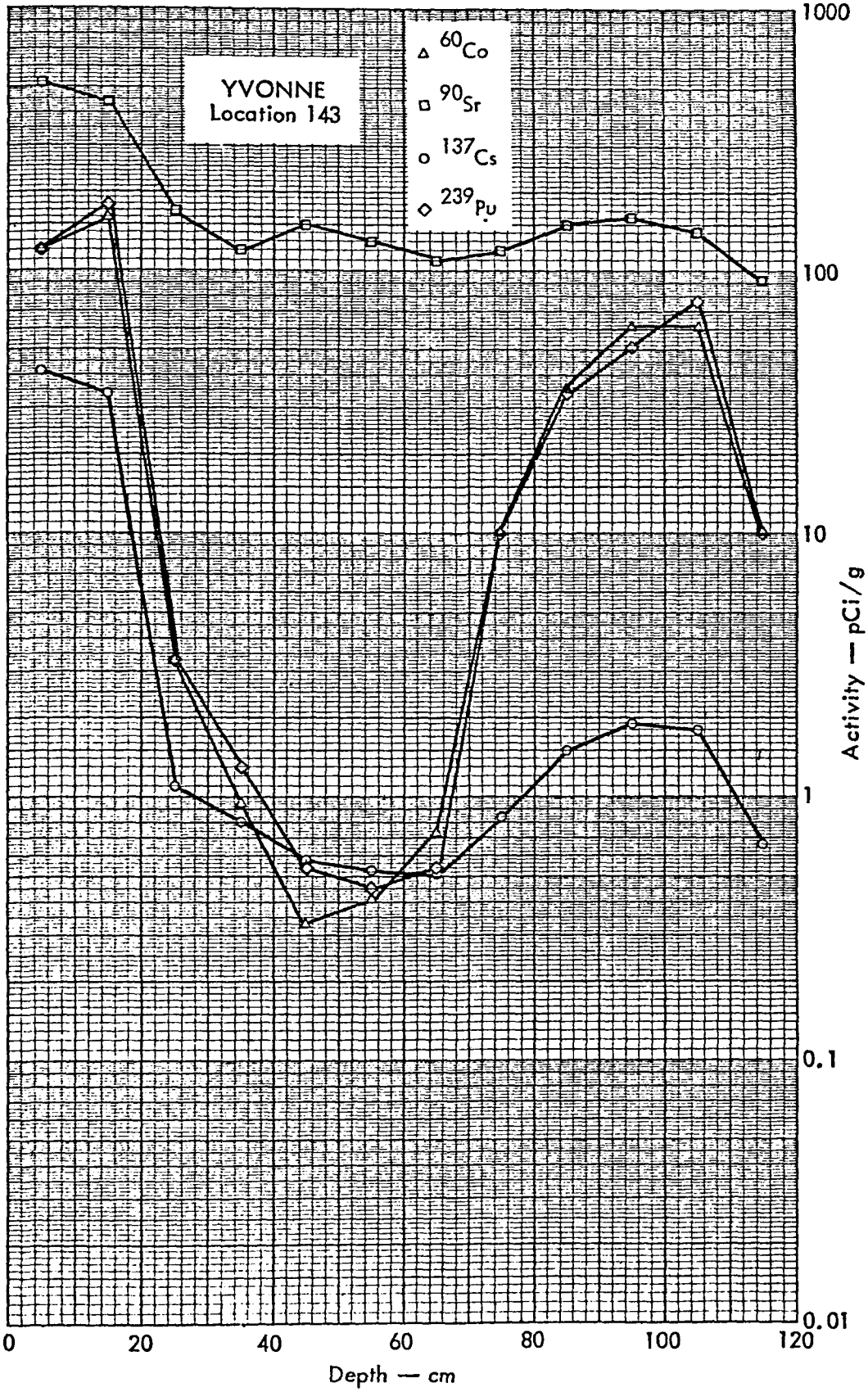

FIGURE 75. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

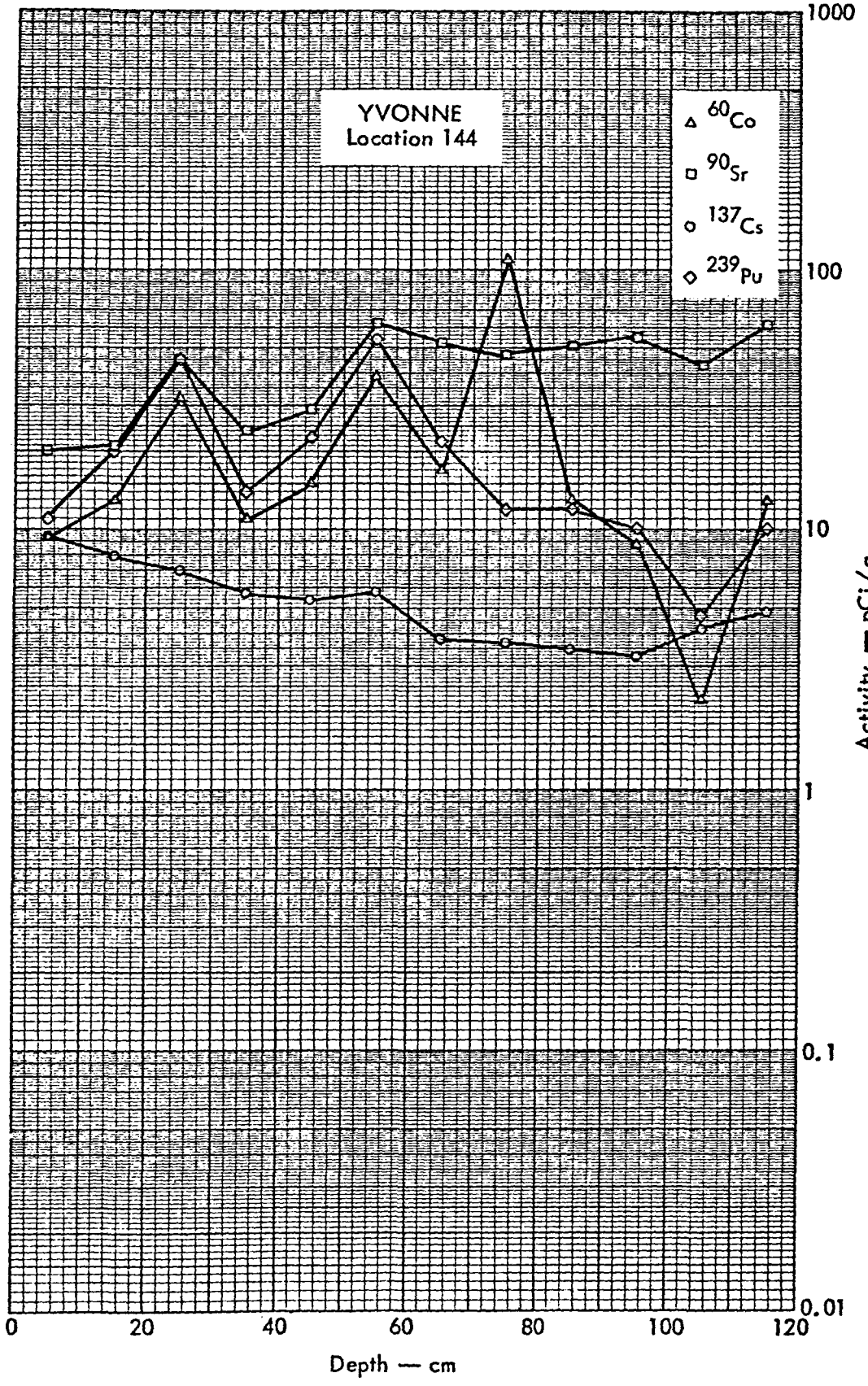

FIGURE 76. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

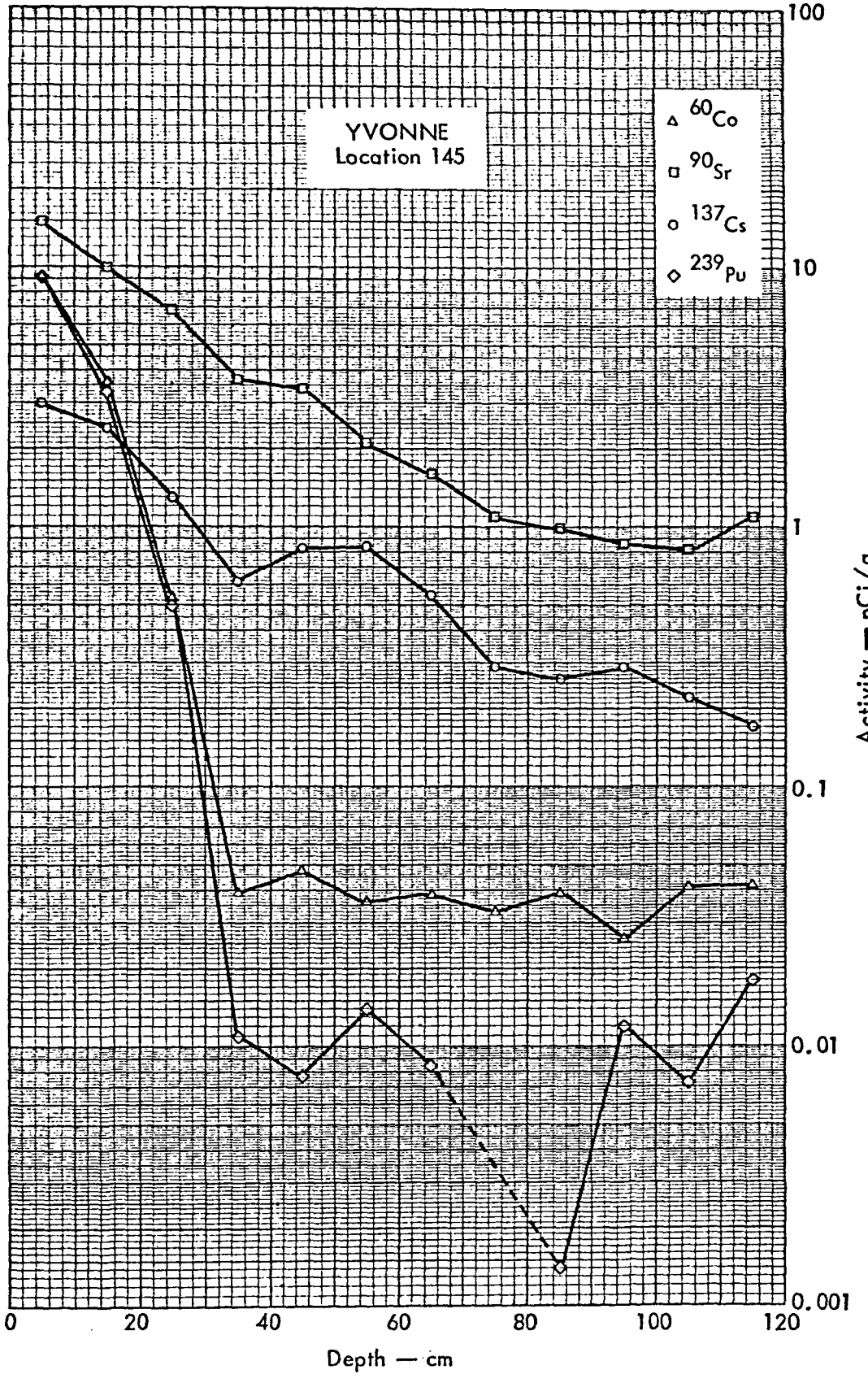

FIGURE 77. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

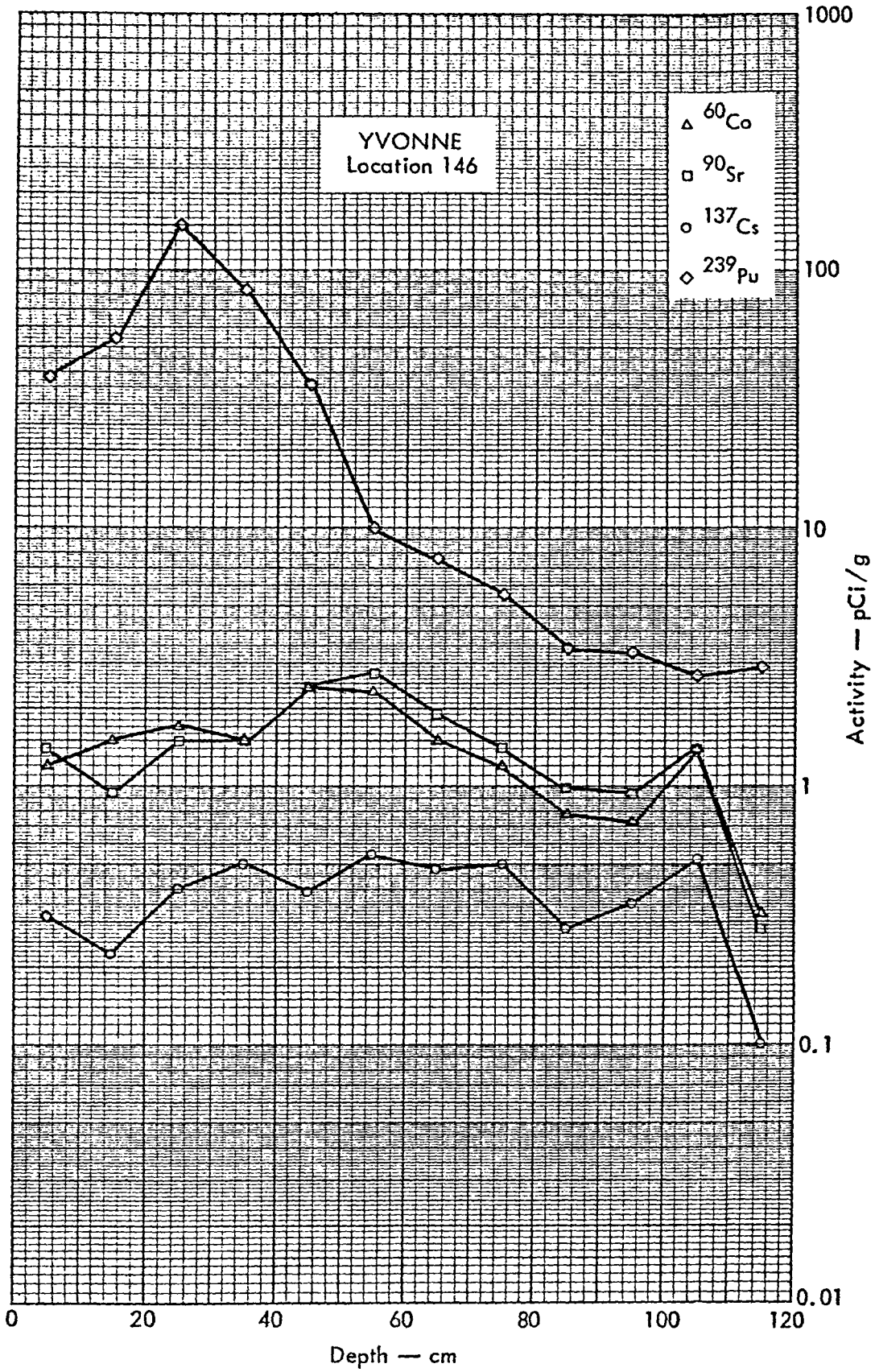

FIGURE 78. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

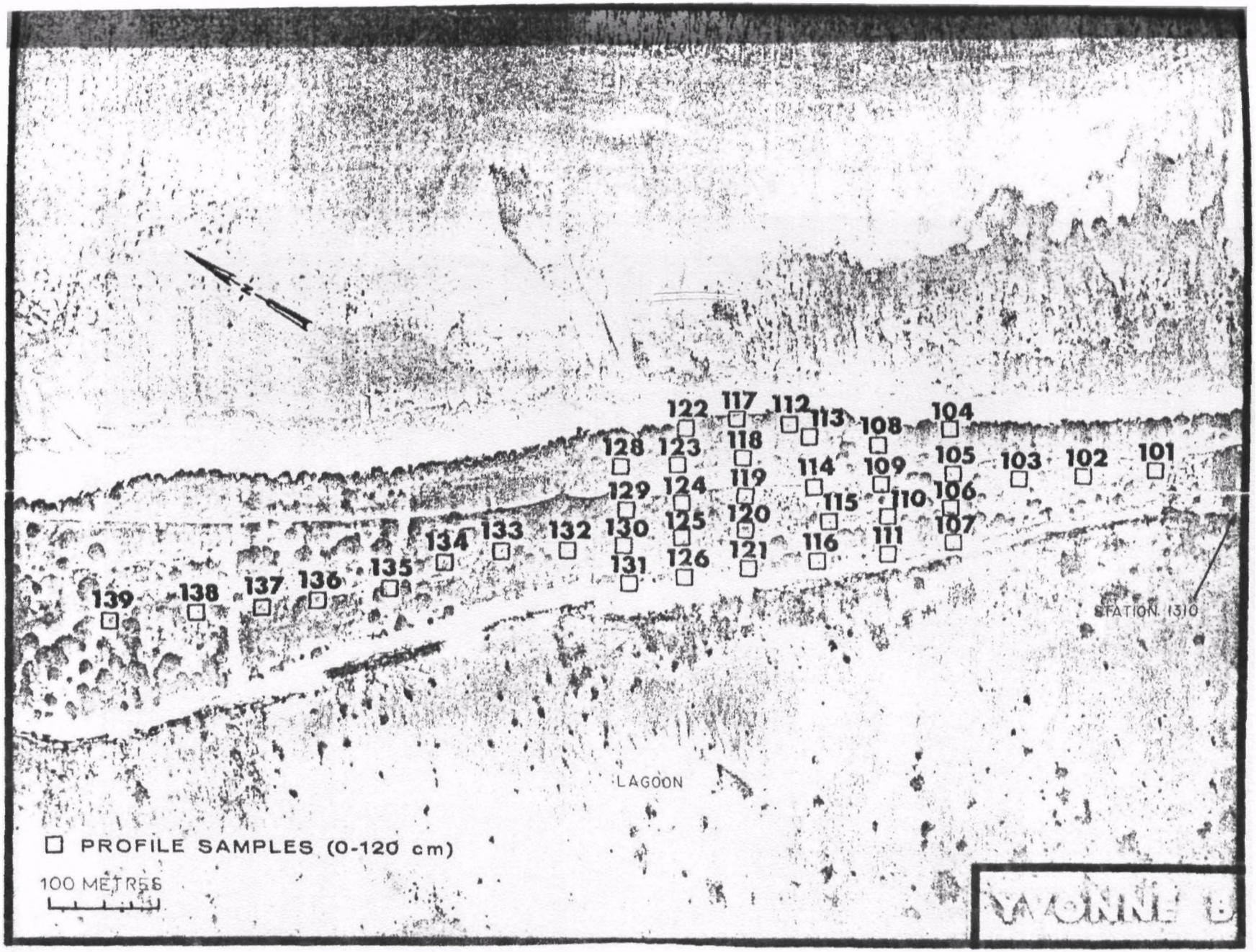

FIGURE 79. SOIL SAMPLE LOCATIONS

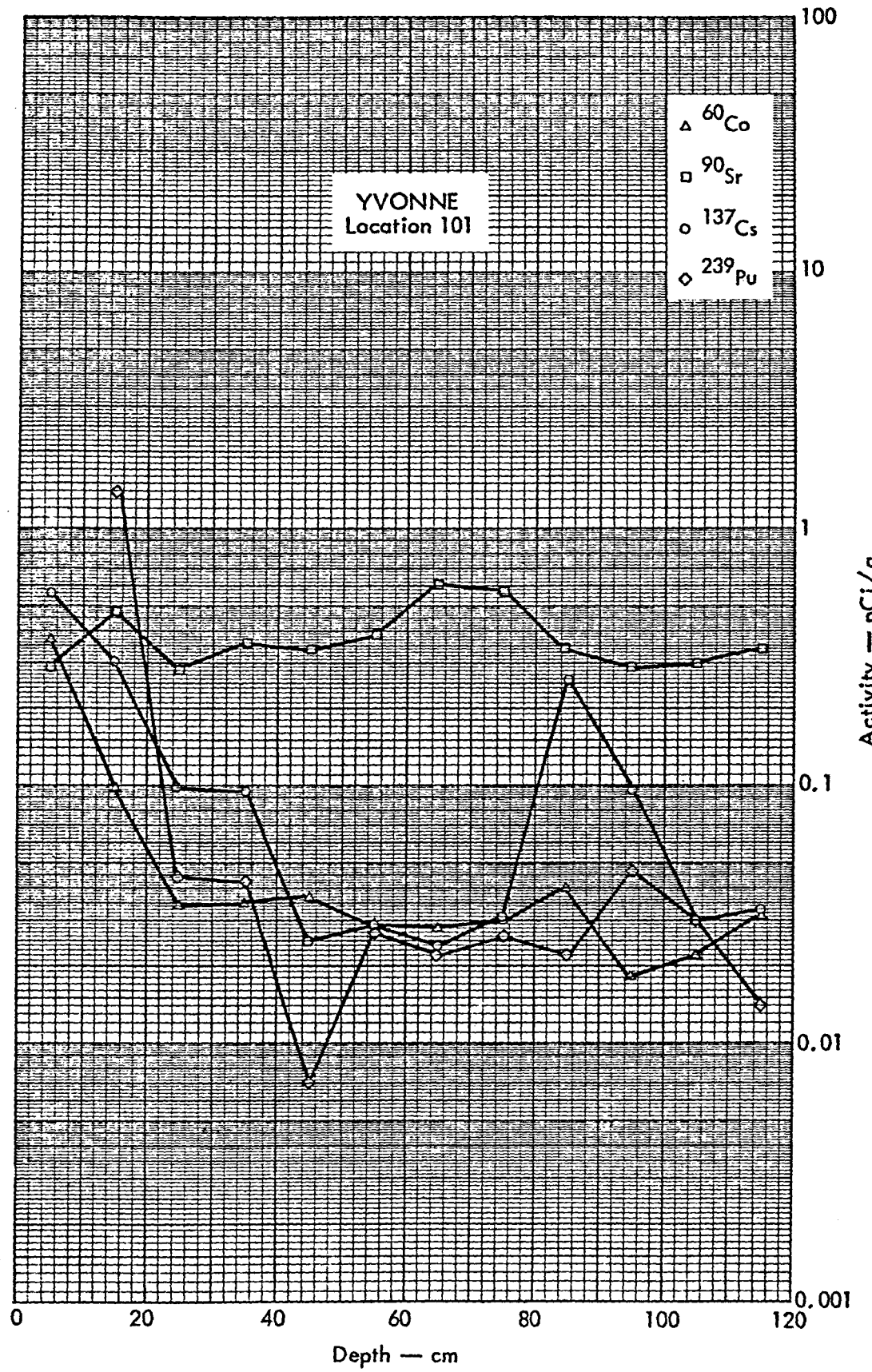

FIGURE 80. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

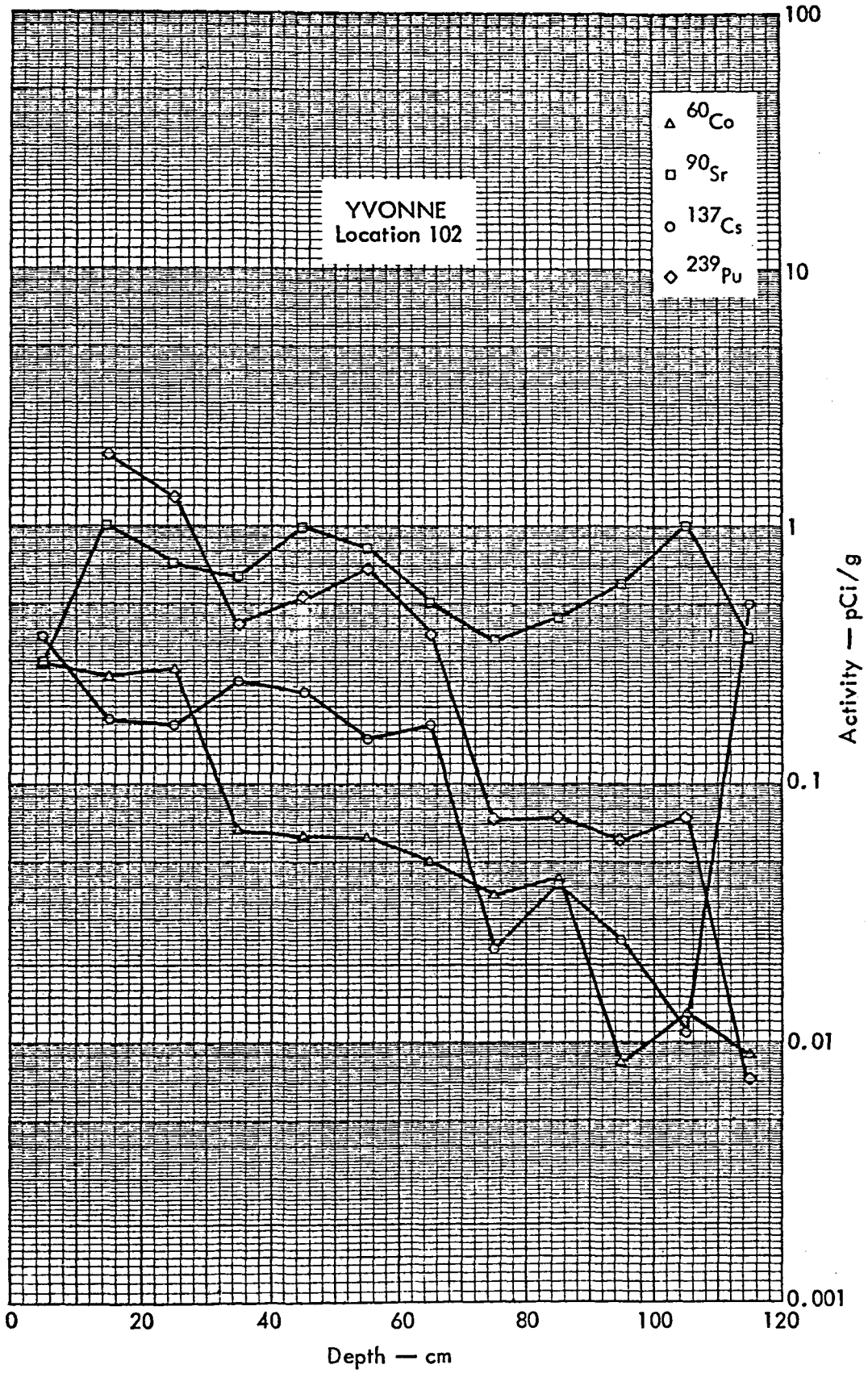

FIGURE 81. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

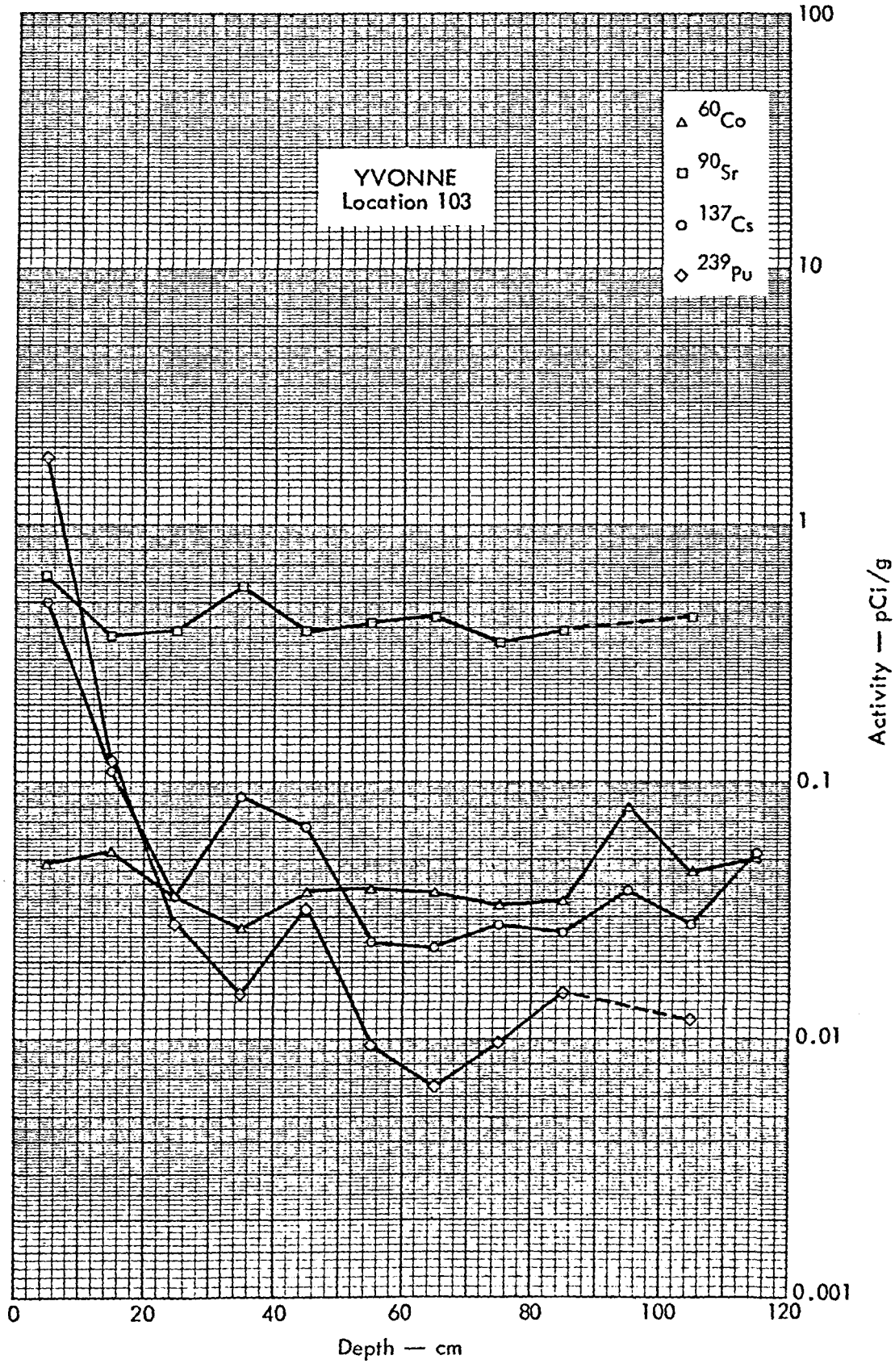

FIGURE 82. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

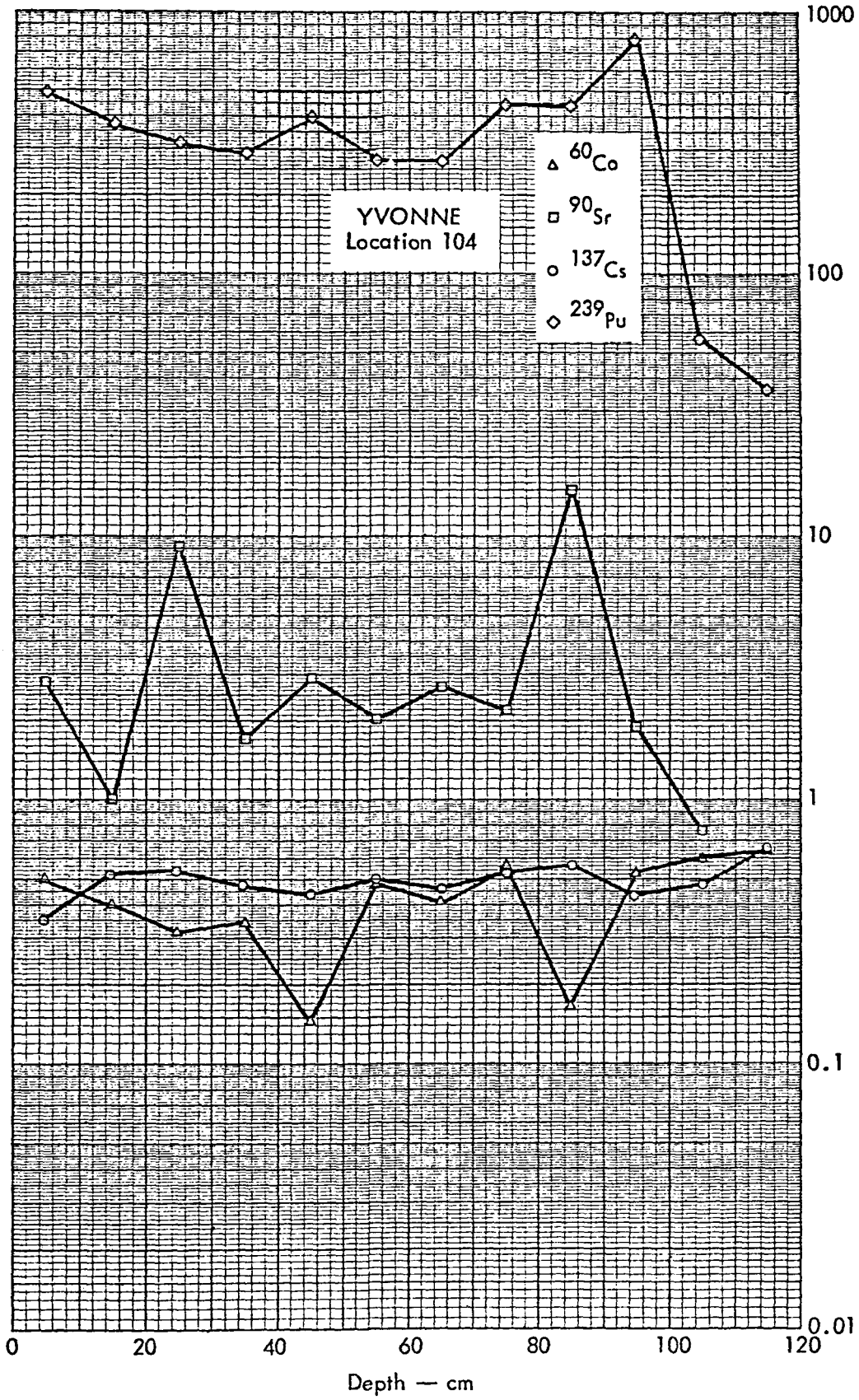

FIGURE 83. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

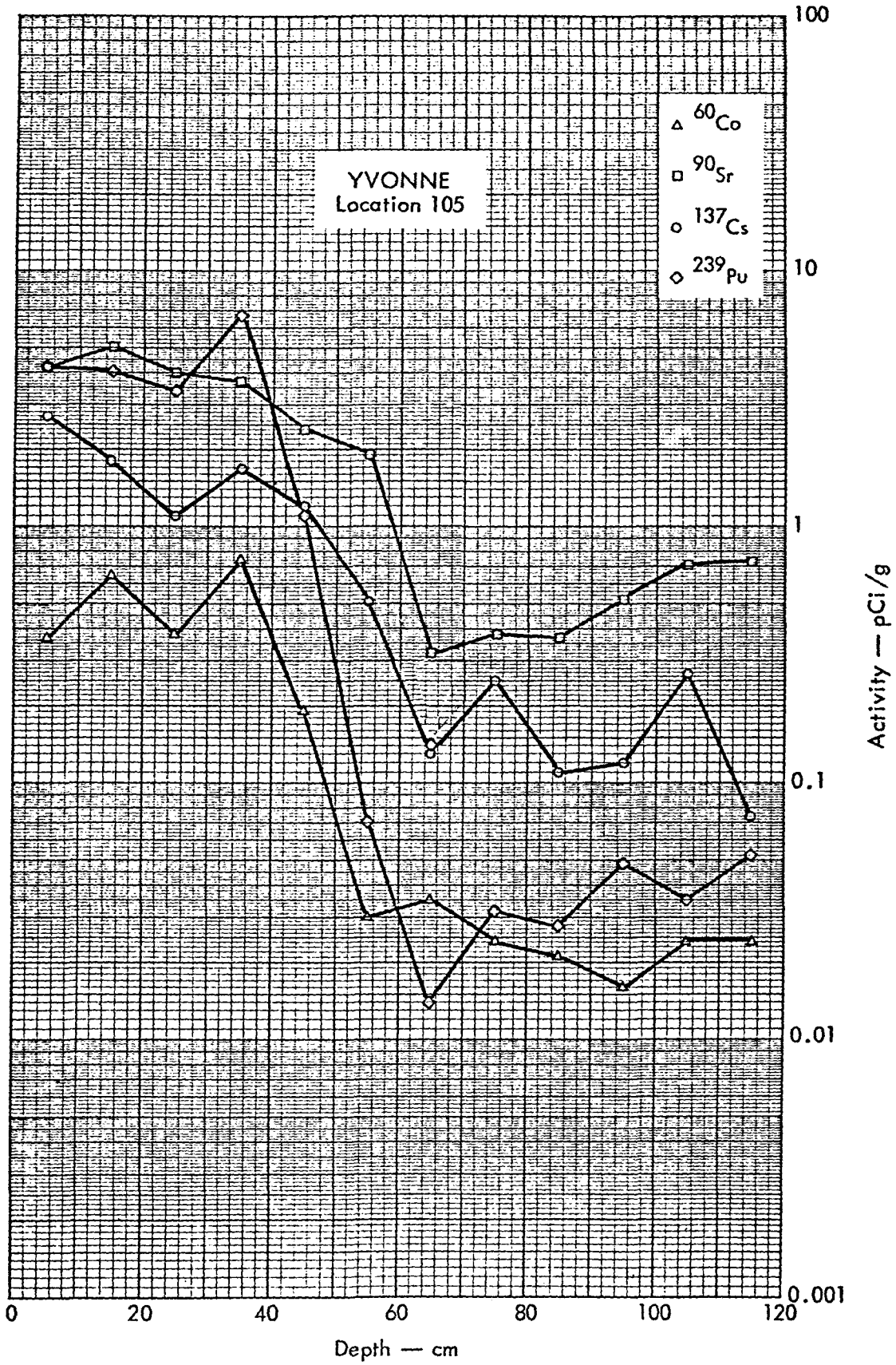

FIGURE 84. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

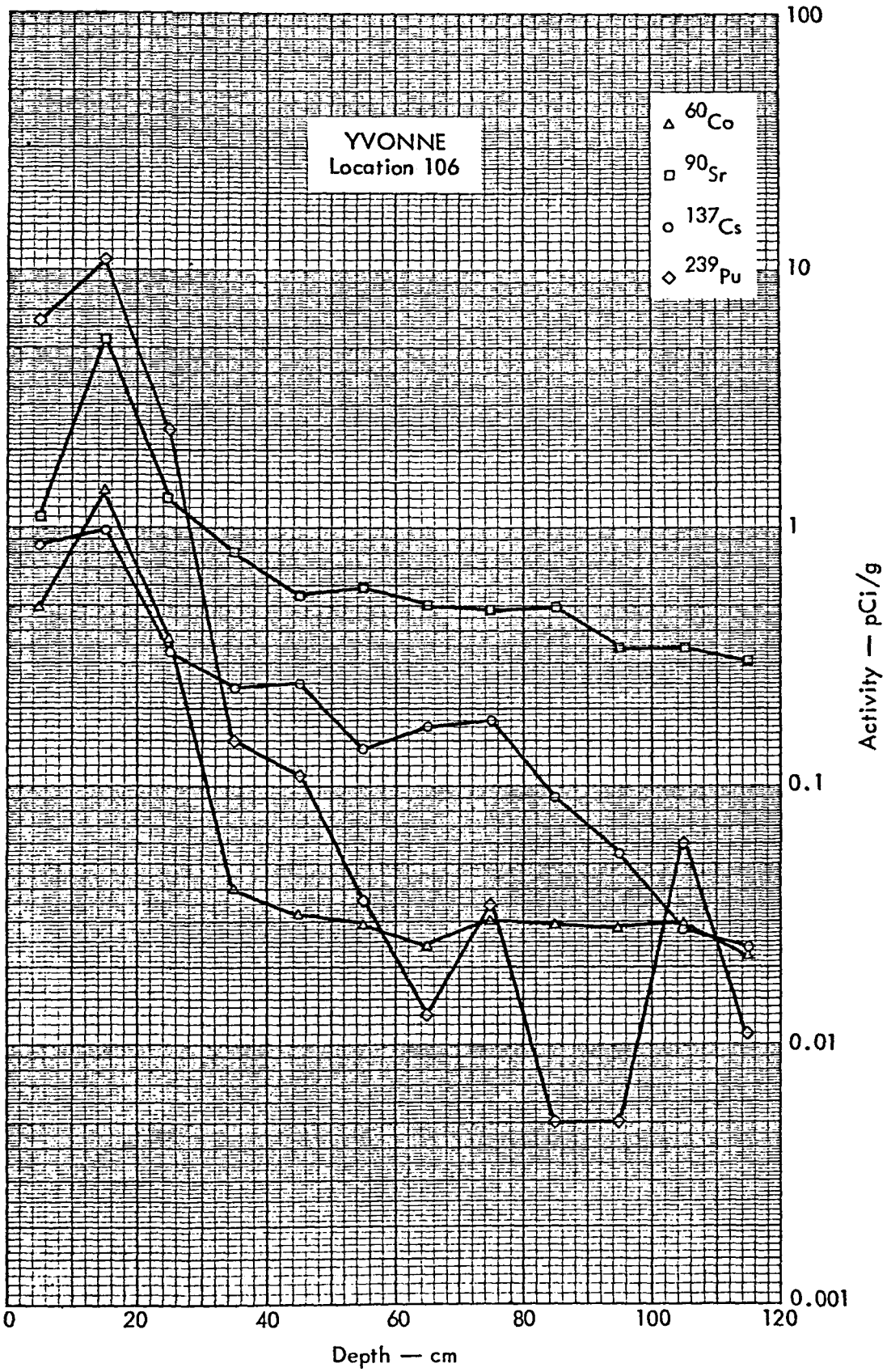

FIGURE 85. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

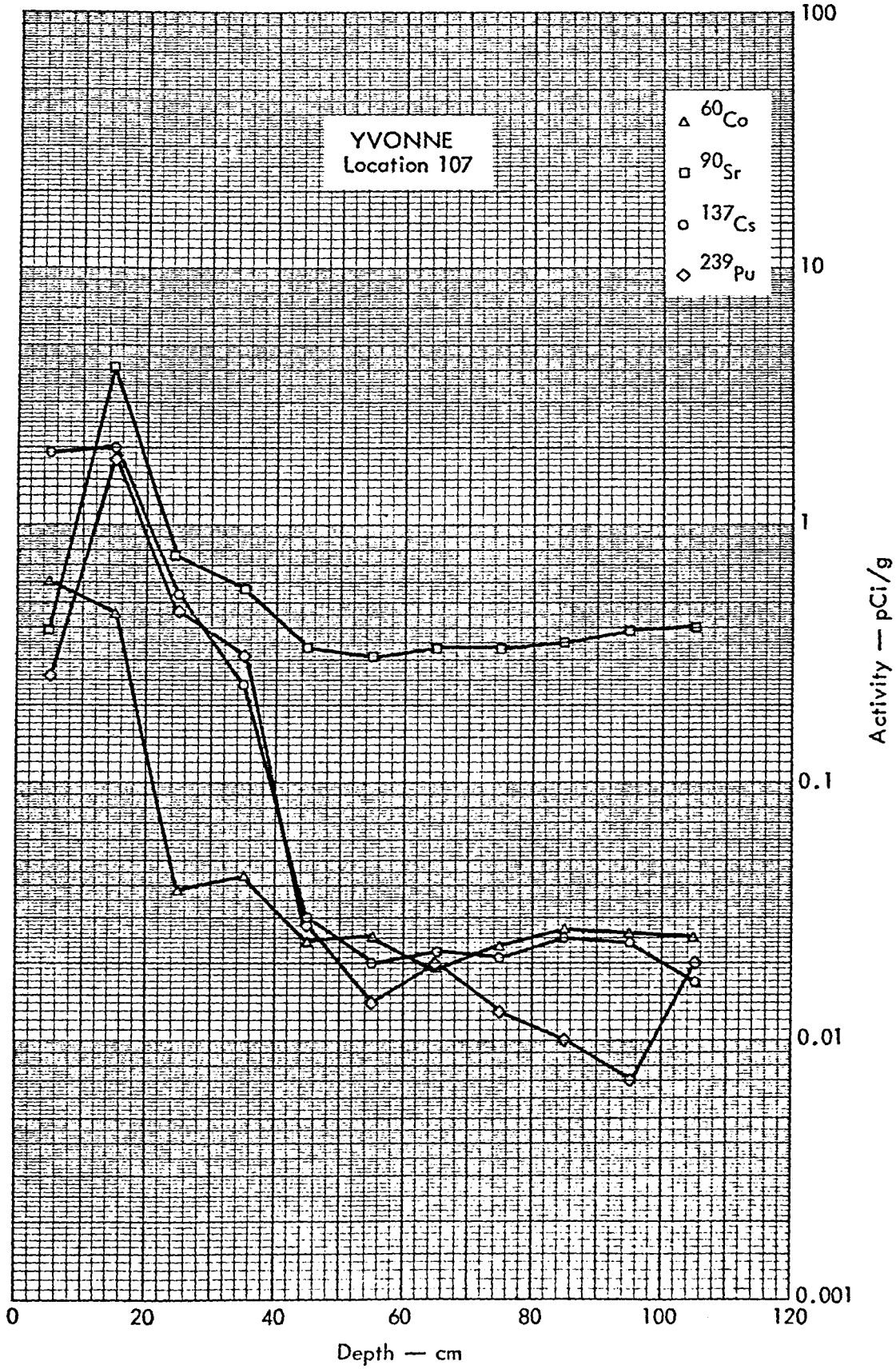

FIGURE 86. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

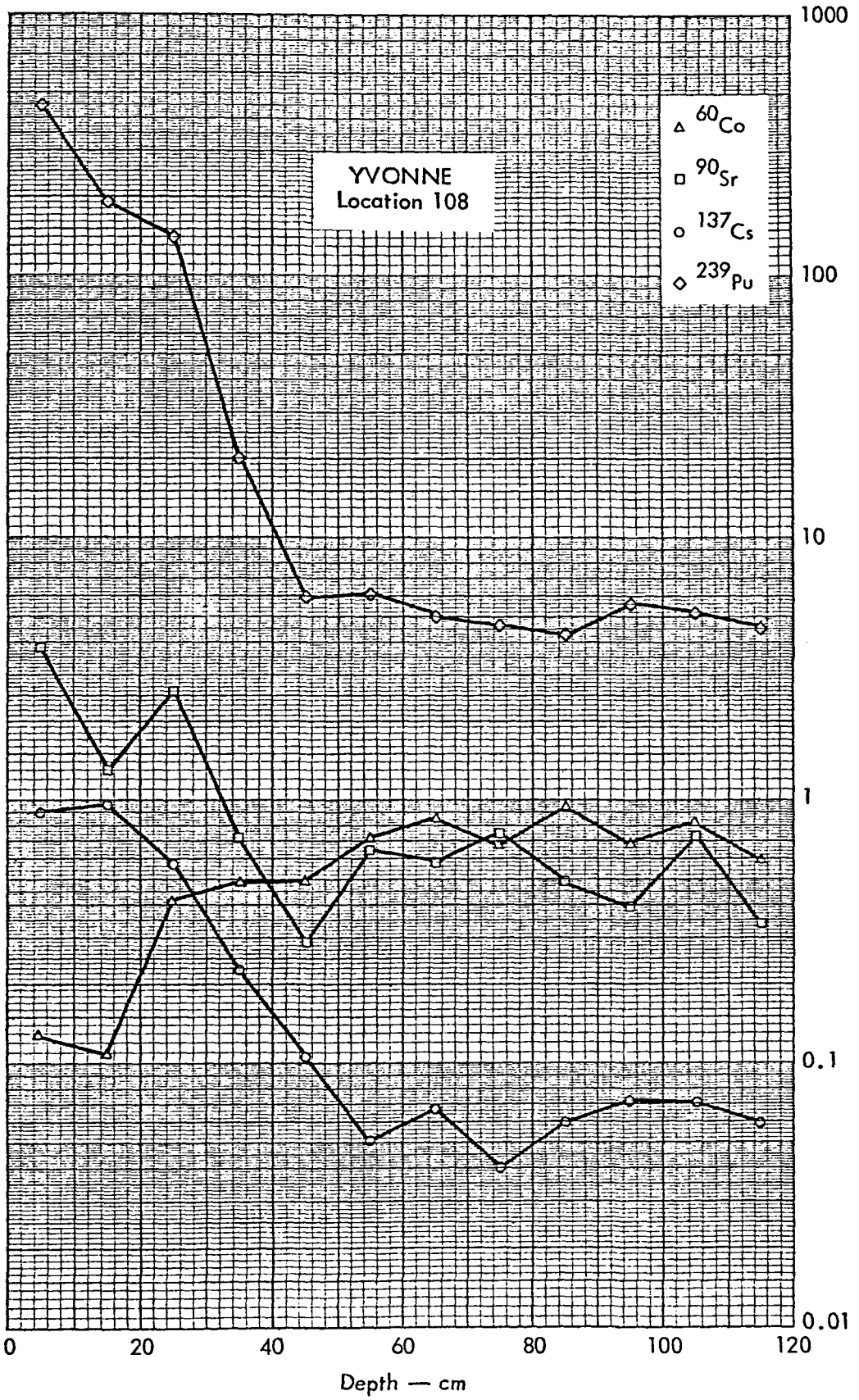

FIGURE 87. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

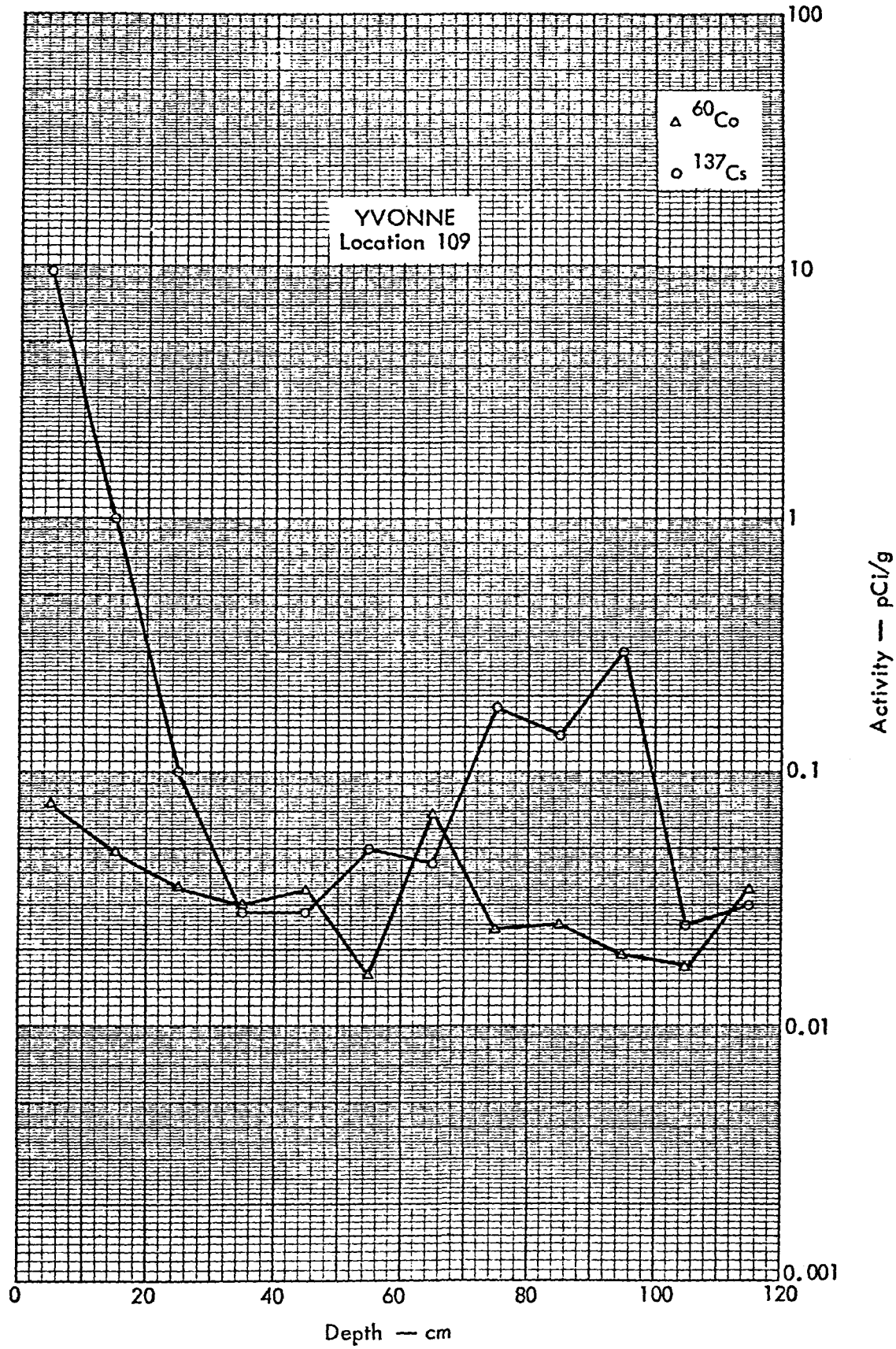

FIGURE 88. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

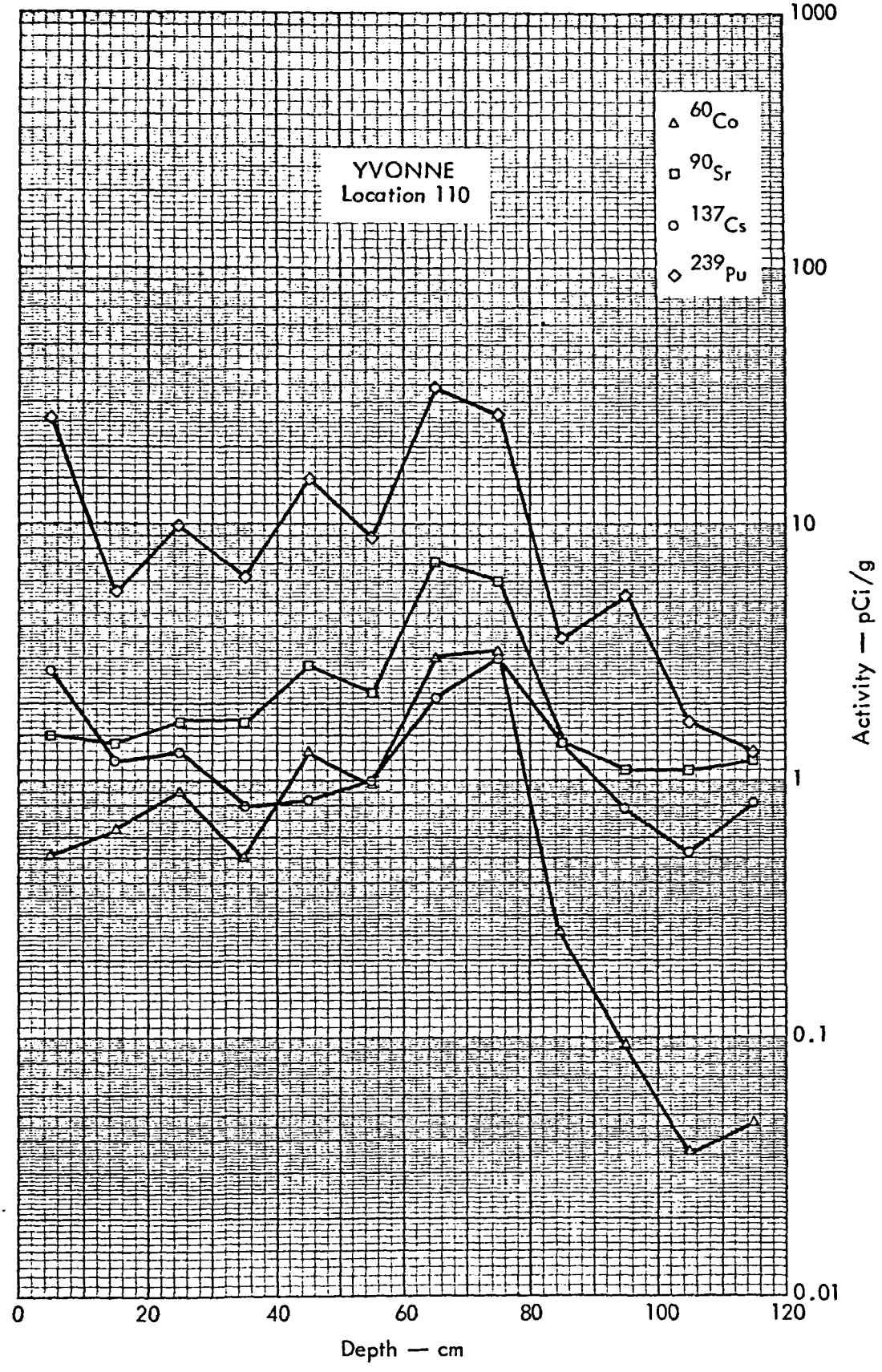

FIGURE 89. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

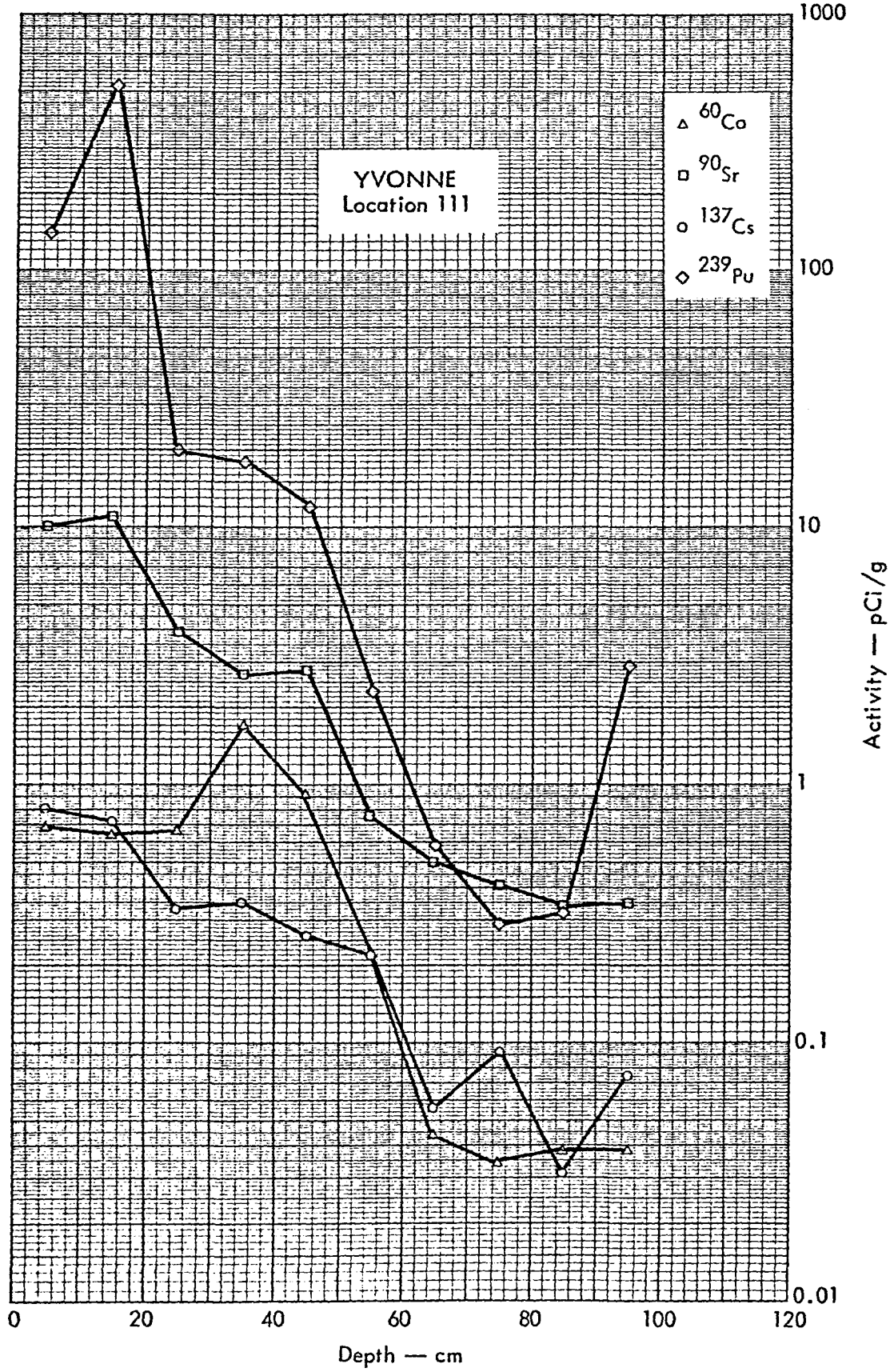

FIGURE 90. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

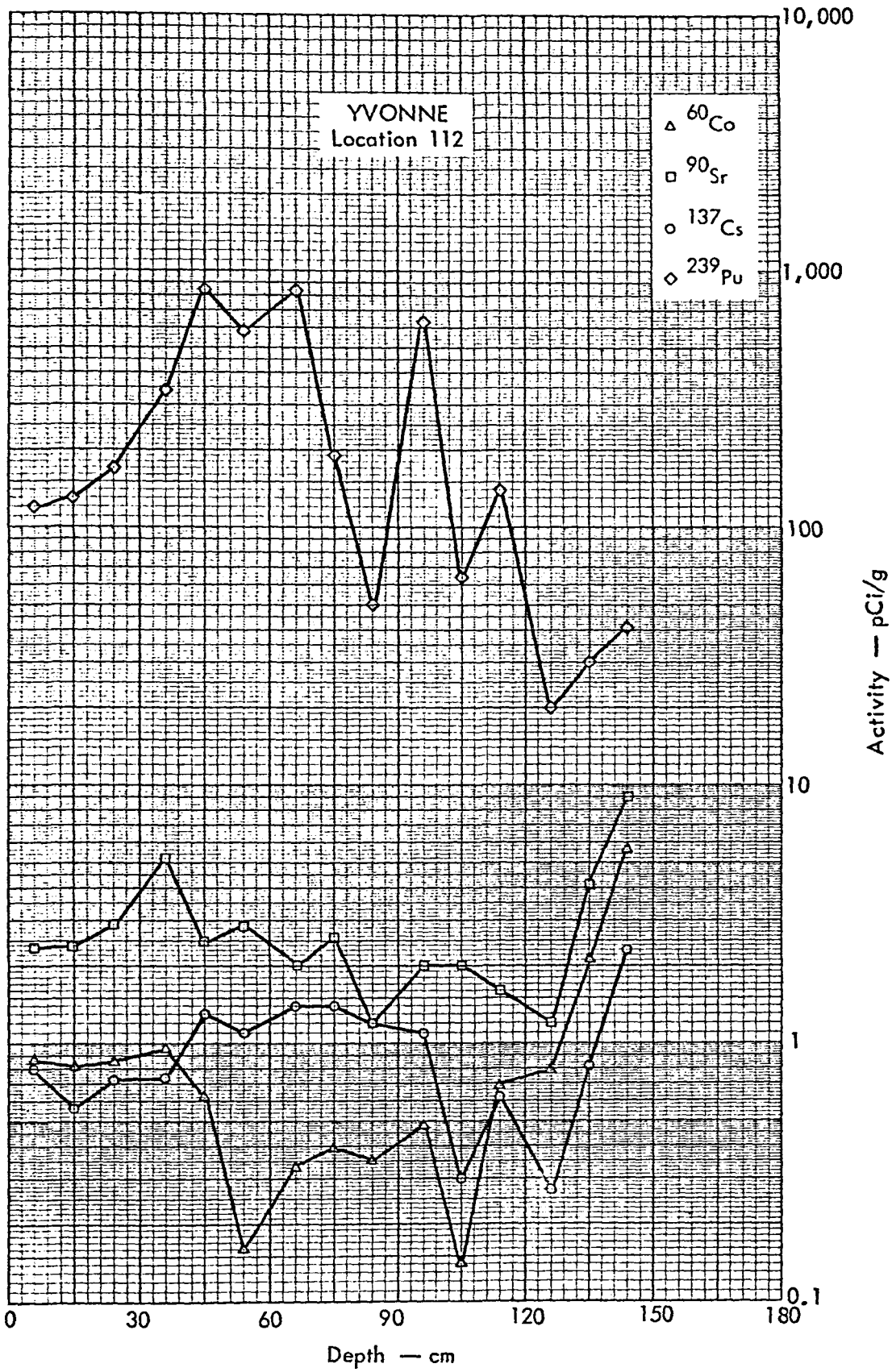

FIGURE 91. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

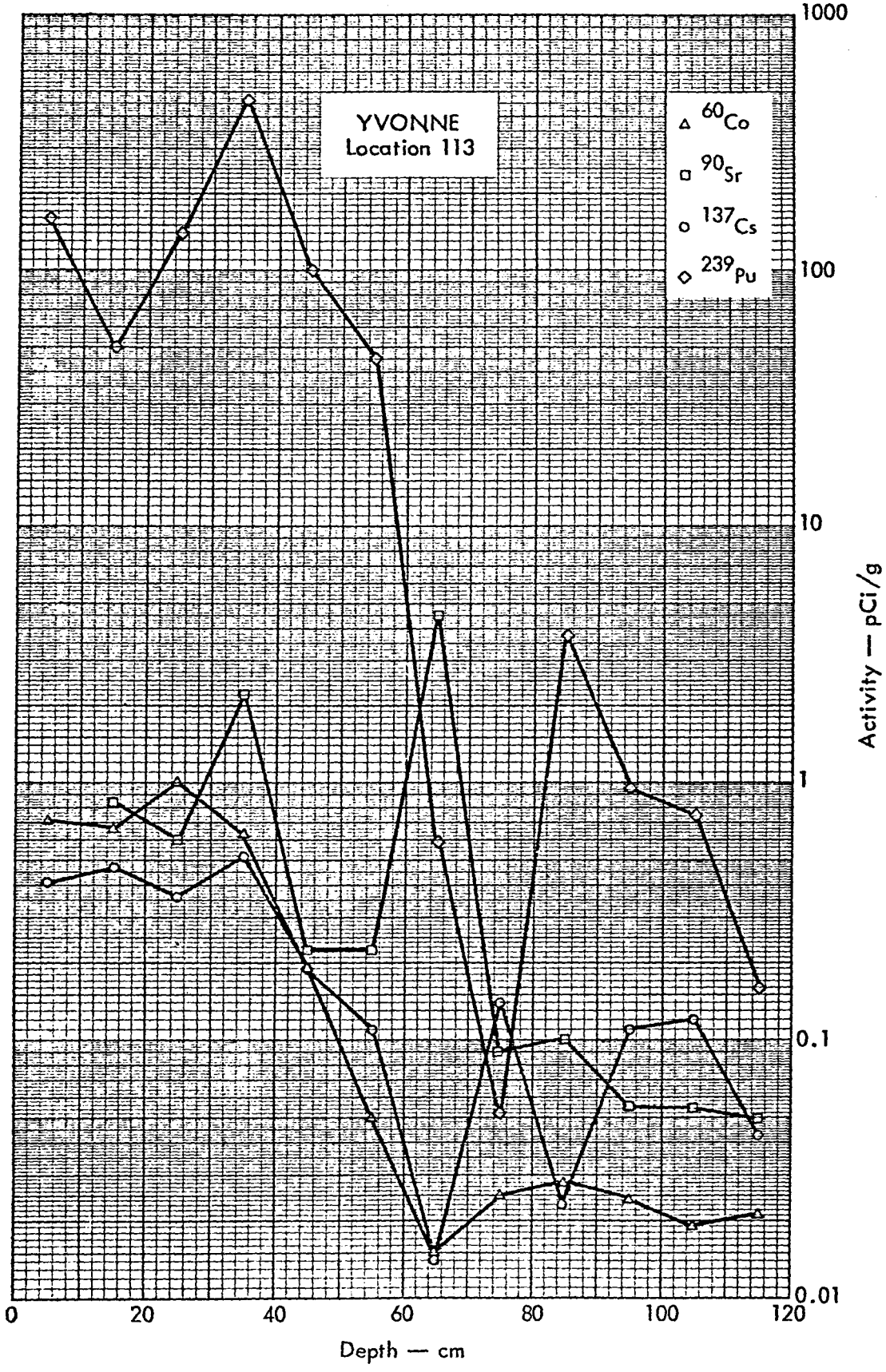

FIGURE 92. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

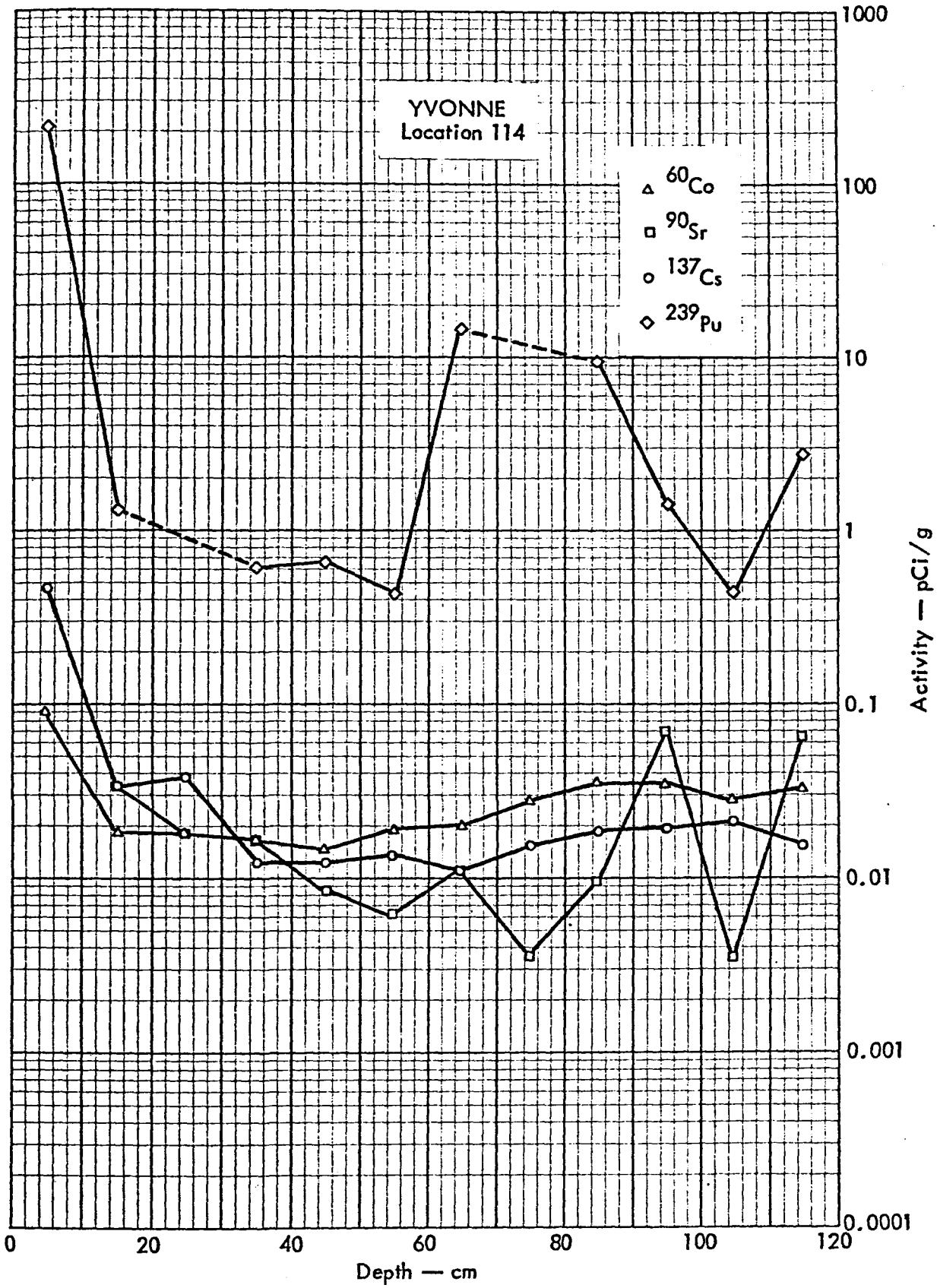

FIGURE 93. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

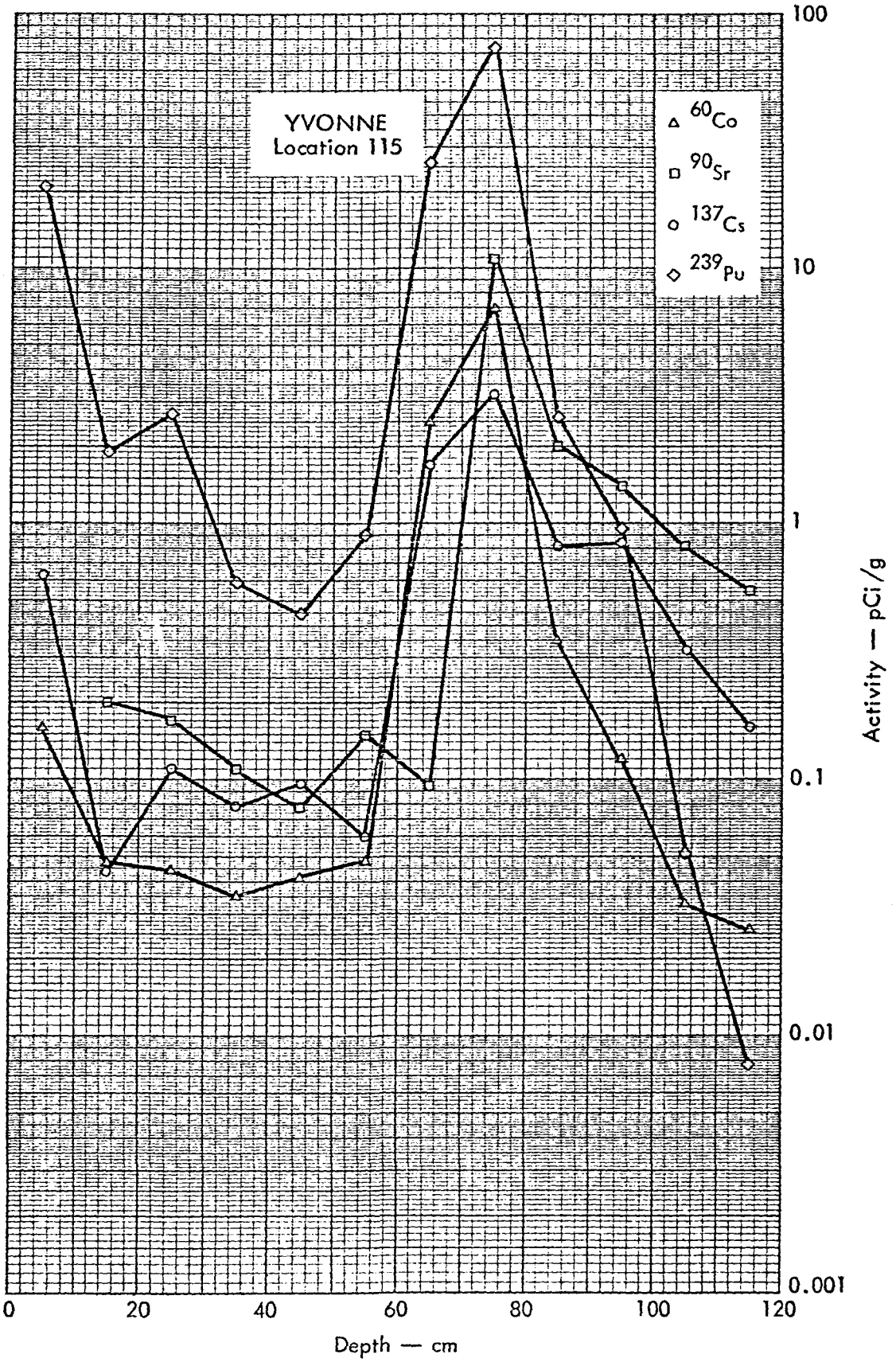

FIGURE 94. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

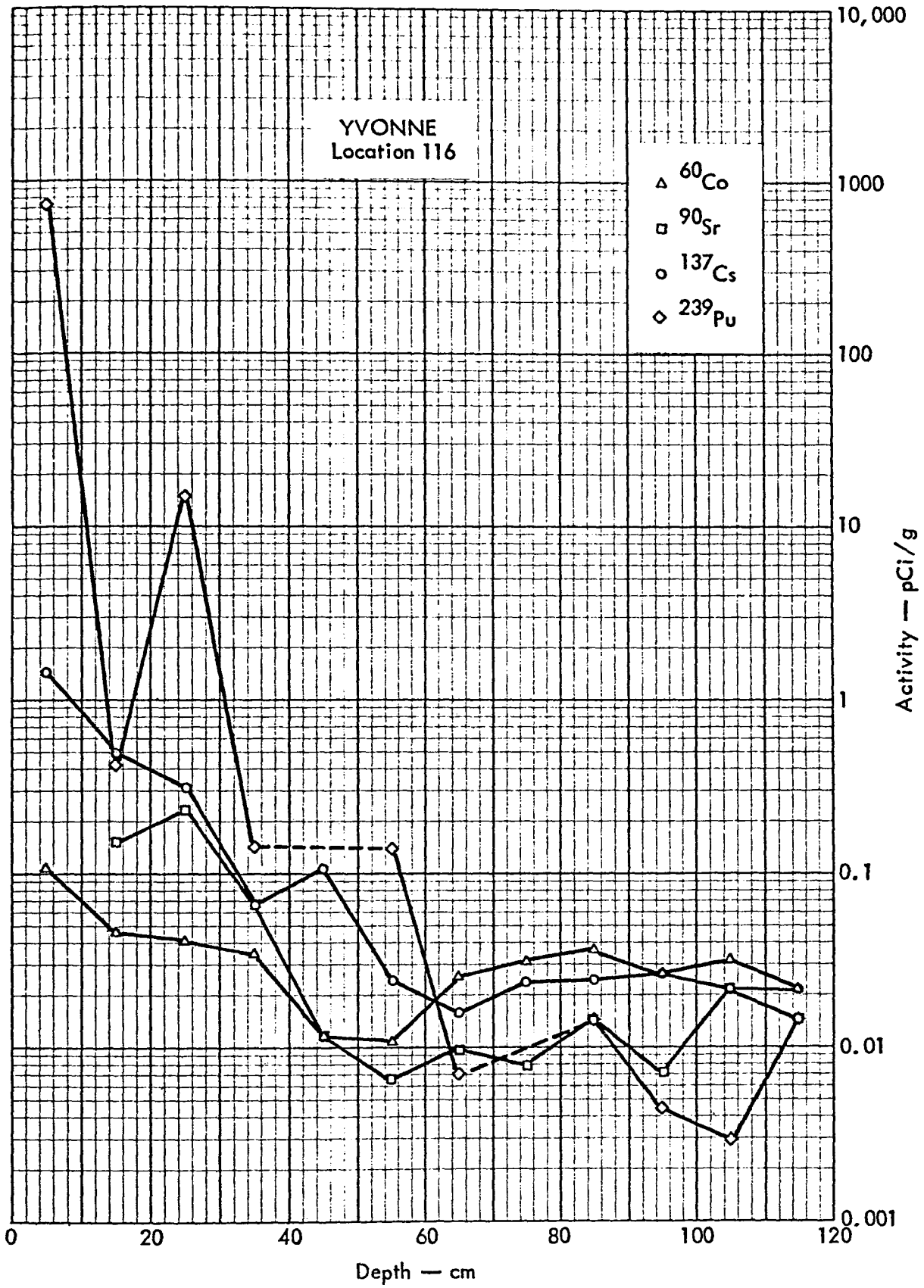

FIGURE 95. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

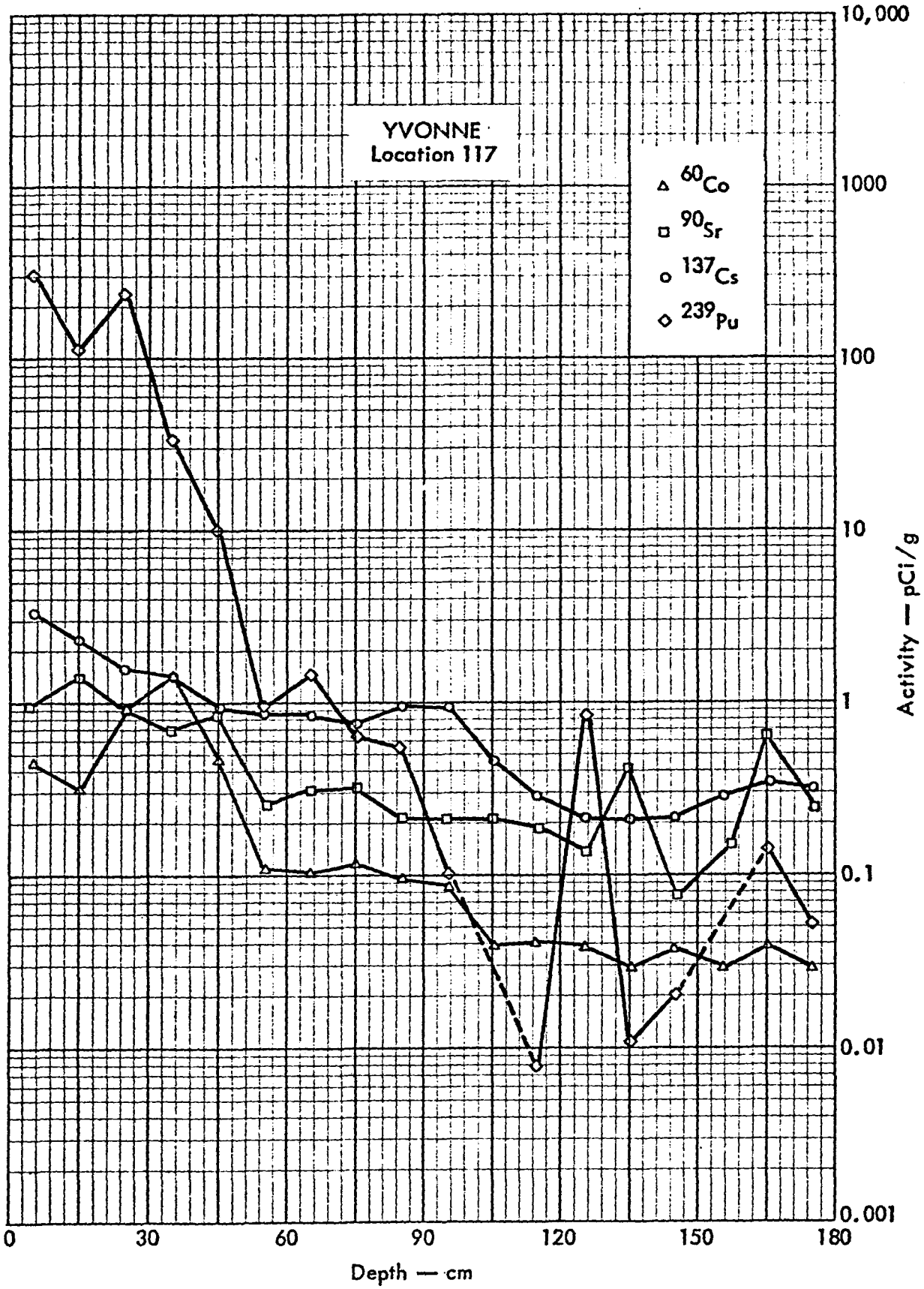

FIGURE 96. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

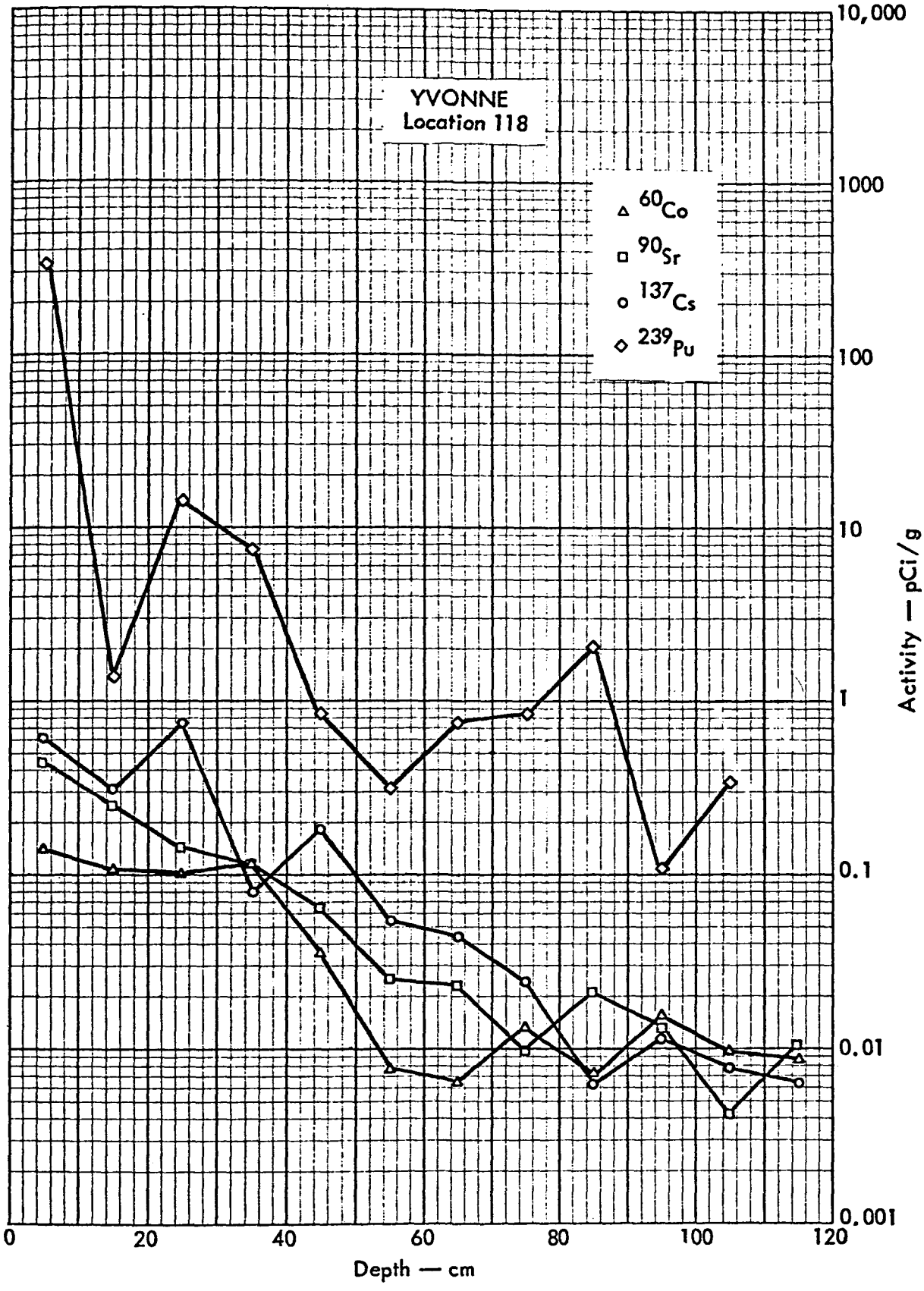

FIGURE 97. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

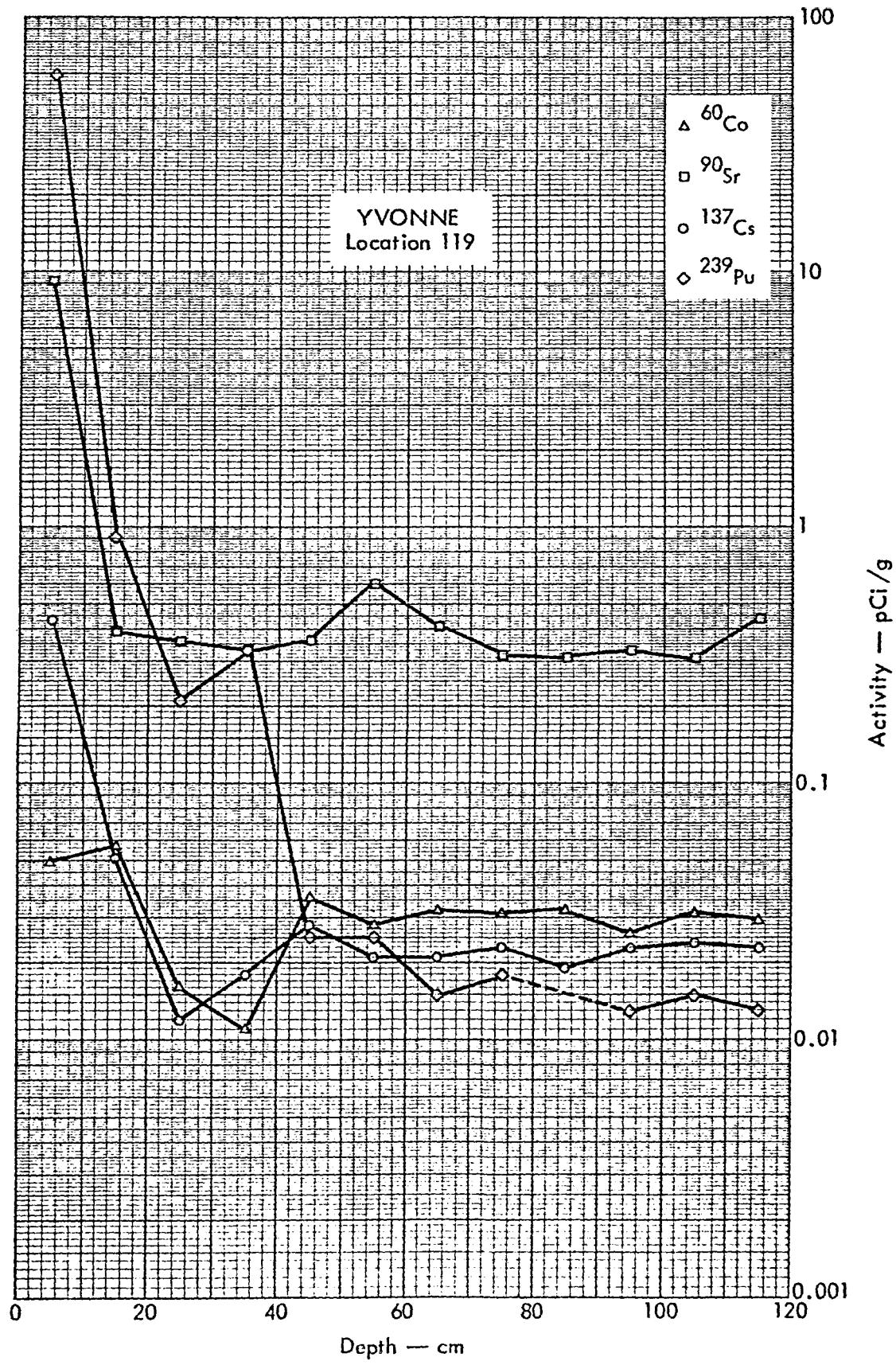

FIGURE 98. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

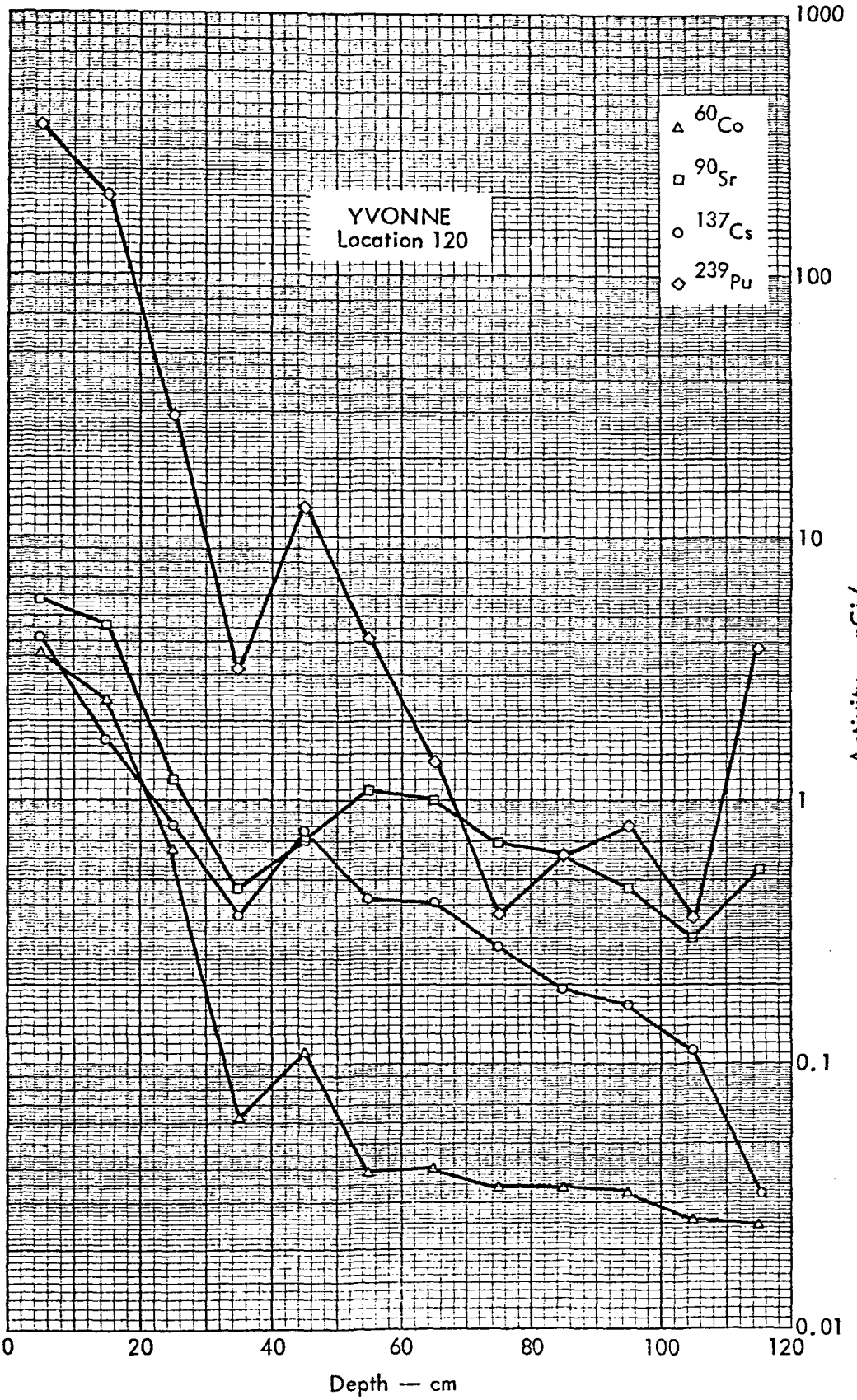

FIGURE 99. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

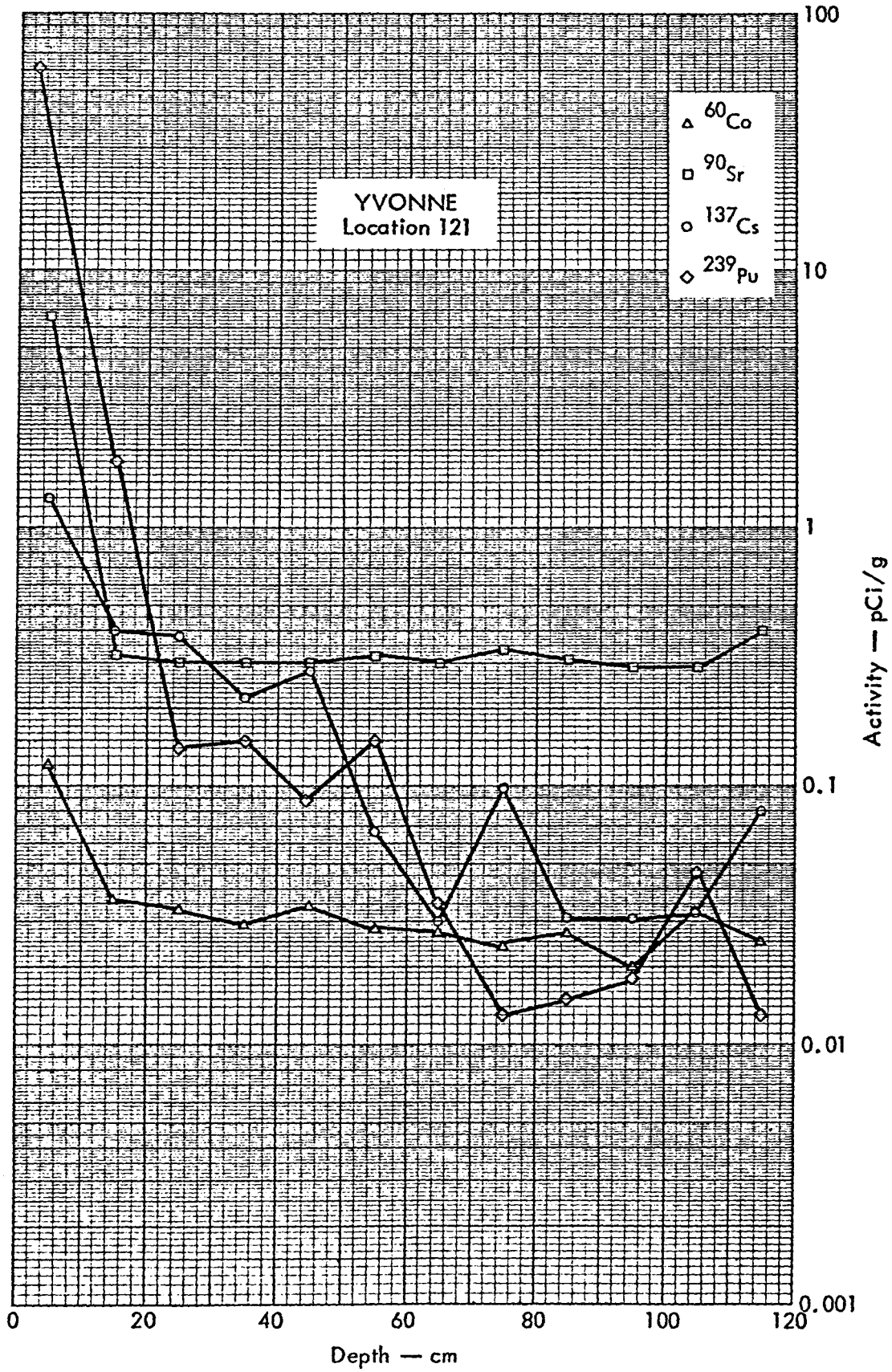

FIGURE 100. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

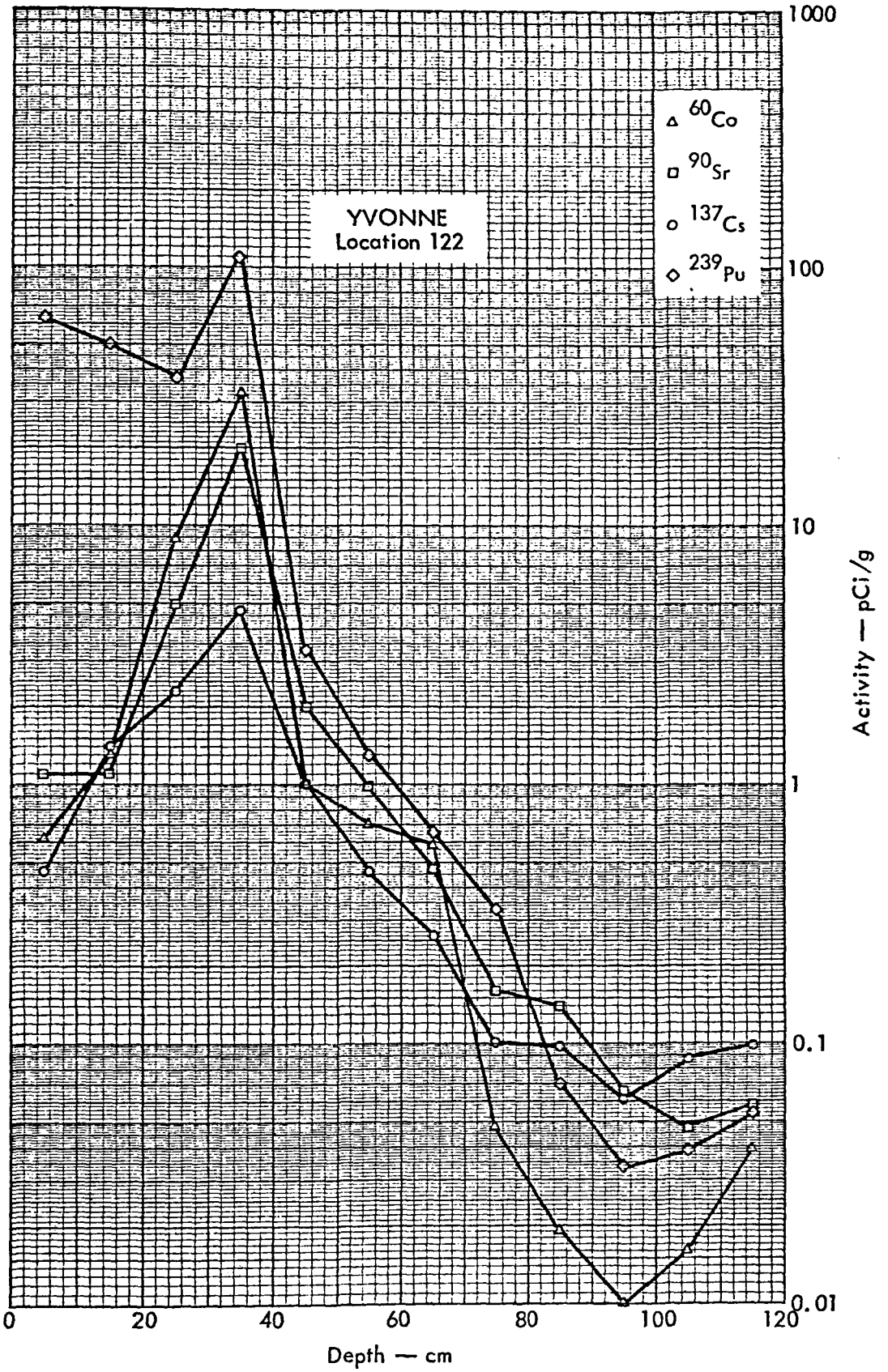

FIGURE 101. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

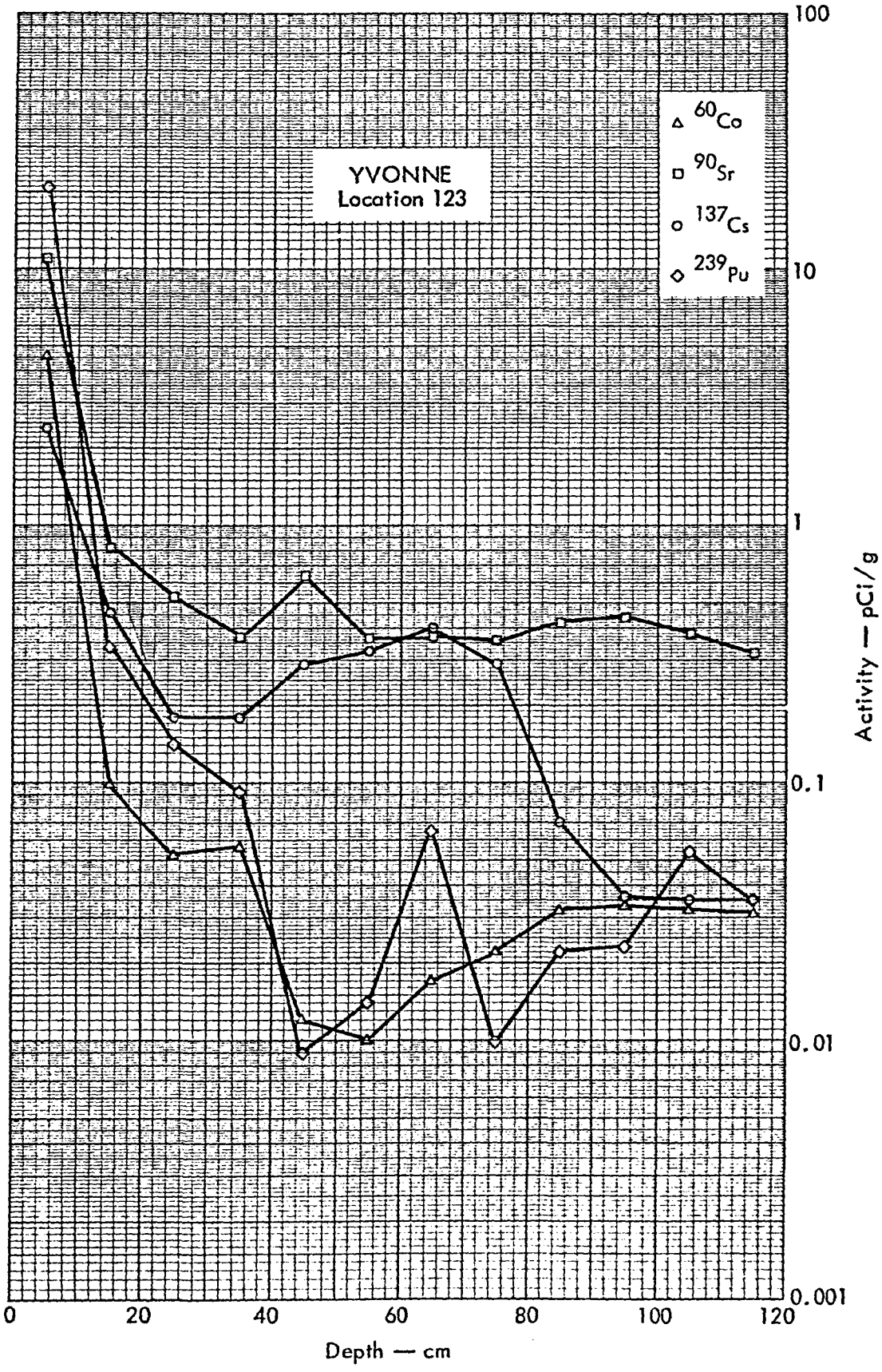

FIGURE 102. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

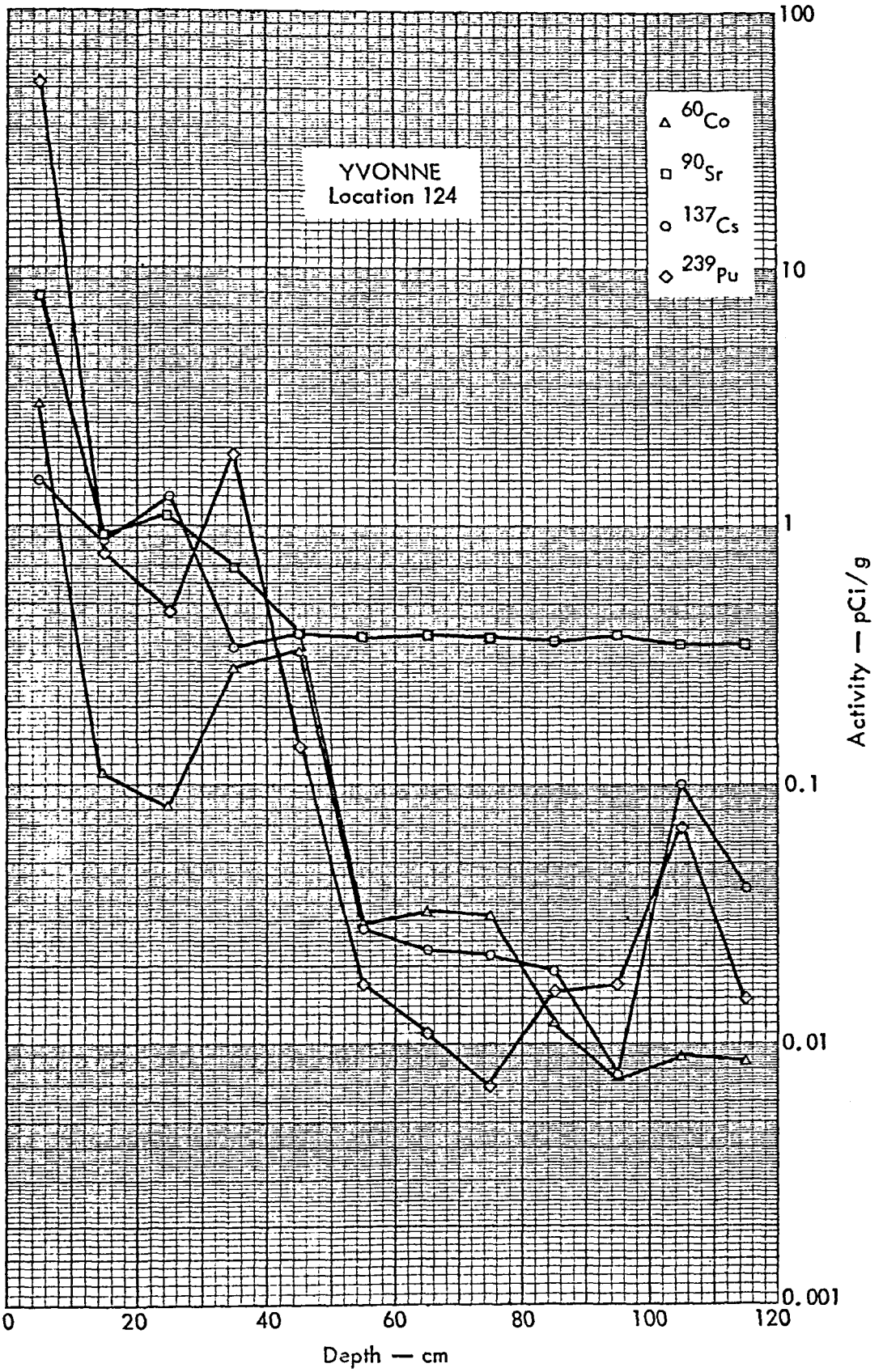

FIGURE 103. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

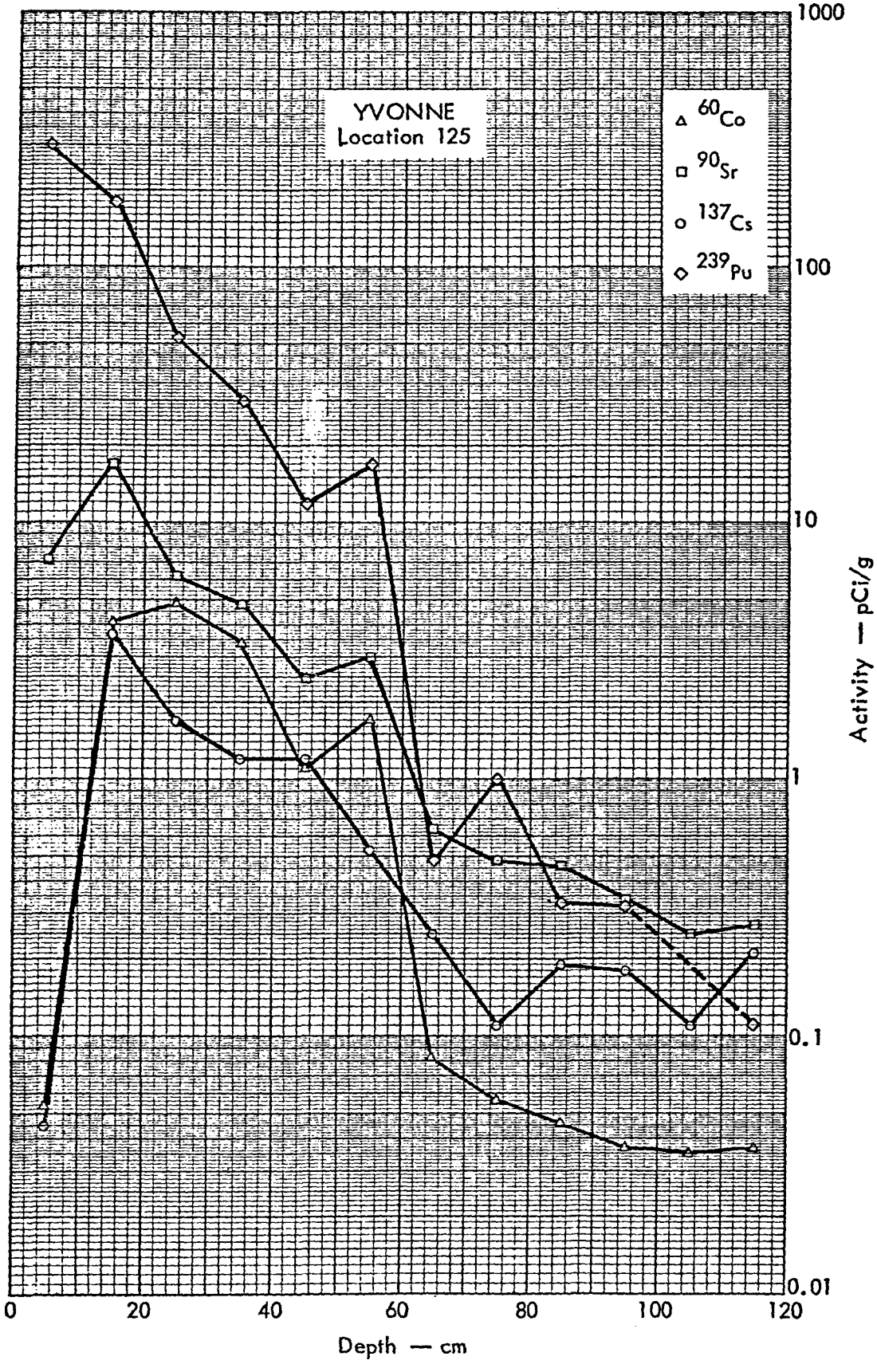

FIGURE 104. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

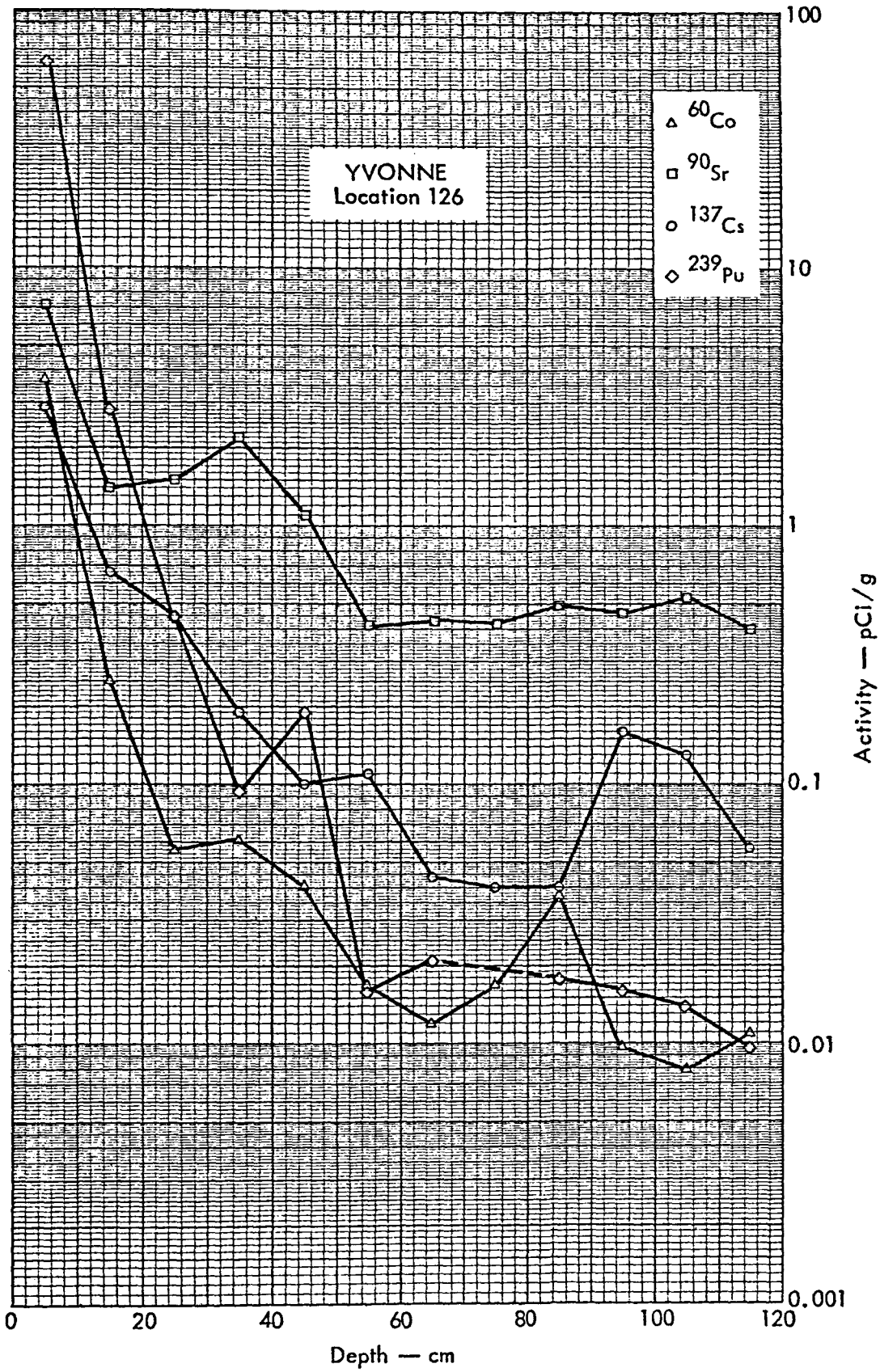

FIGURE 105. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

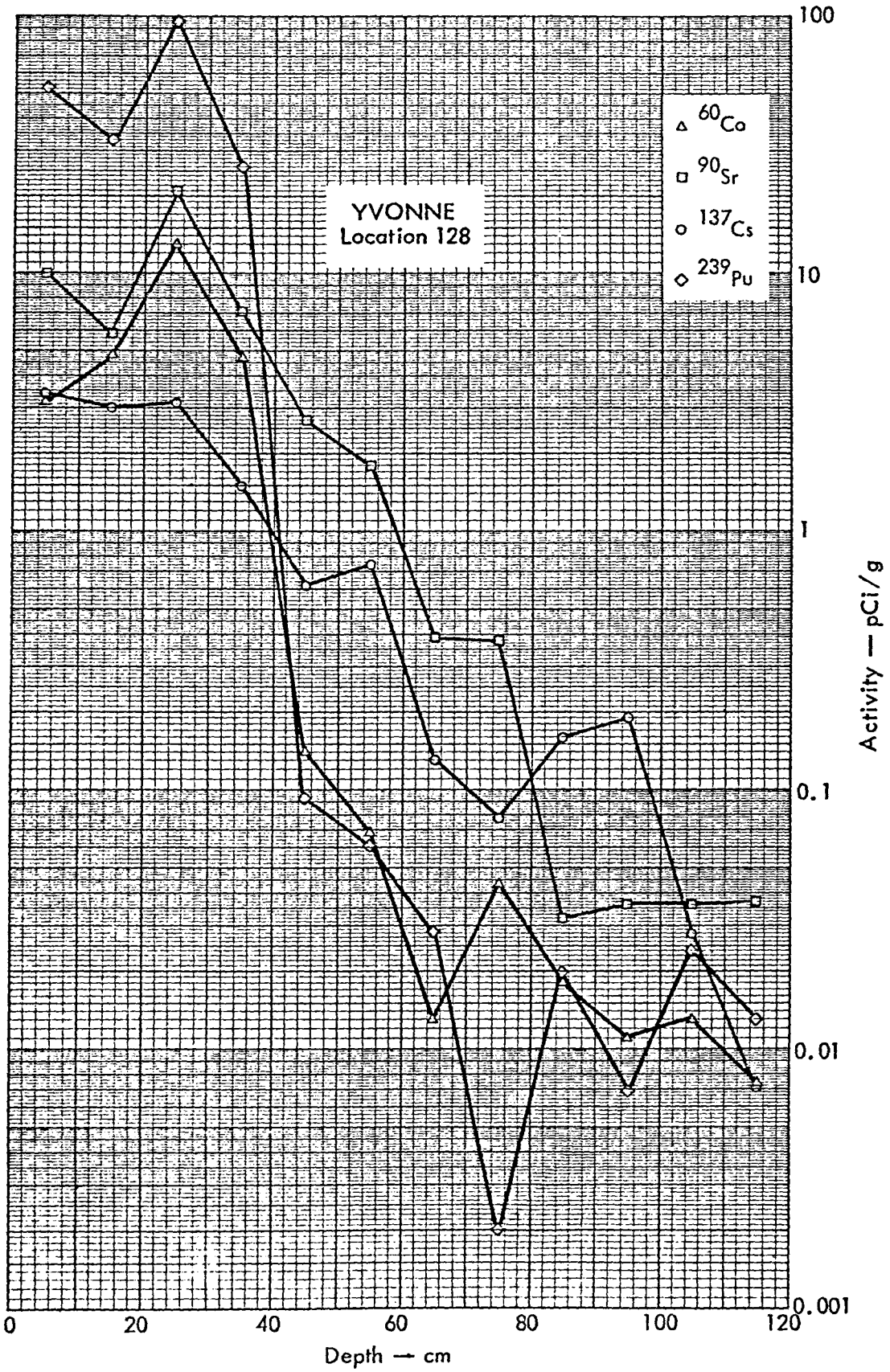

FIGURE 106. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

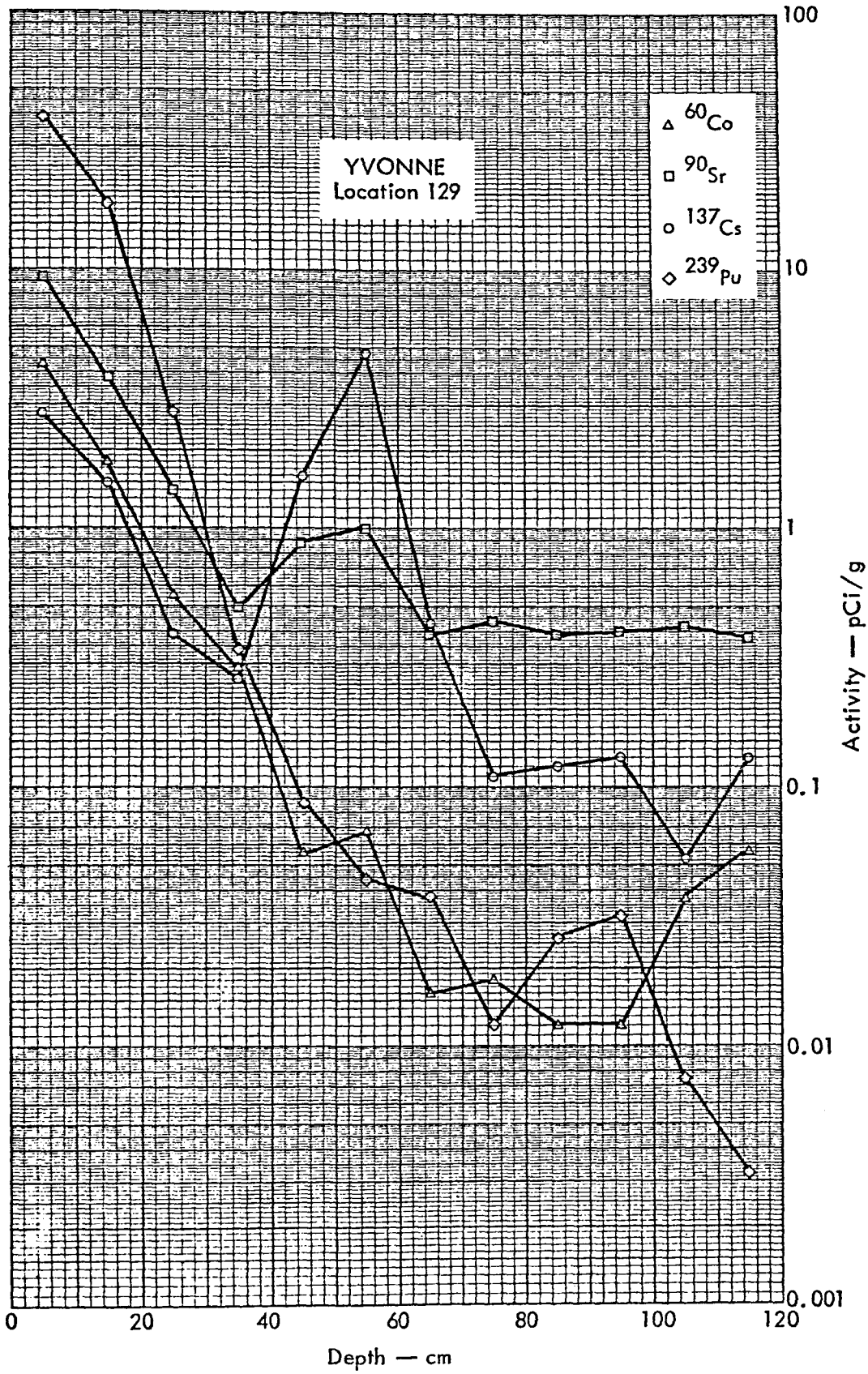

FIGURE 107. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

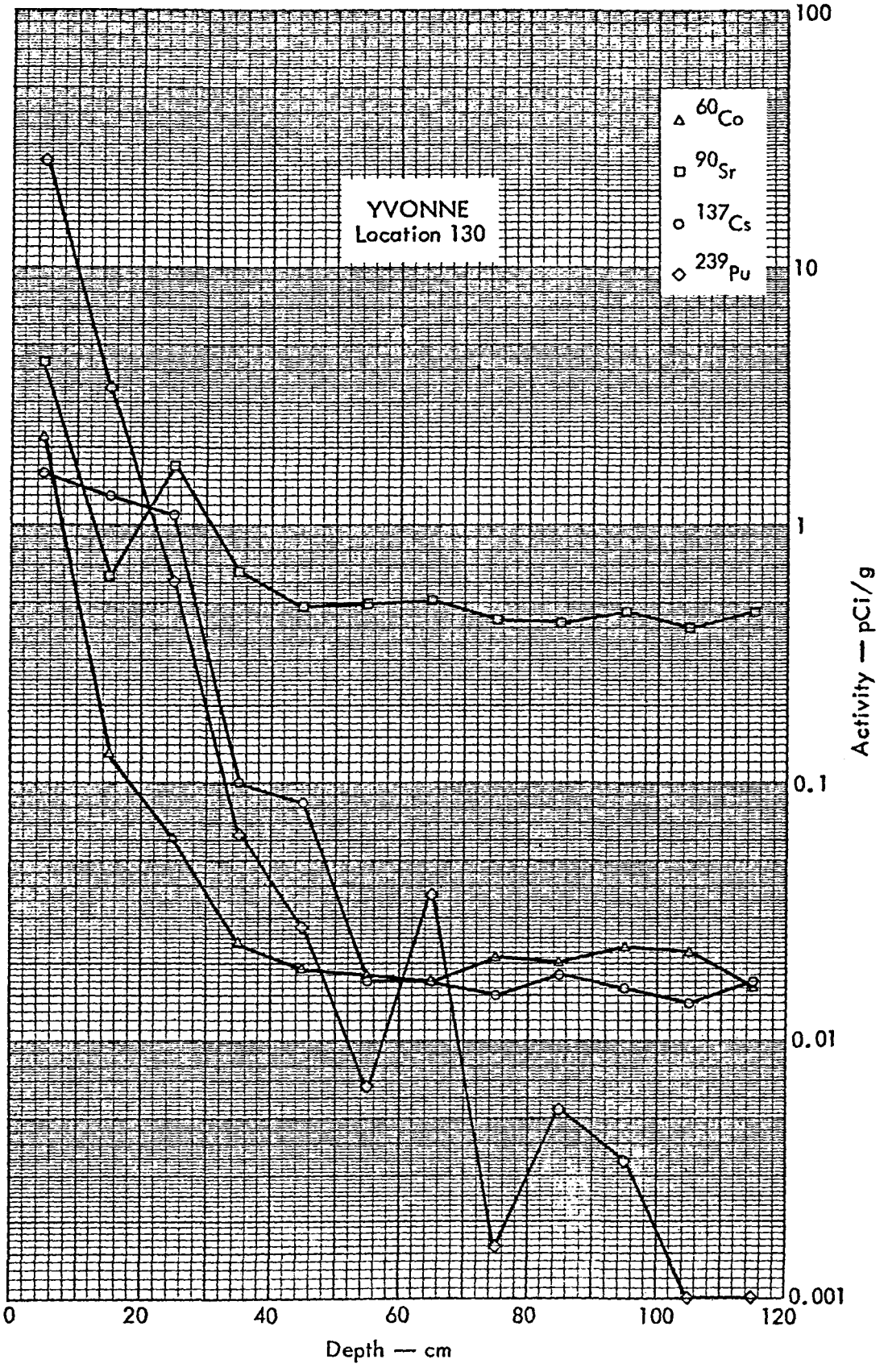

FIGURE 108. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

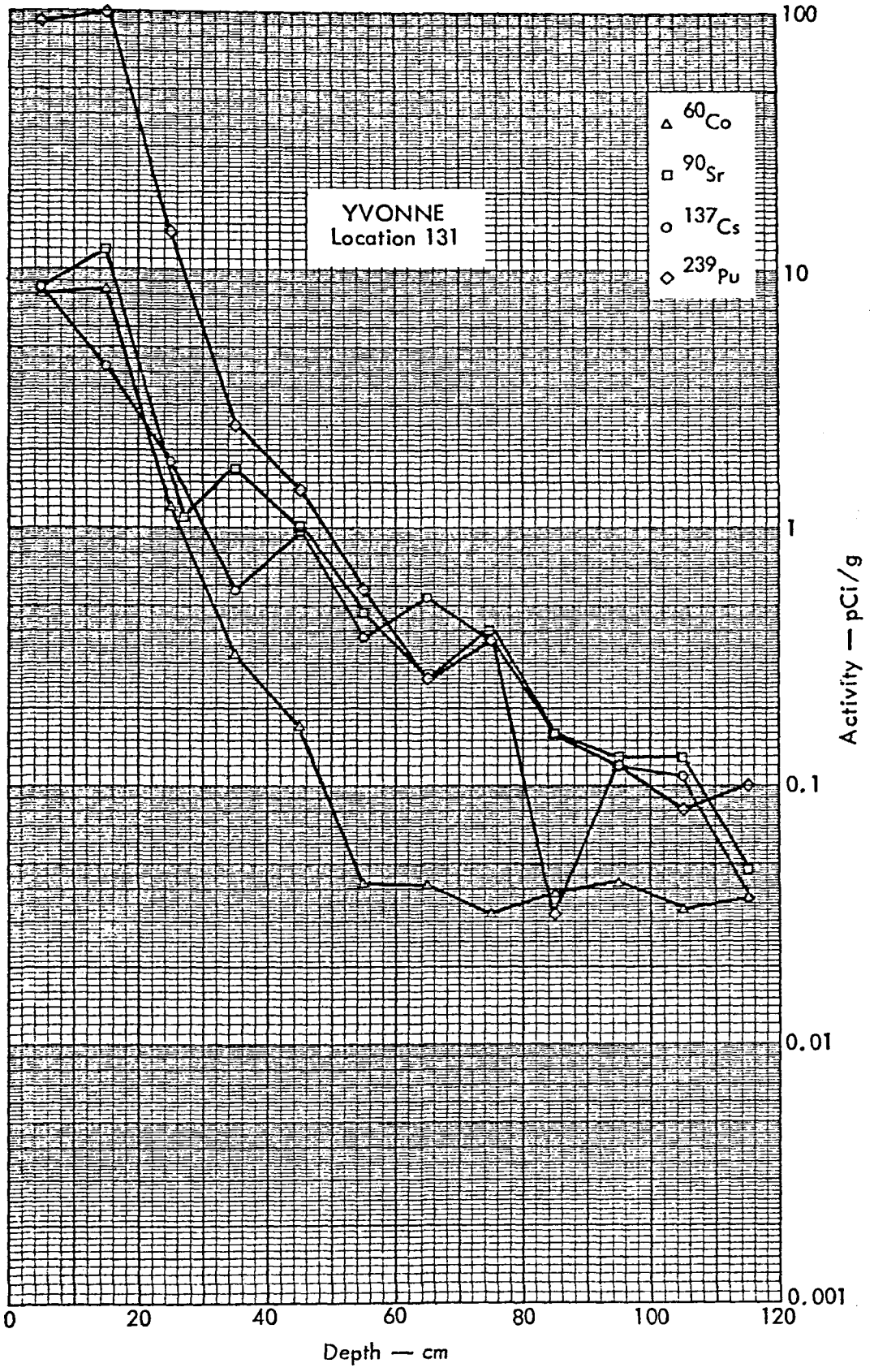

FIGURE 109. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

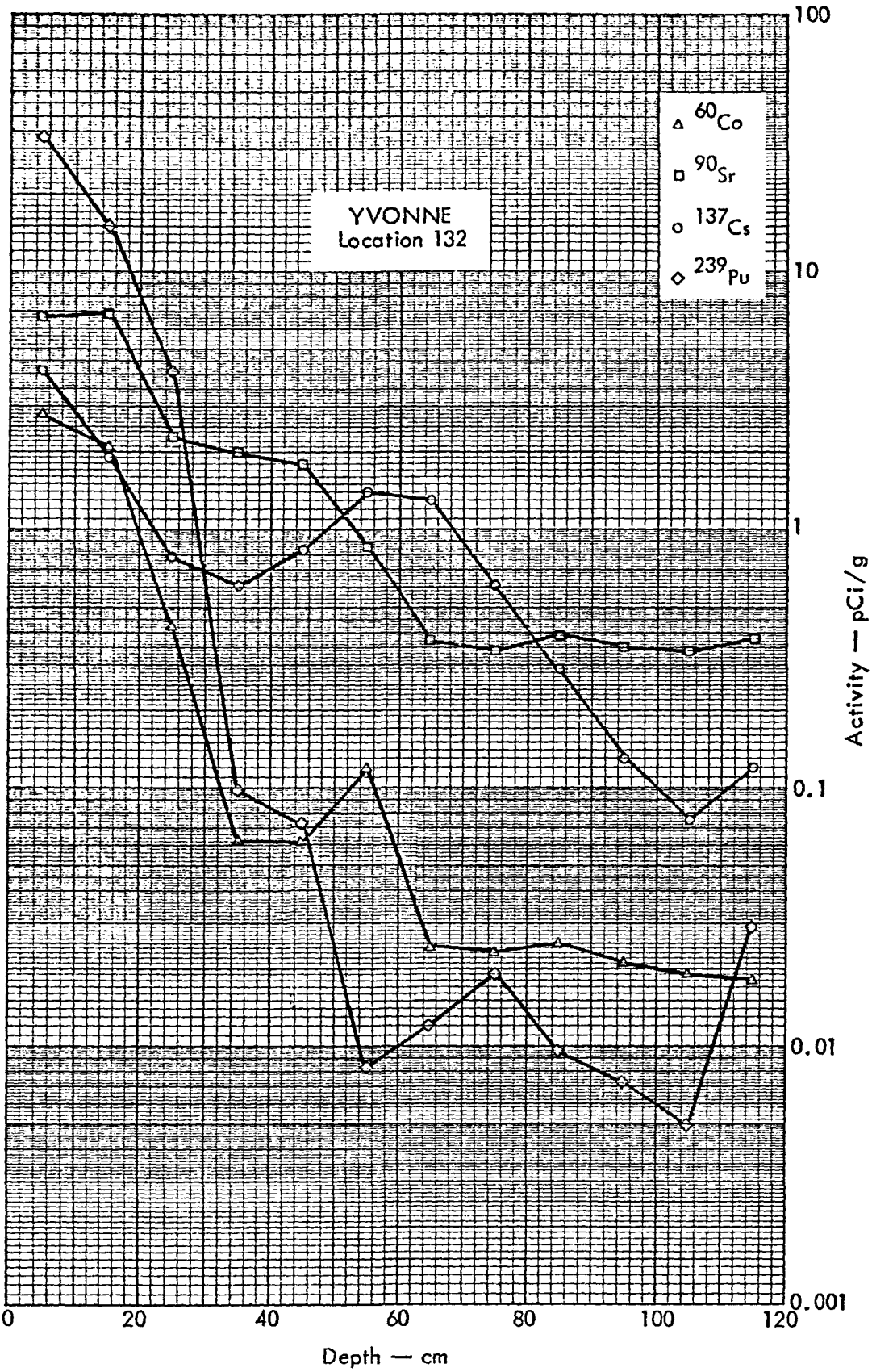

FIGURE 110. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

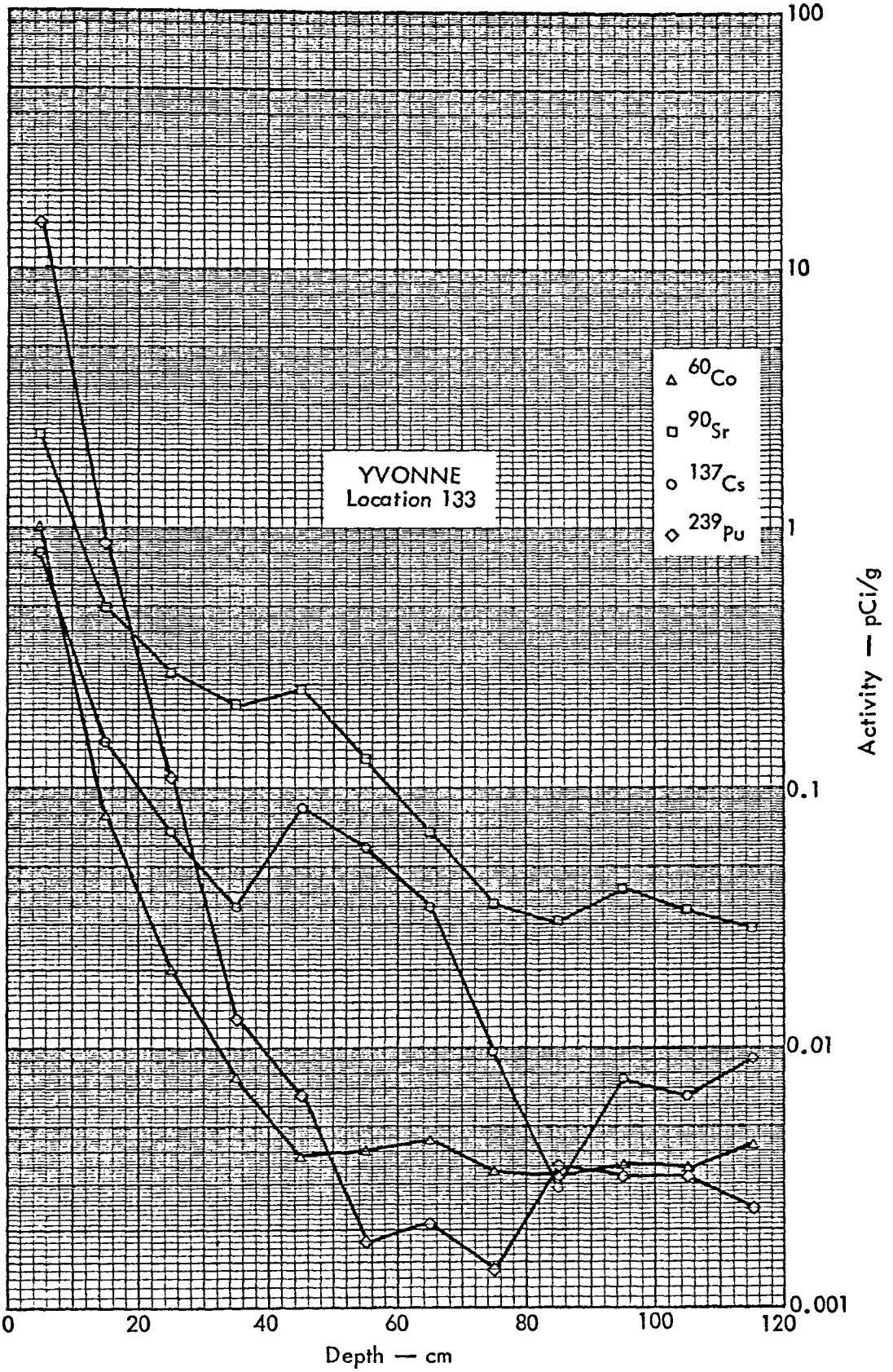

FIGURE 111. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

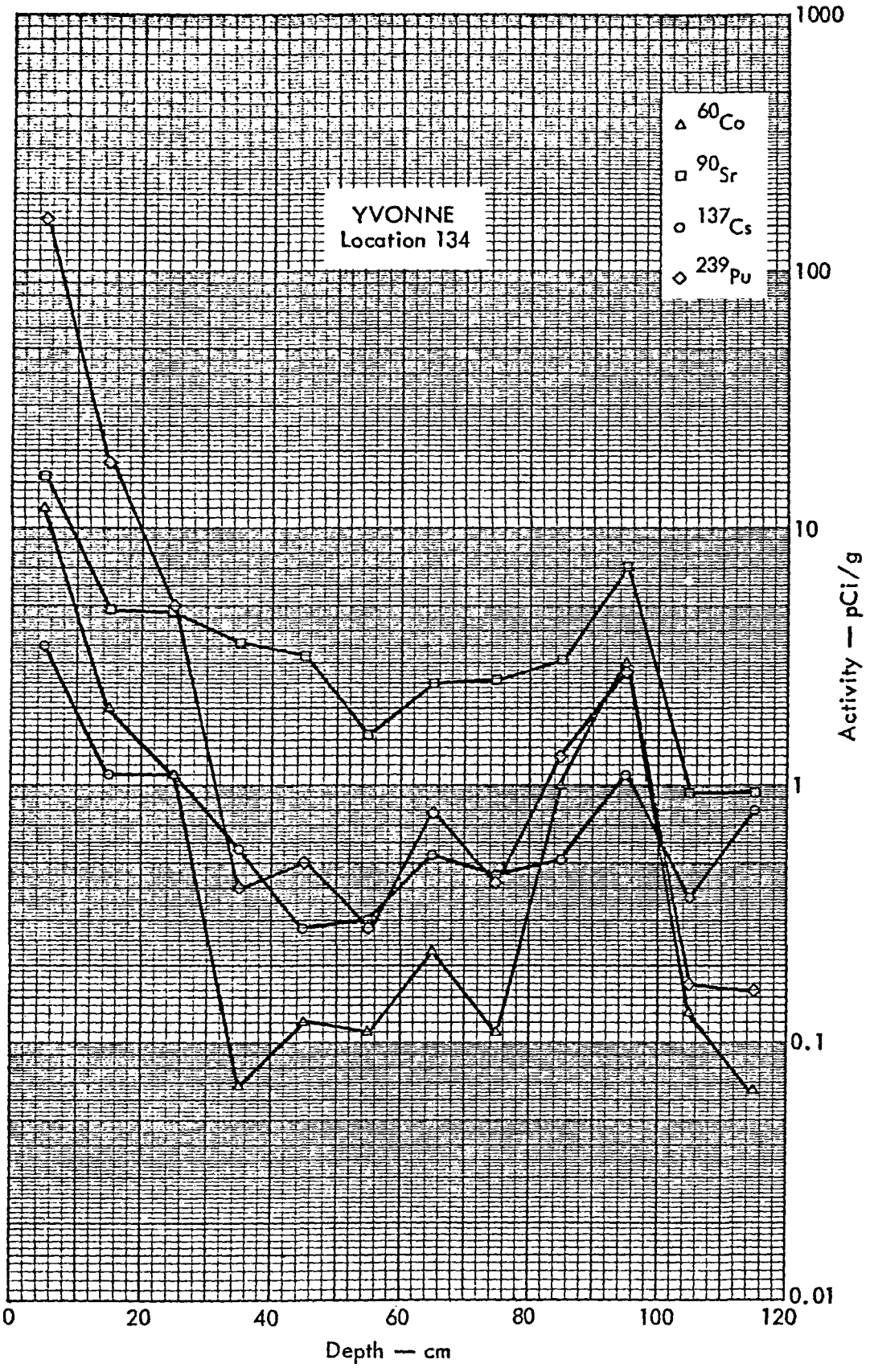

FIGURE 112. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

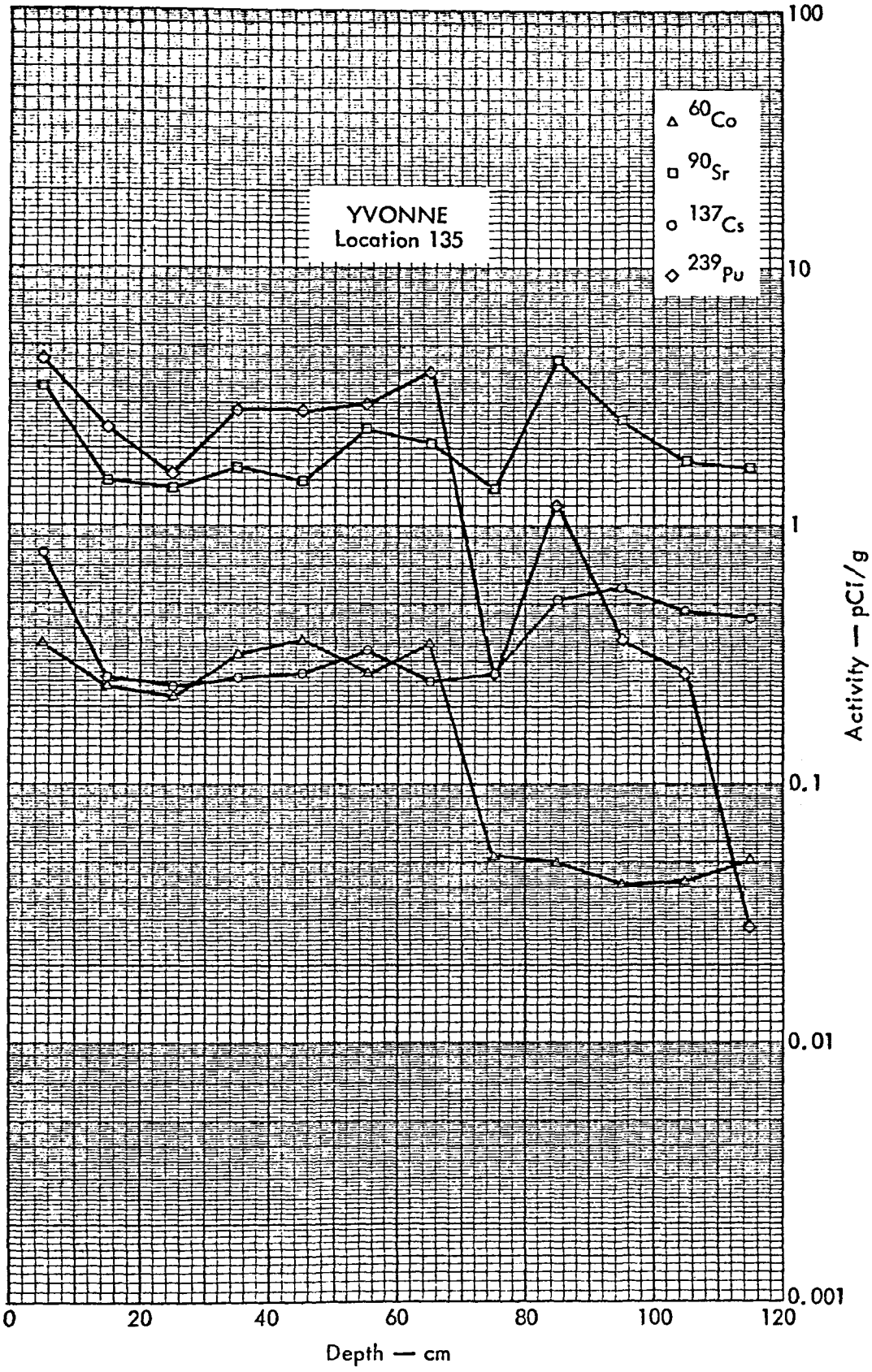

FIGURE 113. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

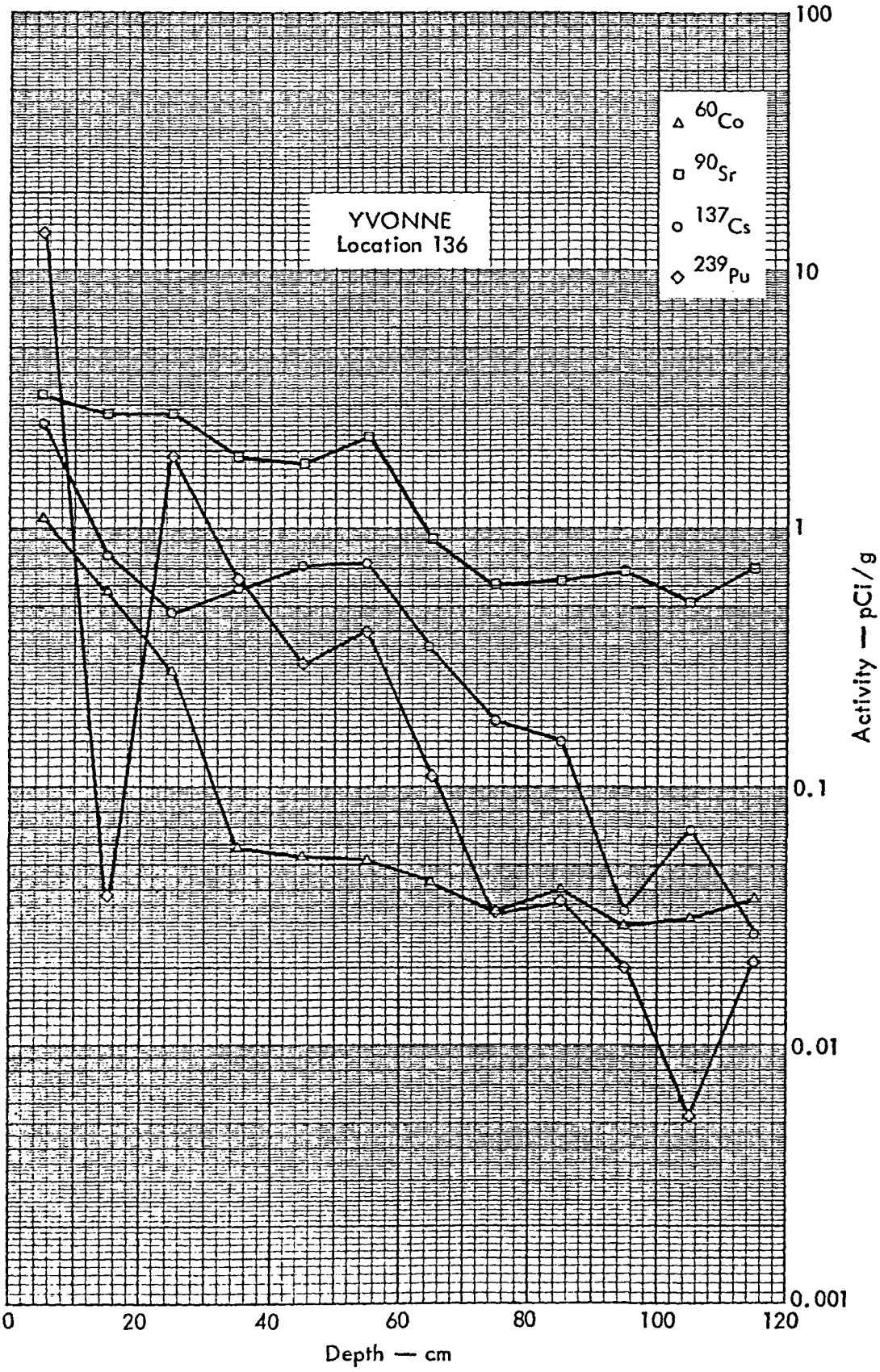

FIGURE 114. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

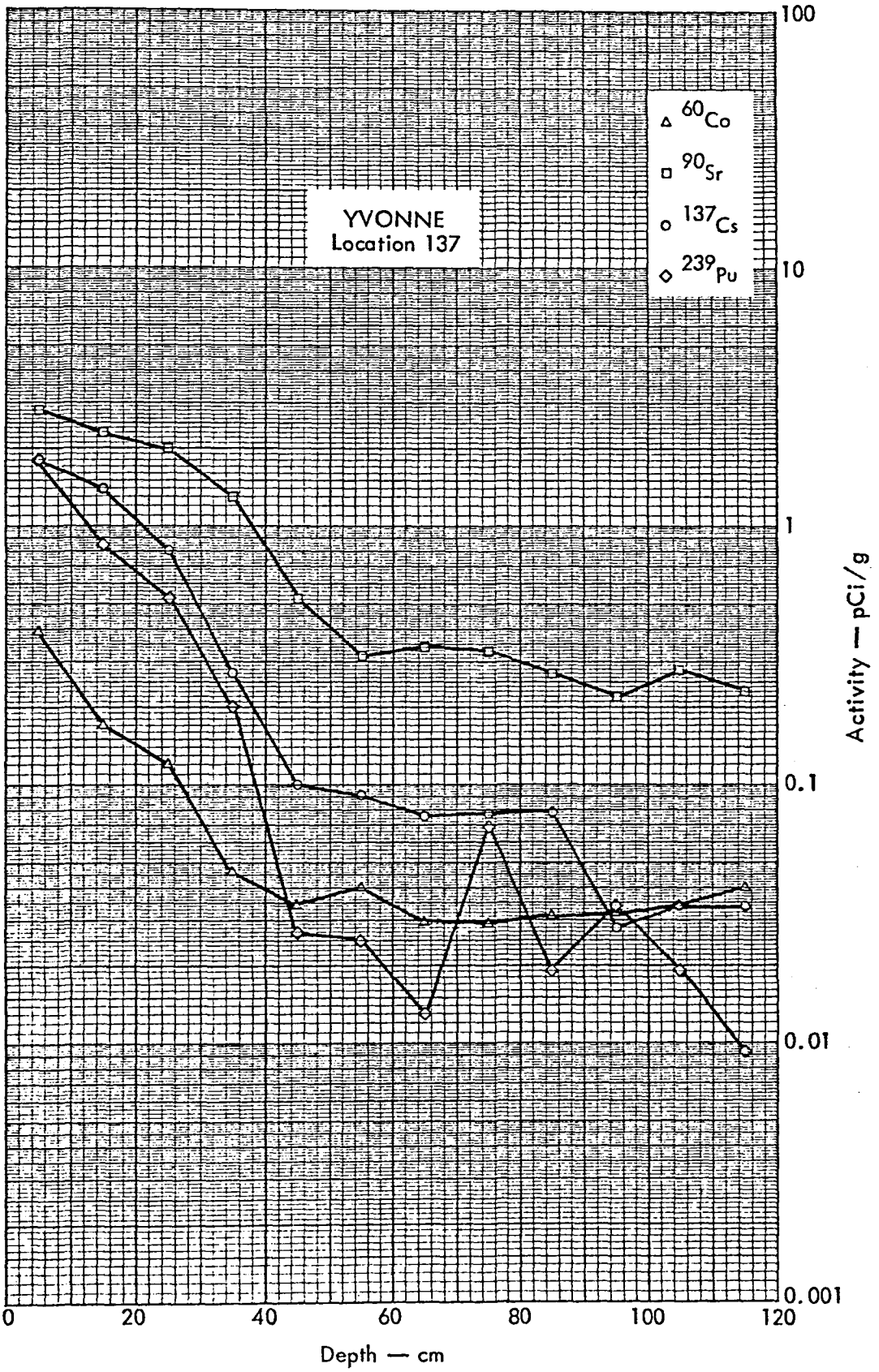

FIGURE 115. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

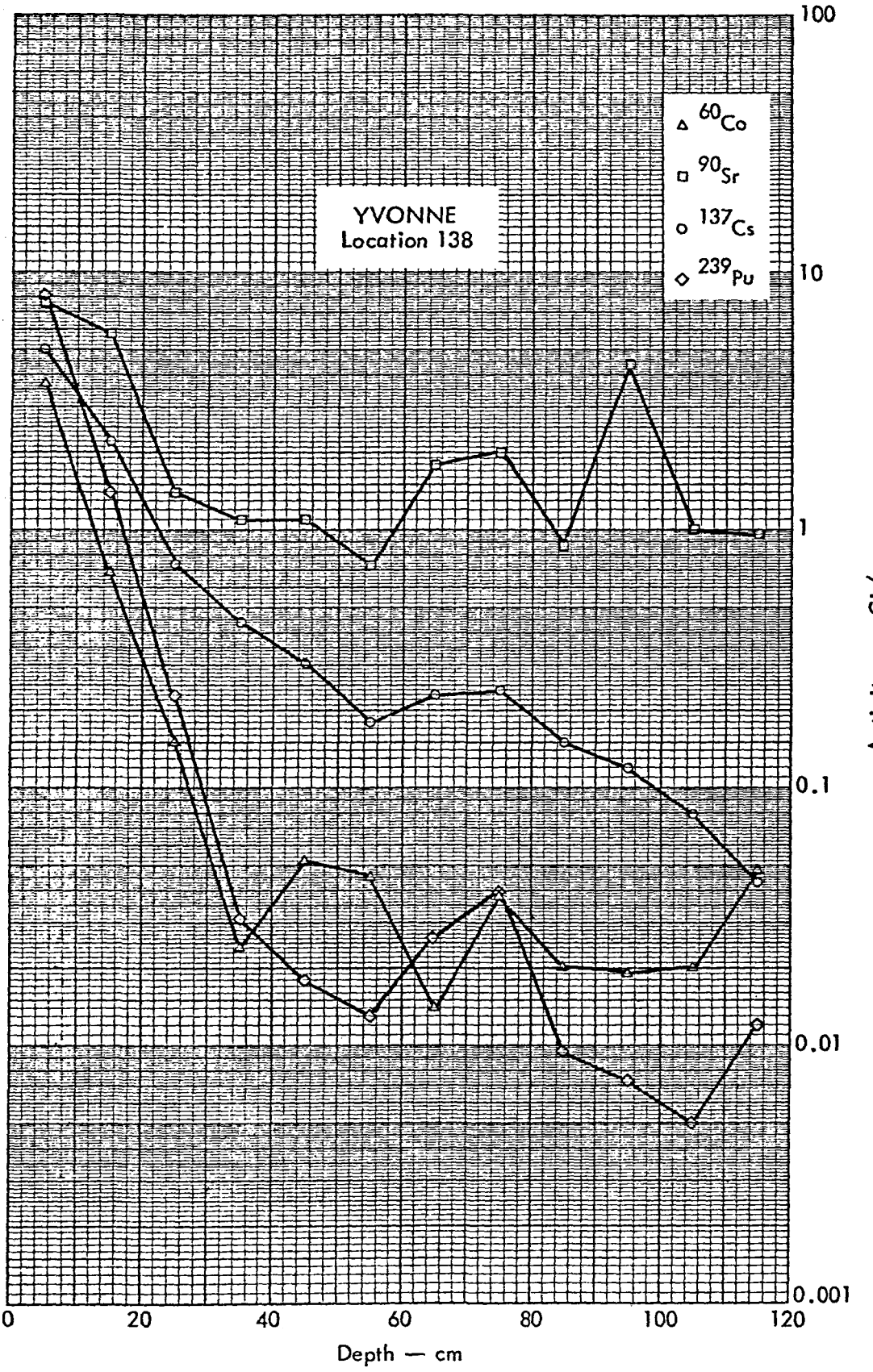

FIGURE 116. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

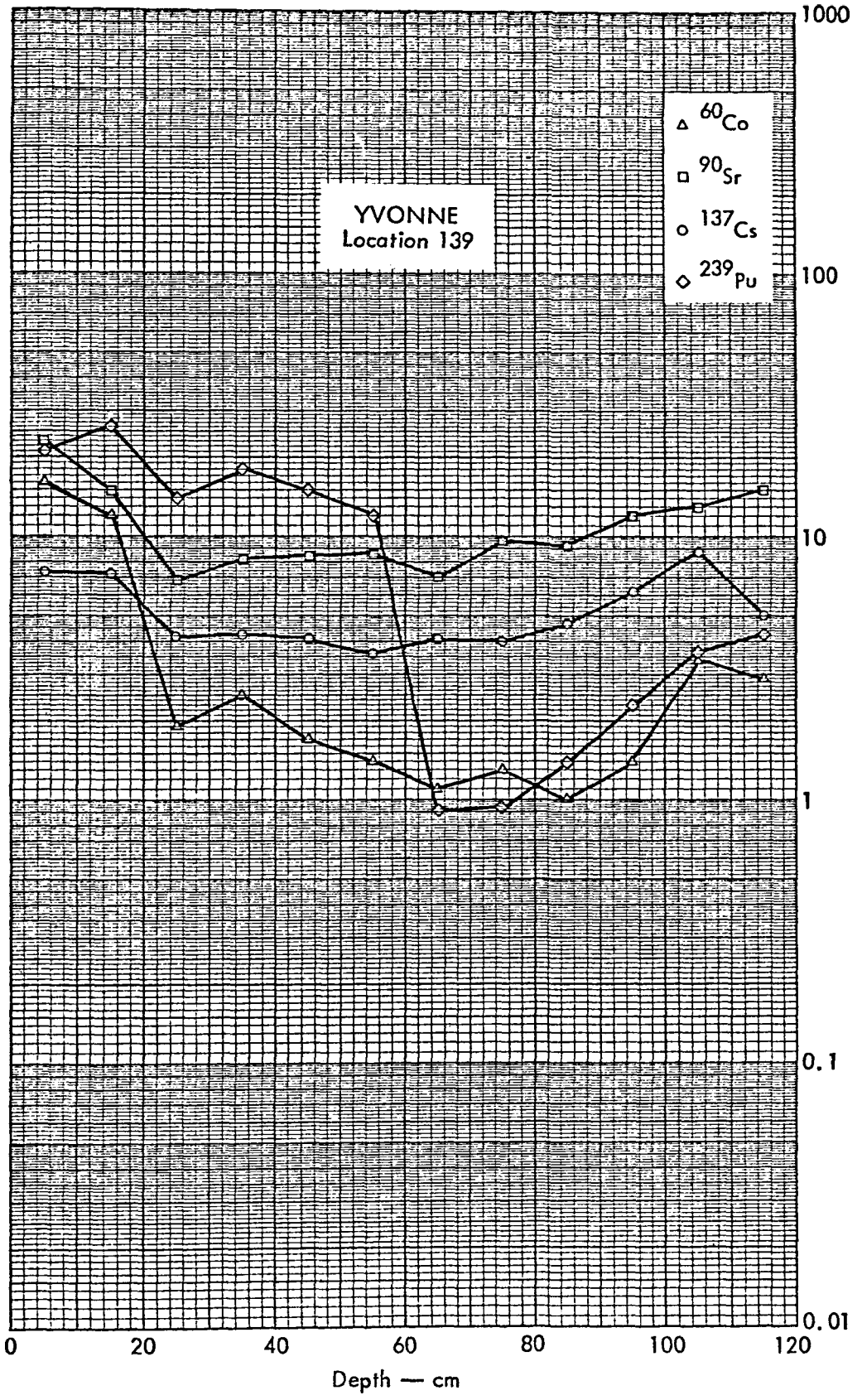

FIGURE 117. ACTIVITIES OF SELECTED RADIONUCLIDES AS A FUNCTION OF SOIL DEPTH

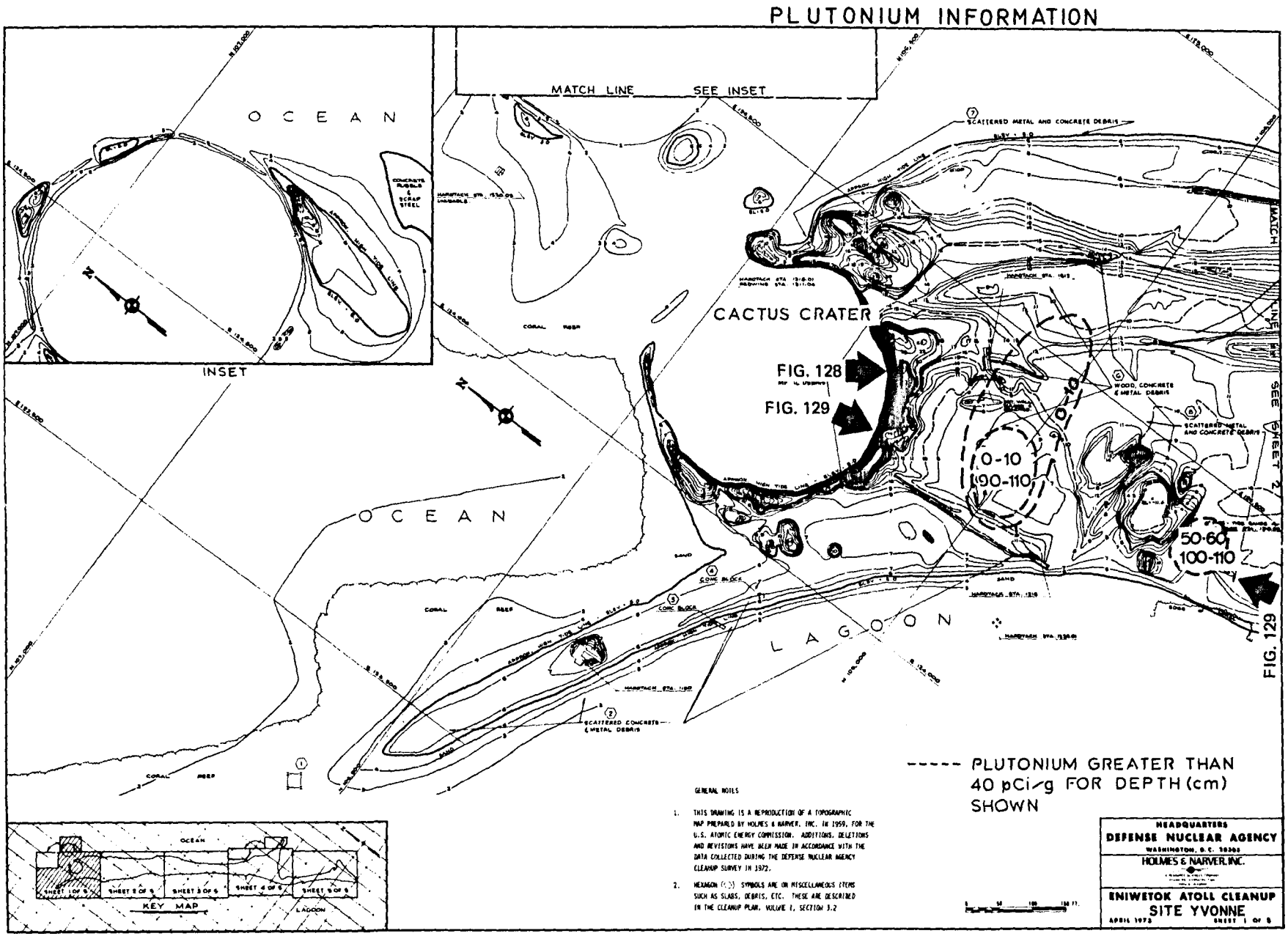

FIGURE 118. SITE YVONNE, PLUTONIUM DATA, SHEET 1 OF 5

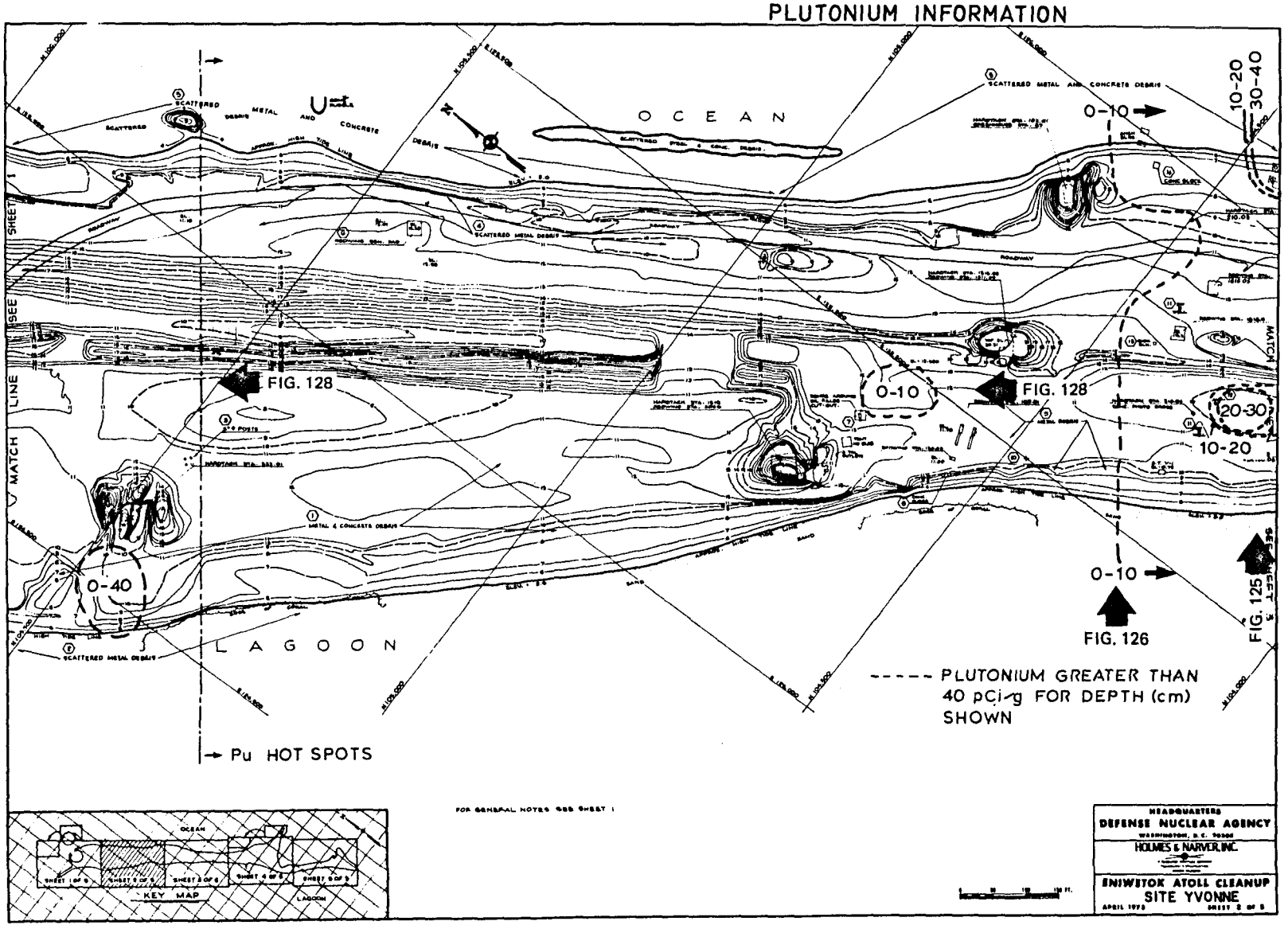

FIGURE 119. SITE YVONNE, PLUTONIUM DATA, SHEET 2 OF 5

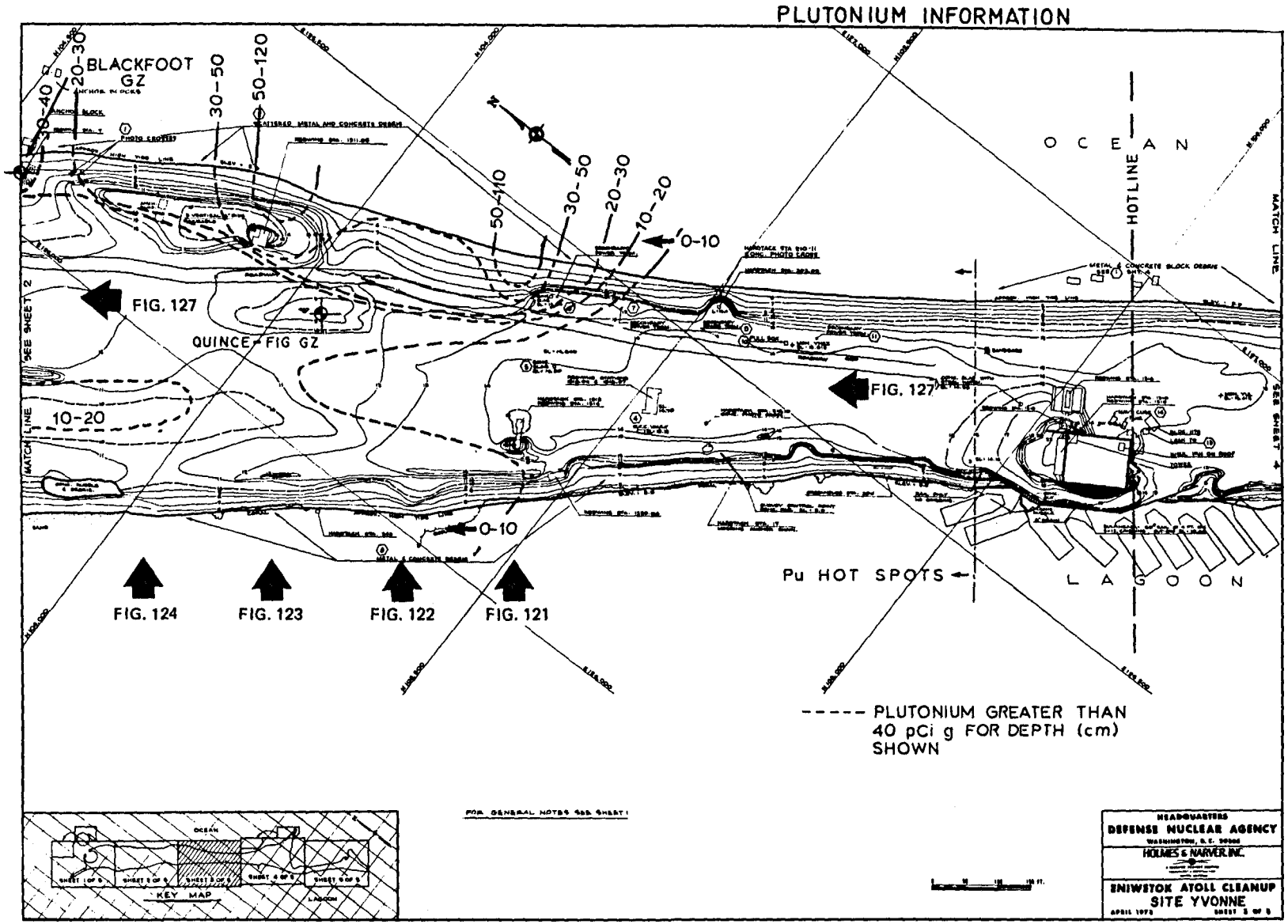

FIGURE 120. SITE YVONNE, PLUTONIUM DATA, SHEET 3 OF 5

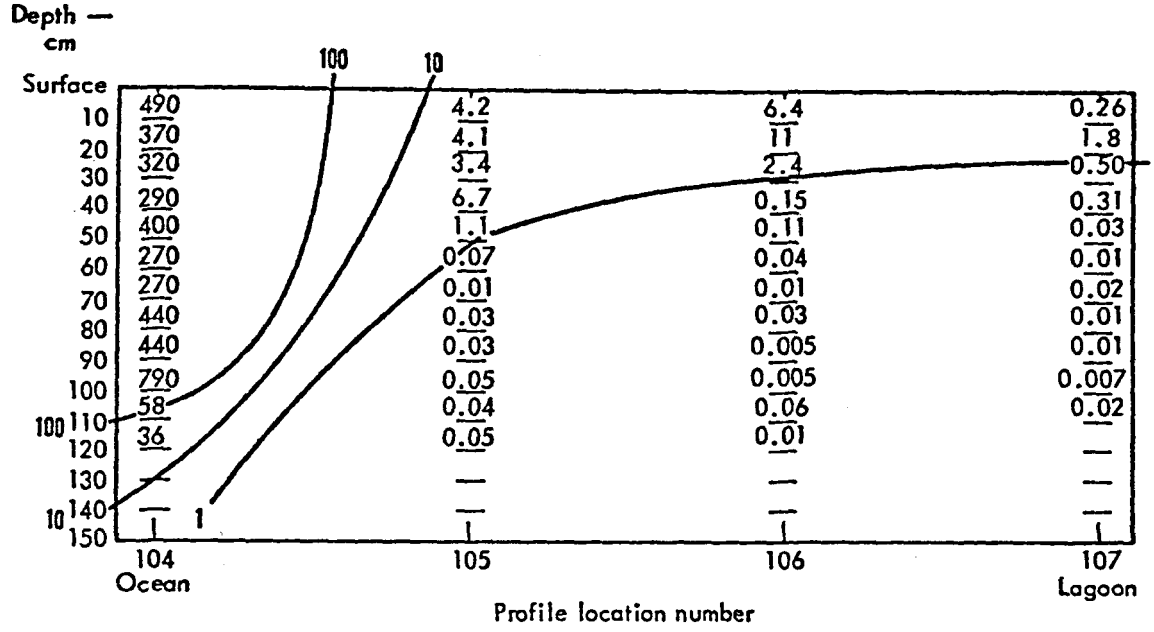

FIGURE 121. SITE YVONNE, PLUTONIUM PROFILE DATA

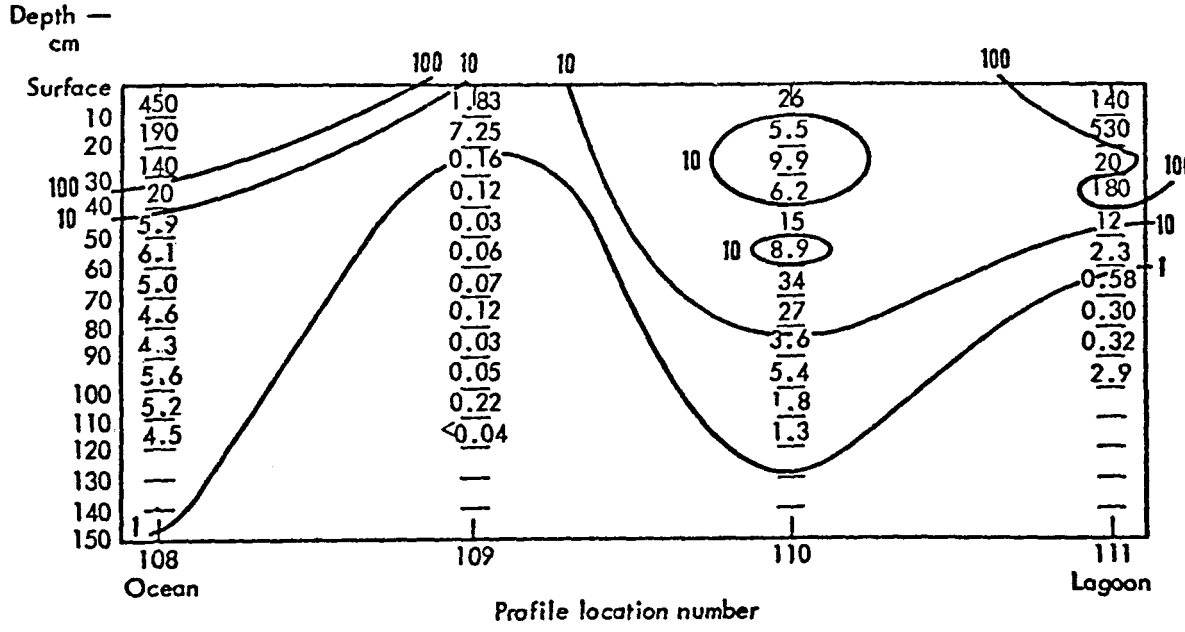

FIGURE 122. SITE YVONNE, PLUTONIUM PROFILE DATA

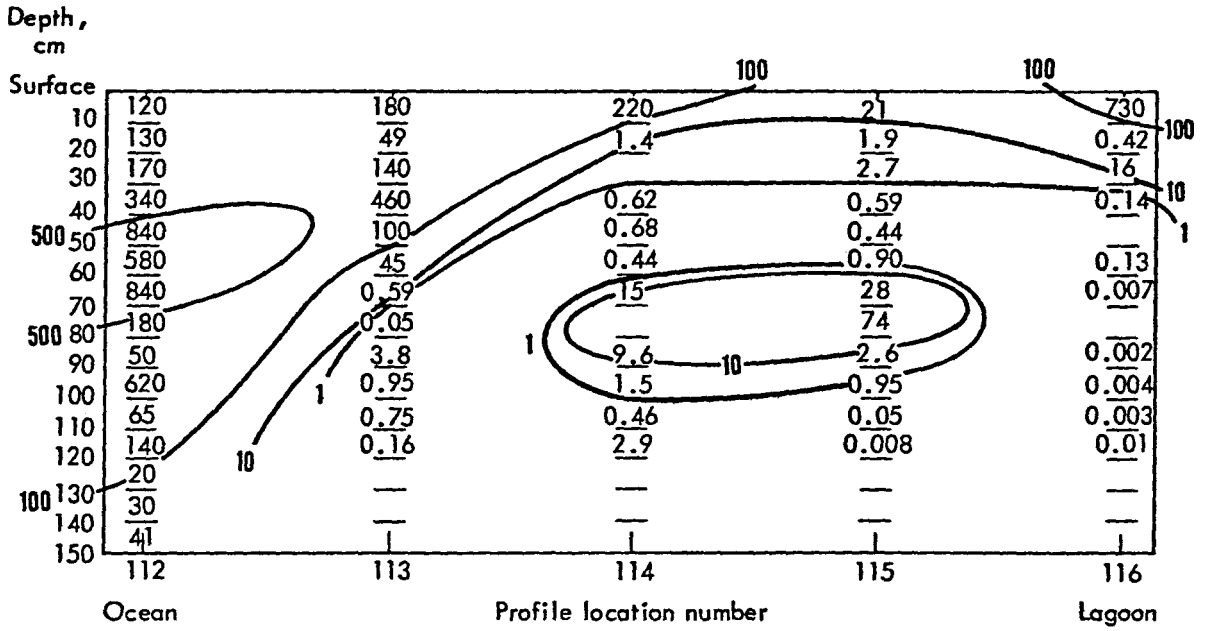

FIGURE 123. SITE YVONNE, PLUTONIUM PROFILE DATA

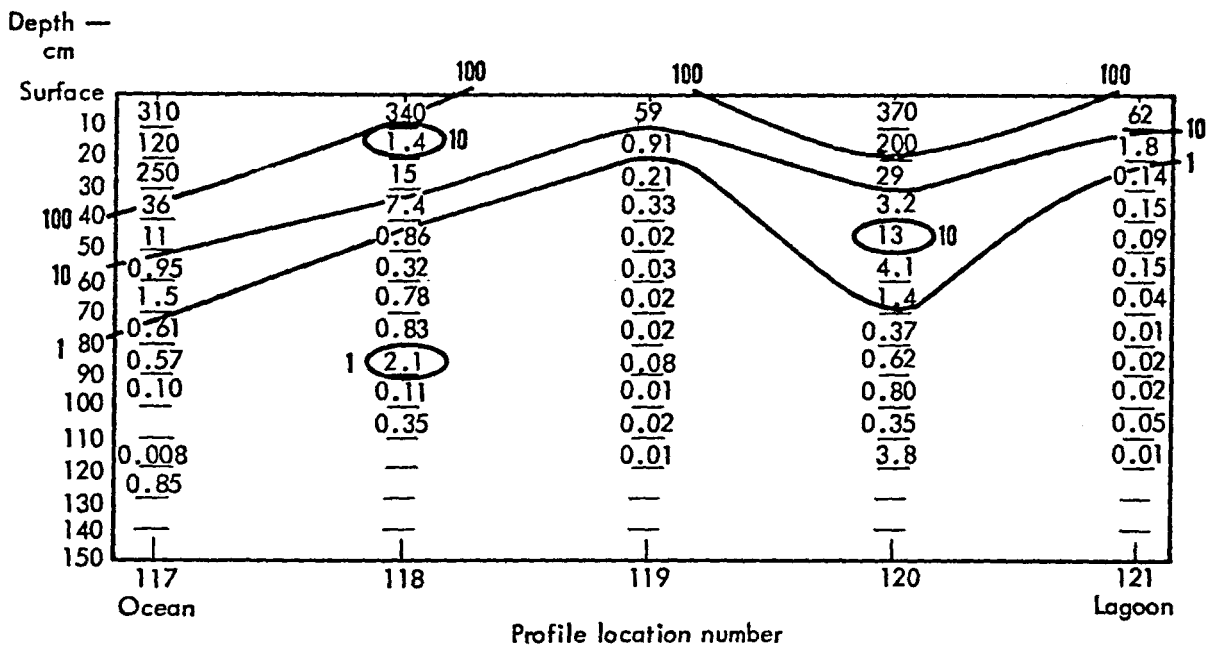

FIGURE 124. SITE YVONNE, PLUTONIUM PROFILE DATA

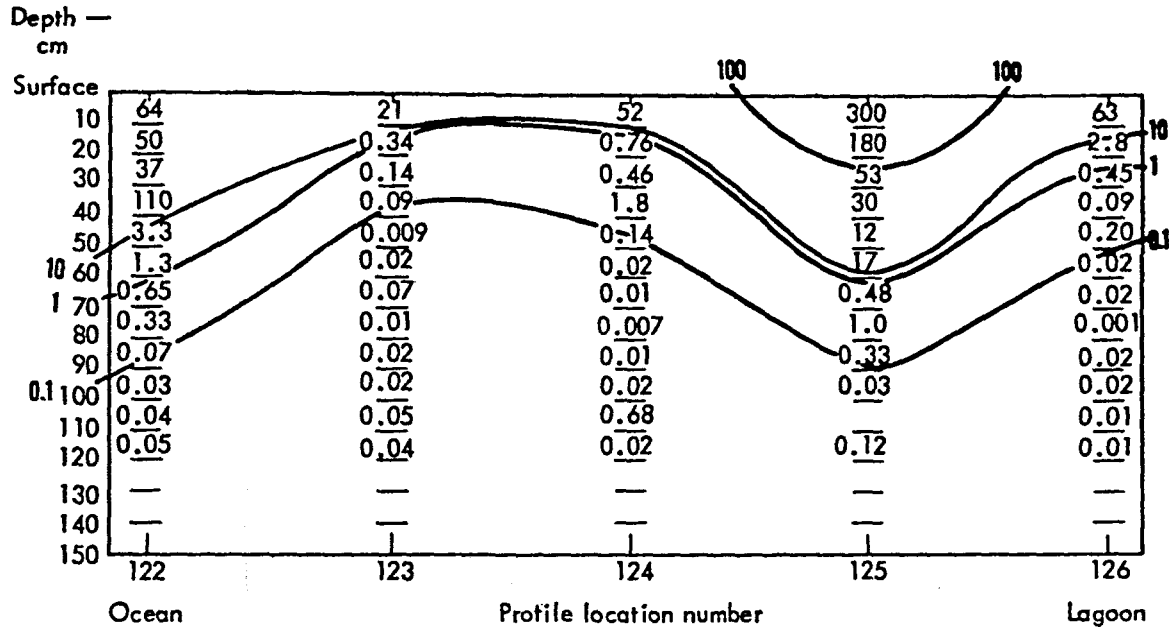

FIGURE 125. SITE YVONNE, PLUTONIUM PROFILE DATA

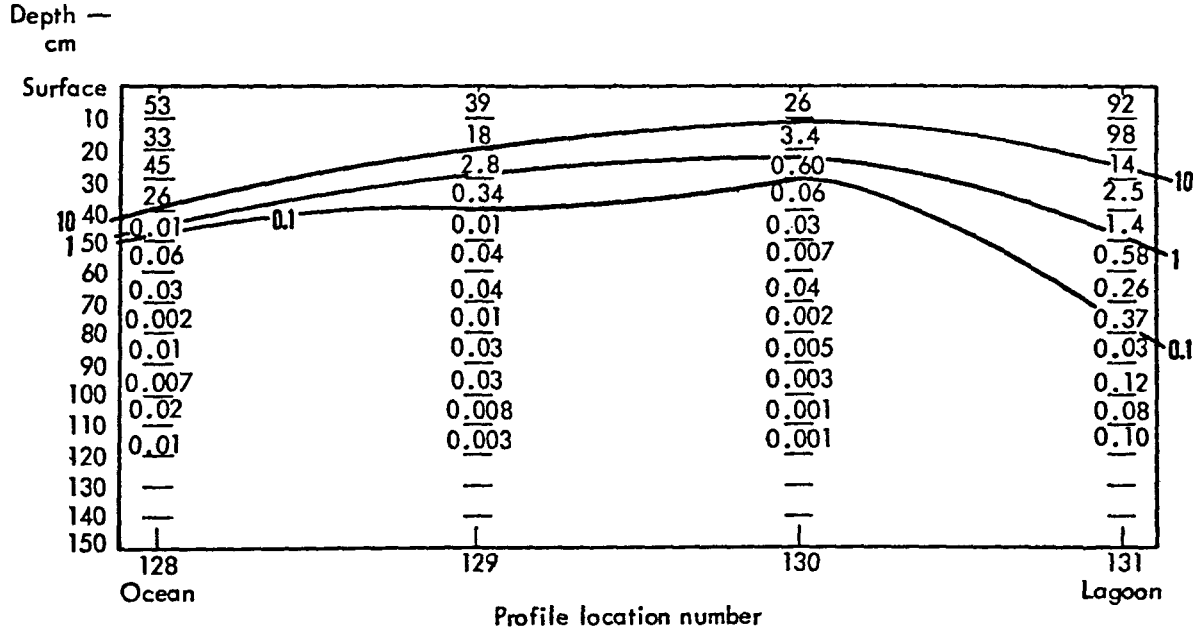

FIGURE 126. SITE YVONNE, PLUTONIUM PROFILE DATA

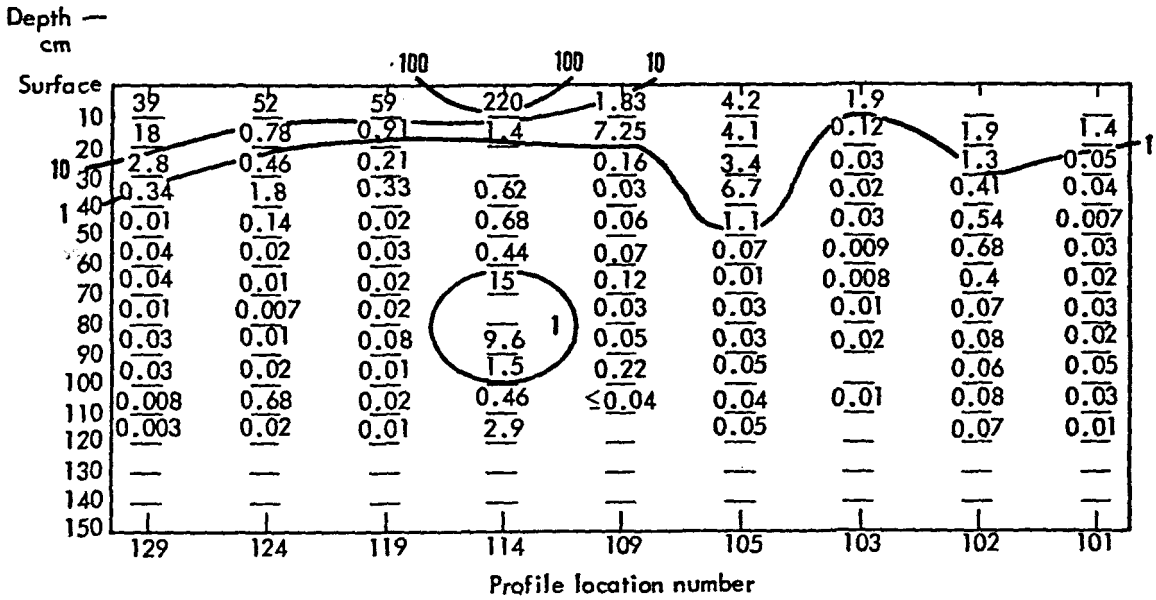

FIGURE 127. SITE YVONNE, PLUTONIUM PROFILE DATA

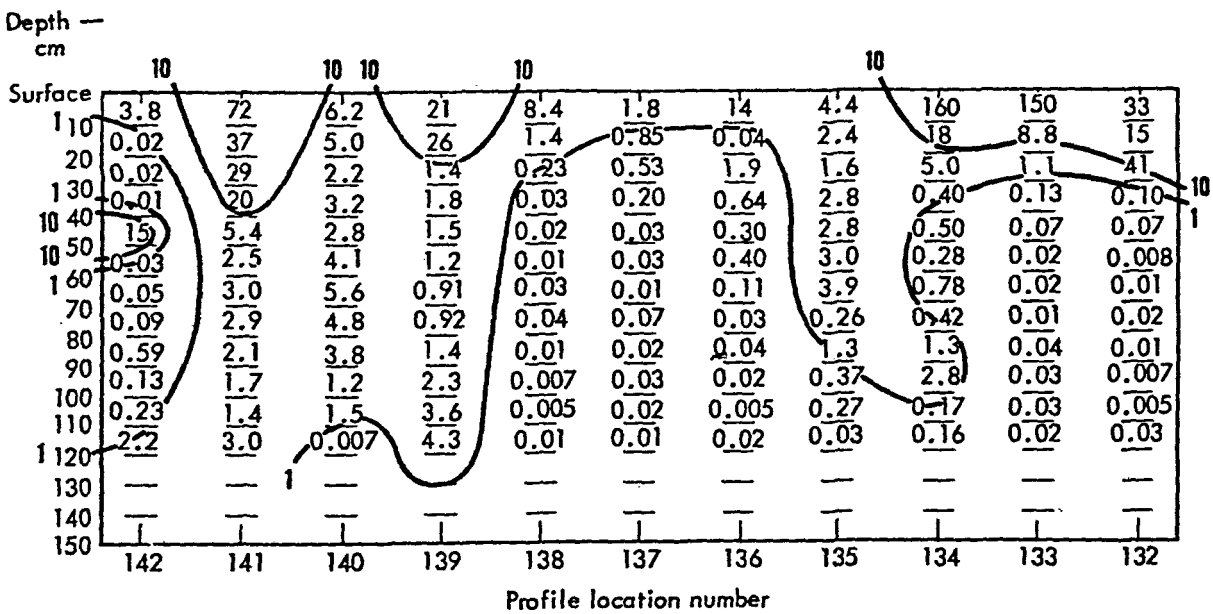

FIGURE 128. SITE YVONNE, PLUTONIUM PROFILE DATA

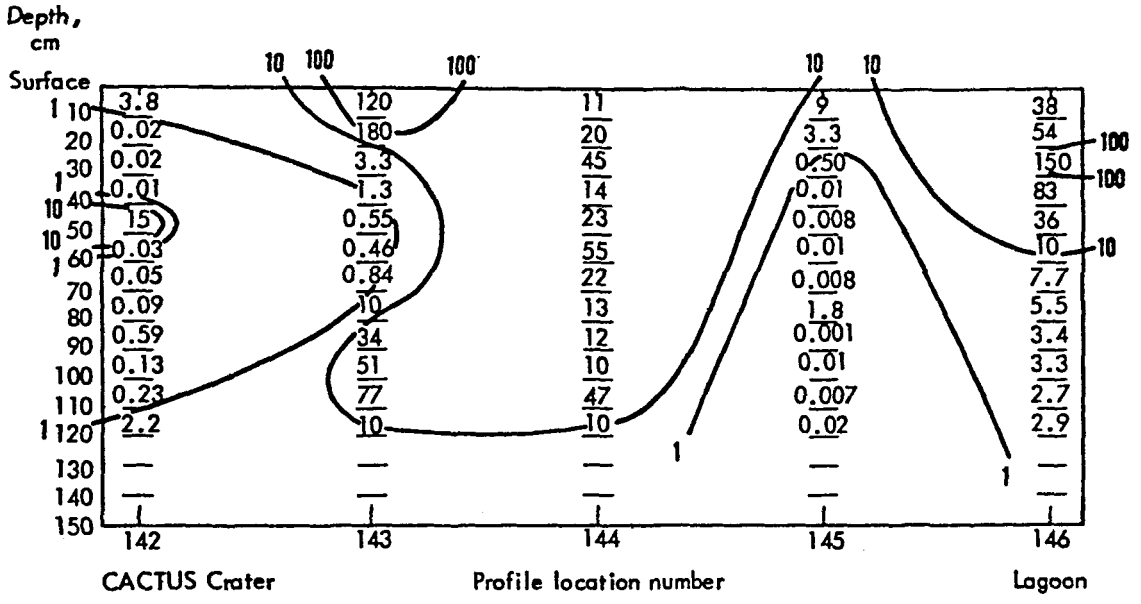

FIGURE 129. SITE YVONNE, PLUTONIUM PROFILE DATA

MINOR SOUTHERN ISLANDS

Site Name: SAM, TOM, URIAH, VAN, ALVIN, BRUCE, CLYDE, REX, WALT, GLENN, HENRY, IRWIN, JAMES, KEITH.

These islands are located in the southeast and southwest quadrants of Enewetak Atoll. They are grouped together for reporting because of their similar relatively low-level radiological conditions. Figures 130-139 are included for the islands BRUCE, GLENN, HENRY, IRWIN, JAMES, KEITH, REX and WALT.

Most of the islands in this group are small - some only 100 to 250 meters from end to end — with very sparse to dense vegetation. For the group, the mean and range of activities obtained from the 15-cm-deep surface soil samples, including those collected on the beaches, are:

Radionuclide	Activity (pCi/g)	
	Mean	Range
^{90}Sr	0.52	0.03 - 3.9
^{137}Cs	0.14	0.004 - 1.8
^{239}Pu	0.07	0.004 - 1.1
^{60}Co	0.06	0.007 - 63

The distributions of these radionuclides with depth display similar characteristics throughout these islands. In areas of dense vegetation, the activities within the top 20 cm decrease relatively slowly — relaxation lengths of about 8 cm. Profiles collected in open or sparsely vegetated areas exhibited essentially homogeneous distributions.

Debris remaining on these islands is not contaminated.

Information given below is specific to the island named.

Site Name: SAM
Marshallese: BOKO

SAM is the nearest island south of YVONNE and has an area of 0.9 acres (0.4 hectares). The island is about 100 meters long and has a few scattered plants. SAM was not used as a scientific site during nuclear testing and is free of debris. The background gamma exposure rate was 1 uR/h in 1972. The mean surface soil sample concentrations of radionuclides was ^{239}Pu = 0.09 pCi/g, ^{90}Sr = 0.72 pCi/g, ^{137}Cs = 0.36 pCi/g, and ^{60}Co = 0.04 pCi/g.

Site Name: TOM
Marshallese: MUNJOR

TOM is adjacent to SAM south of YVONNE and has an area of about 1.8 acres (0.7 hectare). The island was not used for scientific purposes during the test program. Vegetation covers most of the land area in thick clusters. No test related debris exists on TOM. The background gamma exposure rate was 1 uR/h in 1972. The mean surface soil concentrations obtained were: ^{239}Pu = 0.08 pCi/g, ^{90}Sr = 0.72 pCi/g, ^{137}Cs = 0.32 pCi/g, and ^{60}Co = 0.04 pCi/g.

Site Name: URIAH
Marshallese: INEDRAL

URIAH is located on the eastern side of Enewetak Atoll and has an area of about 3.8 acres (1.6 hectares). There is no record of the island being used as a scientific site during nuclear testing. Remains of two structures exist in poor repair, a navigational beacon and a submarine cable terminal box. The island is densely vegetated except for a few small areas. The background gamma exposure rate measured in 1972 was 1 uR/h. The mean surface soil concentrations of radionuclides were: ^{239}Pu = 0.08 pCi/g, ^{90}Sr = 0.45 pCi/g, ^{137}Cs = 0.11 pCi/g, and ^{60}Co = 0.15 pCi/g.

Site Name: VAN

VAN is located on the east side of Enewetak Atoll and has an area of 6.6 acres (2.7 hectares). Records show that the island was not used for scientific purposes during test operations. Dense vegetation completely covers the island to the edge of the beaches. A large steel buoy in deteriorated condition was located at the southern tip of the island in 1972. The background gamma exposure rate for the island was 1 uR/h. The mean surface soil concentrations of radionuclides were: ^{239}Pu = 0.08 pCi/g, ^{90}Sr = 0.41 pCi/g, ^{137}Cs = 0.14 pCi/g, and ^{60}Co = 0.09 pCi/g.

Site Name: ALVIN
Marshallese: JINEDROL

ALVIN is a small island located in the southeast quadrant of the Atoll. ALVIN has an area of about 2.2 acres (0.9 hectares) and dense vegetation covers most of the island. The island was not used as a scientific site during testing. The background gamma exposure rate measured in 1972 was 1 uR/h. The mean surface soil concentrations of radionuclides were: ^{239}Pu = 0.06 pCi/g, ^{90}Sr = 0.44 pCi/g, ^{137}Cs = 0.11 pCi/g, and ^{60}Co = 0.68 pCi/g.

Site Name: BRUCE
Marshallese: ANANIJ

BRUCE is in the southeast quadrant of Enewetak Atoll and has an area of about 25 acres (10 hectares). There are remains of scientific installations on the island as well as a helicopter landing mat. The island is covered with dense vegetation. The background gamma exposure rate measured in 1972 was 1 uR/h. The mean surface soil concentrations of radionuclides were: ^{239}Pu = 0.09 pCi/g, ^{90}Sr = 0.59 pCi/g, ^{137}Cs = 0.40 pCi/g, and ^{60}Co = 0.12 pCi/g.

SITE NAME: CLYDE
MARSHALLESE: JINIMI

CLYDE is also in the southeast quadrant of Enewetak Atoll and is the adjacent island north of DAVID (JAPTAN). CLYDE has an area of about 3 acres (1.2 hectares) and is sparsely vegetated. The island was not used for scientific purposes during testing and no debris is present. The background gamma exposure rate measured in 1972 was 1 μR/h. The mean concentrations of radionuclides in surface soil were: ^{239}Pu = 0.06 pCi/g, ^{90}Sr - 0.23 pCi/g, ^{137}Cs - 0.06 pCi/g, and ^{60}Co = 0.04 pCi/g.

Site Name: REX
Marshallese: JEDROL

REX is located about a mile west of DAVID north of the deep entrance to the lagoon. REX has an area of about 5.3 acres (2.2 hectares). Vegetation ranges from sparse to dense. The island has been used as an explosives storage facility. A quantity of dynamite was reported in 1972 to be in an igloo at the northern end of the island. The remains of numerous other structures are present. The background gamma exposure rate measured in 1972 was 1 uR/h. The mean surface soil concentrations of radionuclides were: ^{239}Pu = 0.04 pCi/g, ^{90}Sr = 0.51 pCi/g, ^{137}Cs = 0.51 pCi/g, and ^{60}Co = 0.09 pCi/g.

Site Name: WALT
Marshallese: BOKANDRETOK

WALT is located near the north end of FRED (ENEWETAK). WALT has an area of less than one acre (about 0.3 hectares) and is densely vegetated. During nuclear testing, the island contained a navigational beacon, generator, transmitter and two-man accommodations. Debris remains from these facilities. The background gamma exposure rate measured in 1972 was 1 uR/h. The mean surface soil concentrations of radionuclides were: ^{239}Pu = 0.04 pCi/g, ^{90}Sr = 0.41 pCi/g, ^{137}Cs = 0.15 pCi/g, and ^{60}Co = 1.04 pCi/g.

Site Name: GLENN
Marshallese: IKUREN

GLENN is located in the southwest quadrant of Enewetak Atoll and has an area of about 41 acres (17 hectares). GLENN is the first island west of the wide passage through the reef to the lagoon. The island consists of two islets connected by a high ridge in the reef. The two land areas are densely overgrown.

The island was used as a photo station and location for other scientific instrumentation during nuclear testing. There are some derelict marine craft on the lagoon side of the island as well as a large quantity of miscellaneous debris scattered over the island — principally on the west end of the eastern islet. The UMBRELLA EVENT was detonated on June 8, 1958, 150 feet underwater about 1.4 miles north of the west tip of the island.

The background gamma exposure rate measured in 1972 was 1 μR/h. The mean surface soil concentrations of radionuclides were: ^{239}Pu = 0.11 pCi/g, ^{90}Sr = 1.4 pCi/g, ^{137}Cs = 0.60 pCi/g, and ^{60}Co = 0.21 pCi/g.

Site Name: HENRY
Marshallese: MUT

HENRY is located in the southwest quadrant of Enewetak Atoll and has an area of about 40 acres (16 hectares). The island is heavily overgrown with dense vegetation. During the nuclear test program, HENRY was used for various scientific purposes and a moderate amount of debris remains. The background gamma exposure rate measured in 1972 was 1 uR/h. Mean concentrations of radionuclides in surface soil samples were: ^{239}Pu = 0.14 pCi/g, ^{90}Sr = 0.75 pCi/g, ^{137}Cs = 0.25 pCi/g, and ^{60}Co = 4.3 pCi/g. (Figure B.49.1.n in NVO-140 shows a ^{60}Co value of 63 pCi/g for one sample. The mean ^{60}Co value excluding the 63 pCi/g is 0.07 pCi/g.)

Site Name: IRWIN
Marshallese: BOKEN

IRWIN is located in the southwest quadrant of Enewetak Atoll and has an area of about 29 acres (12 hectares). The dry land area is covered with dense vegetation. A nominal amount of debris remains from scientific measurements made on the island during the HARDTACK OPERATION. The background gamma exposure rate measured in 1972 was 1 uR/h. The average concentrations of radionuclides in surface soil samples were: ^{239}Pu = 0.14 pCi/g, ^{90}Sr = 0.65 pCi/g, ^{137}Cs = 0.12 pCi/g, and ^{60}Co = 0.62 pCi/g.

Site Name: JAMES
Marshallese: RIBEWON

JAMES is located in the southwest quadrant of Enewetak Atoll and has an area of about 19 acres (7.6 hectares). The island is densely vegetated. JAMES was used as a scientific site for OPERATION HARDTACK. Some debris remains on the island as well as three derelict marine craft rest on the ocean beach.

The WAHOO EVENT of OPERATION HARDTACK was detonated on May 16, 1958, 500 feet underwater 1.4 miles south of JAMES.

The background gamma exposure rate measured in 1972 was 1 - 5 uR/h. The mean concentrations of radionuclides in soil were: ^{239}Pu = 0.08 pCi/g, ^{90}Sr = 0.69 pCi/g, ^{137}Cs = 0.09 pCi/g, and ^{60}Co = 6.5 pCi/g. (The mean ^{60}Co value contains a datum of 46 pCi/g, ten times the next lower value. Excluding this point the mean becomes 0.87 pCi/g.)

Site Name: KEITH
Marshallese: KIDRENEN

KEITH is located in the southwest quadrant of Enewetak Atoll and has an area of about 24 acres (9.8 hectares). The island was used as a meteorological station during OPERATION HARDTACK. The island is heavily vegetated including coconut and pandanus. The background gamma exposure rate measured in 1972 was 1-2 uR/h.

The mean concentrations of radionuclides measured in surface soil samples were: ^{239}Pu = 0.11 pCi/g, ^{90}Sr = 0.88 pCi/g, ^{137}Cs = 0.28 pCi/g, and ^{60}Co = 0.17 pCi/g.

CASE 3: UNLIMITED USE

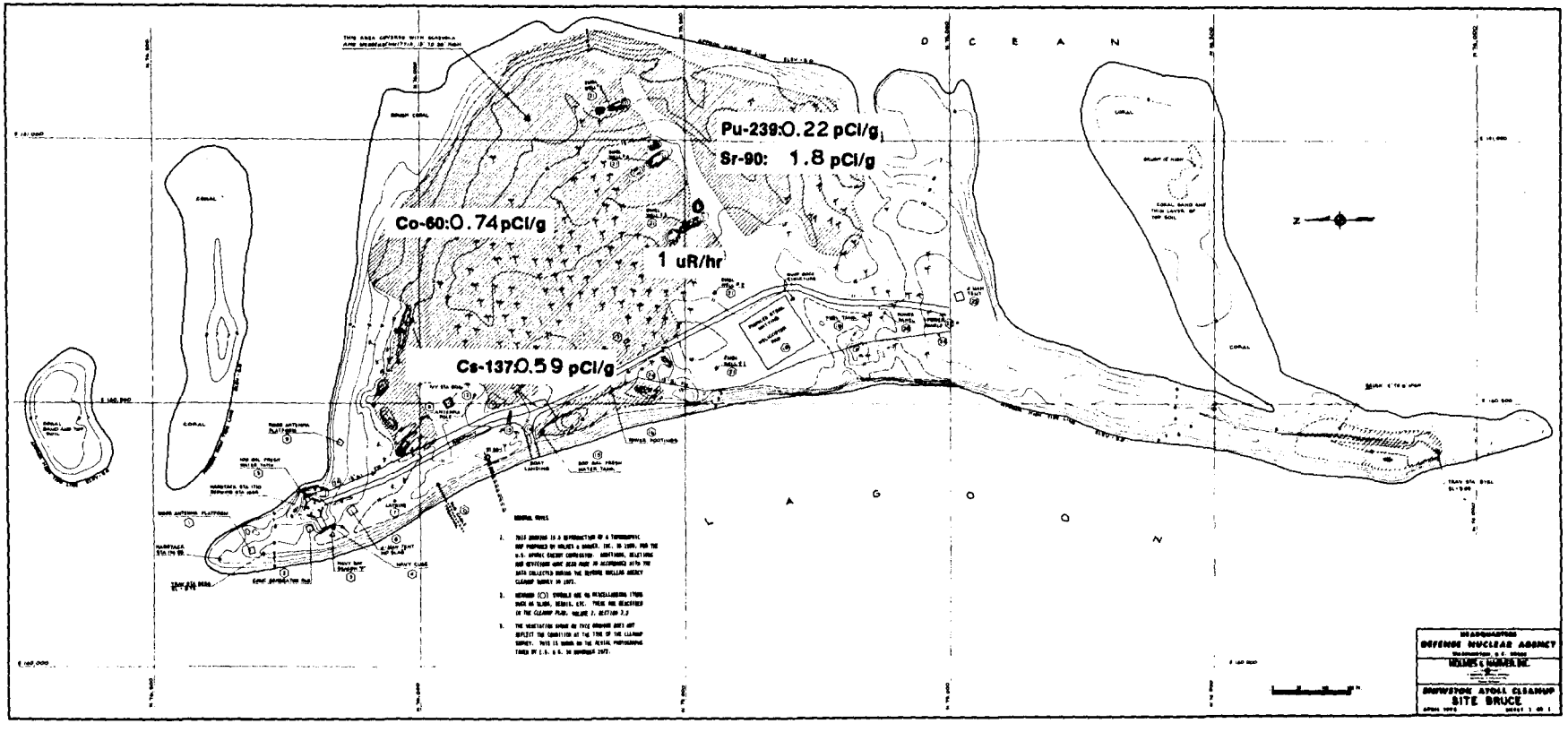

FIGURE 130. SITE BRUCE

CASE 3: UNLIMITED USE

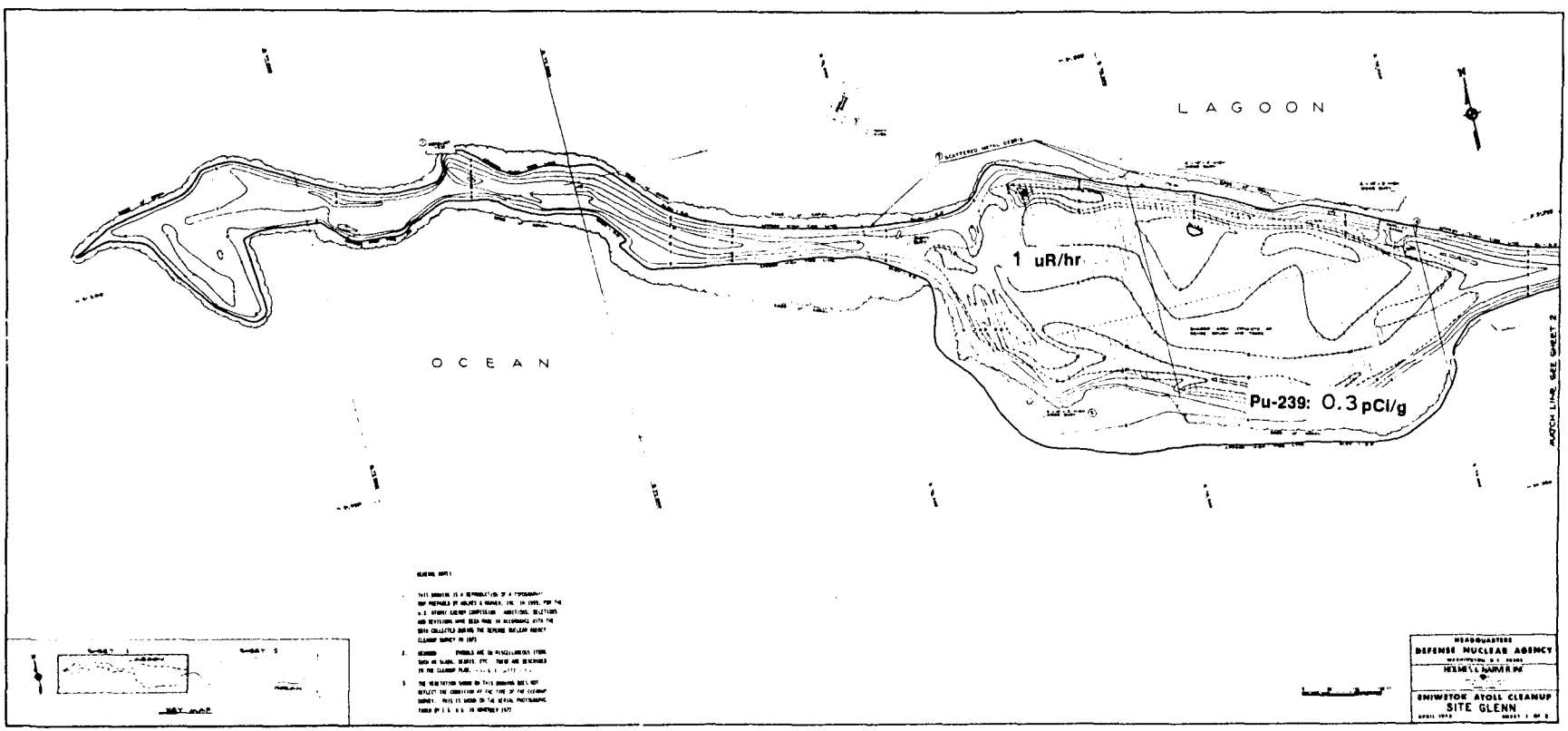

FIGURE 131. SITE GLENN, SHEET 1 OF 2

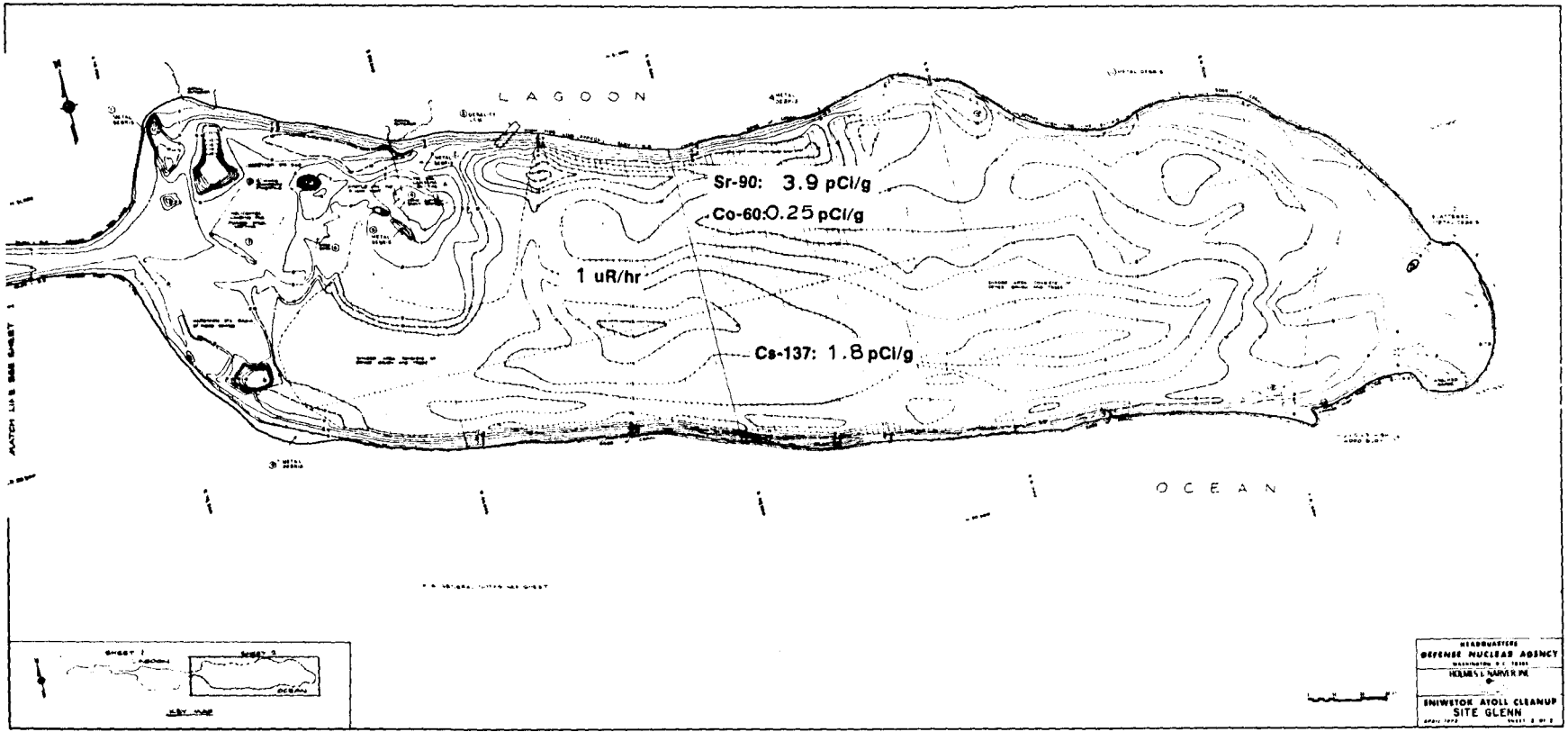

FIGURE 132. SITE GLENN, SHEET 2 OF 2

CASE 3: UNLIMITED USE

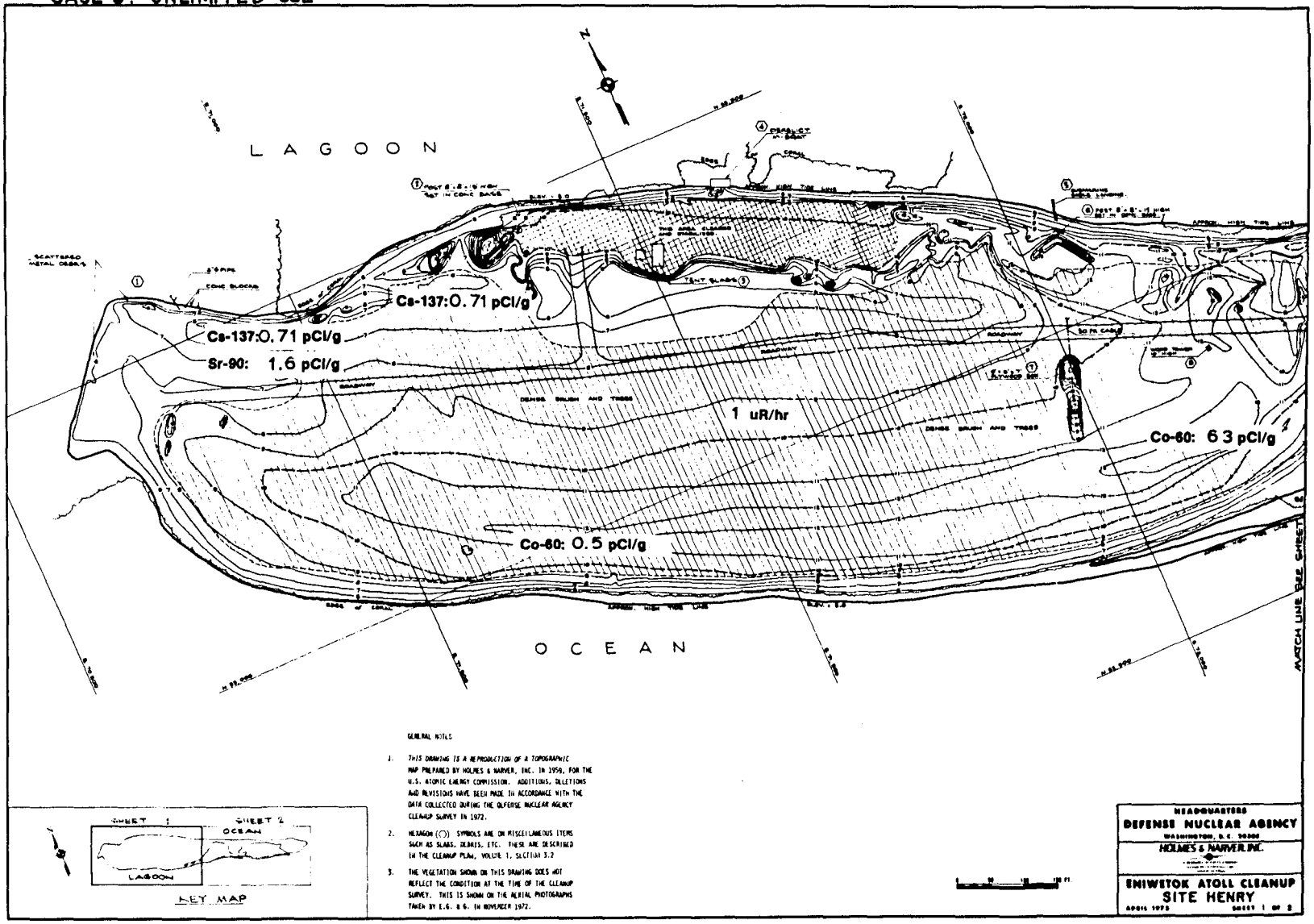

FIGURE 133. SITE HENRY, SHEET 1 OF 2

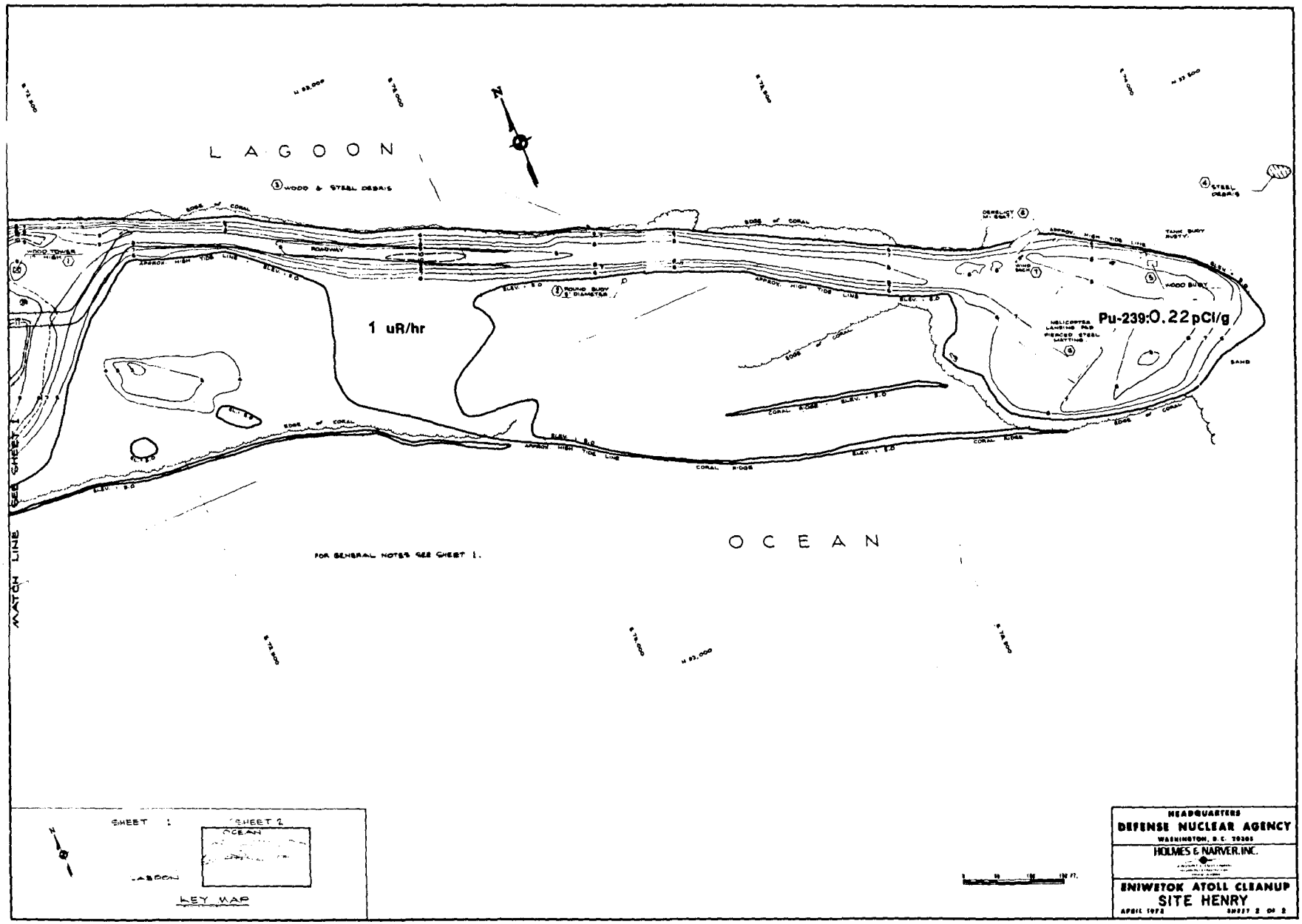

FIGURE 134. SITE HENRY, SHEET 2 OF 2

CASE 3: UNLIMITED USE

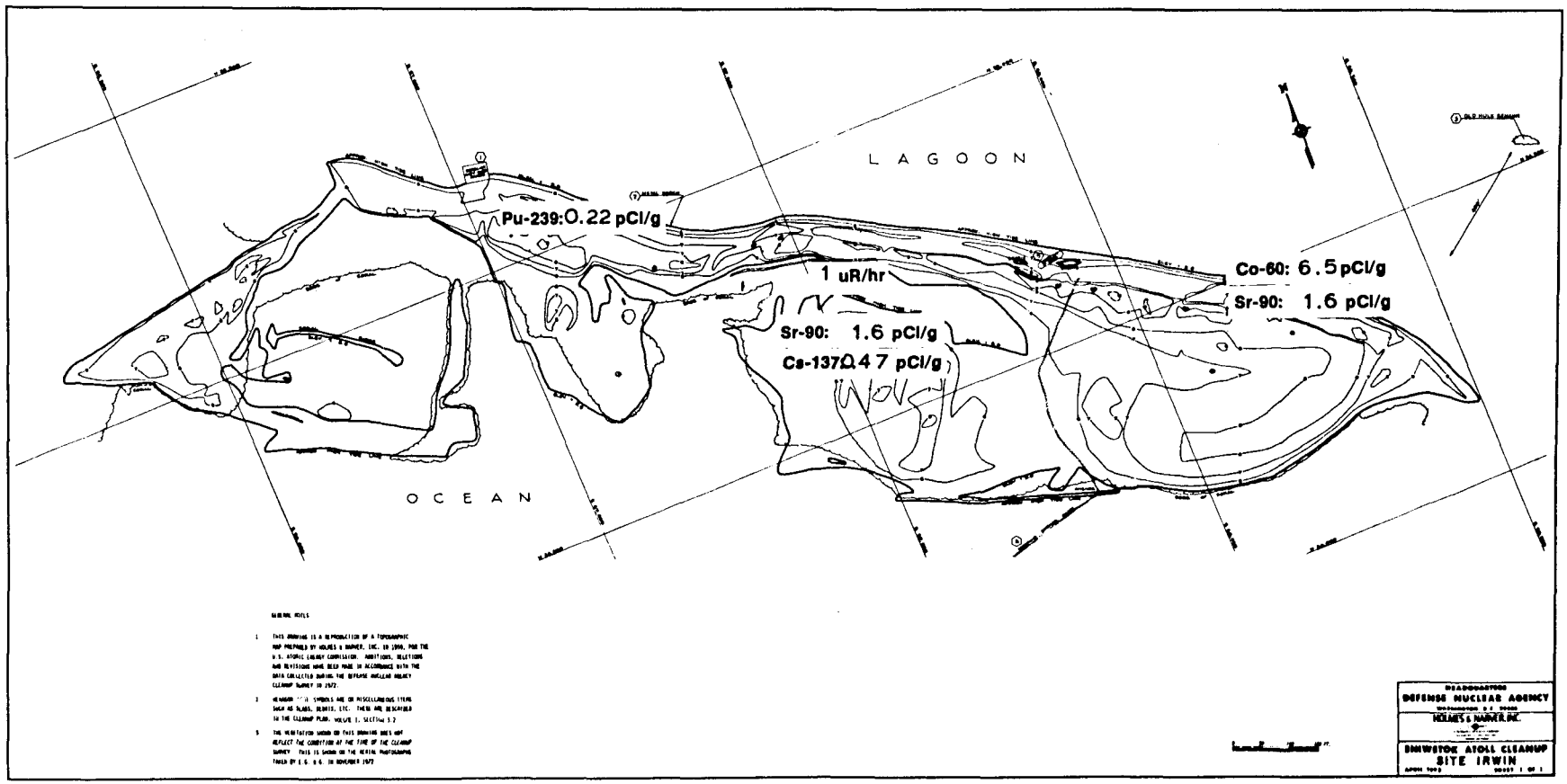

FIGURE 135. SITE IRWIN

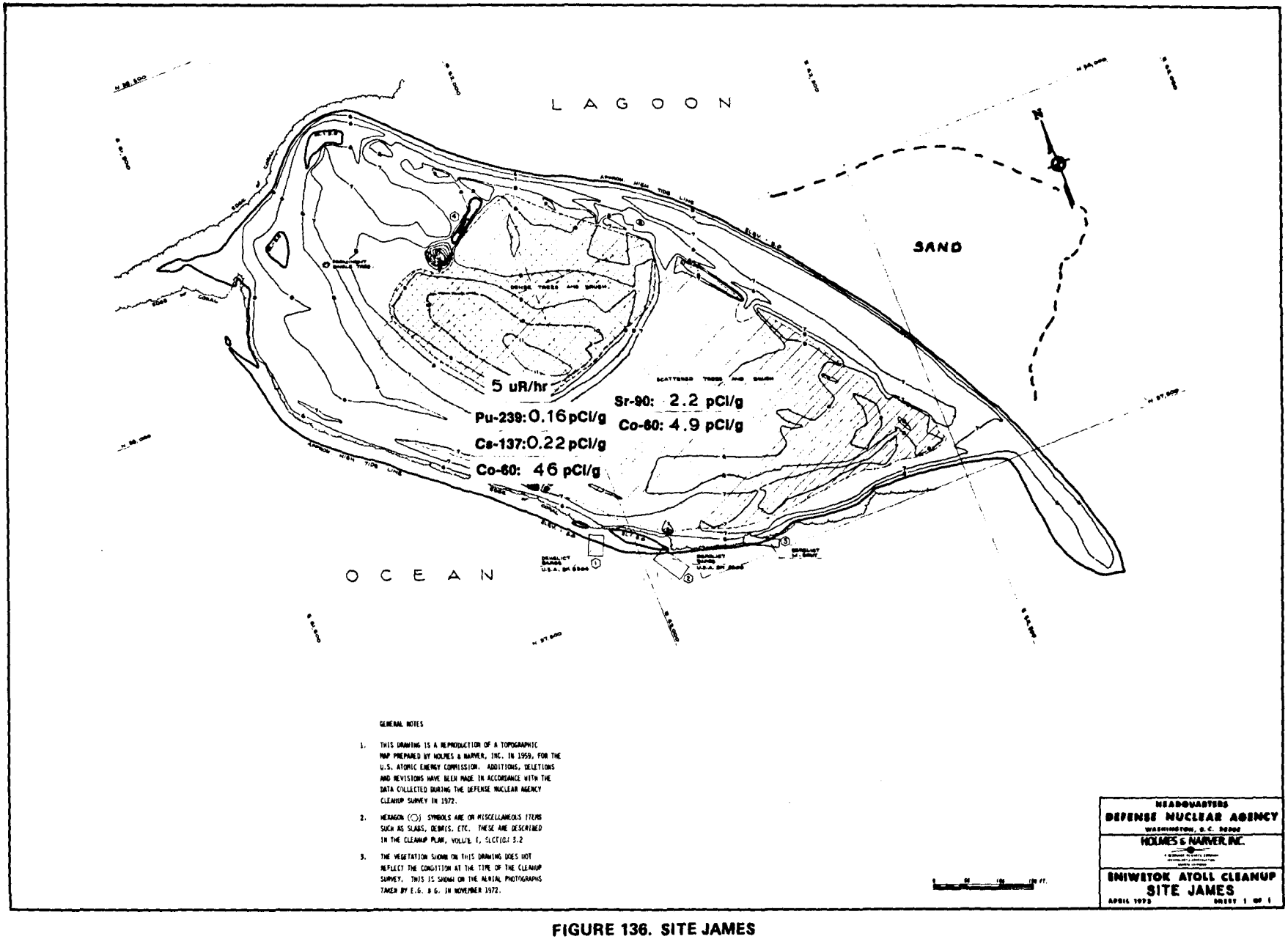

FIGURE 136. SITE JAMES

CASE 3: UNLIMITED USE

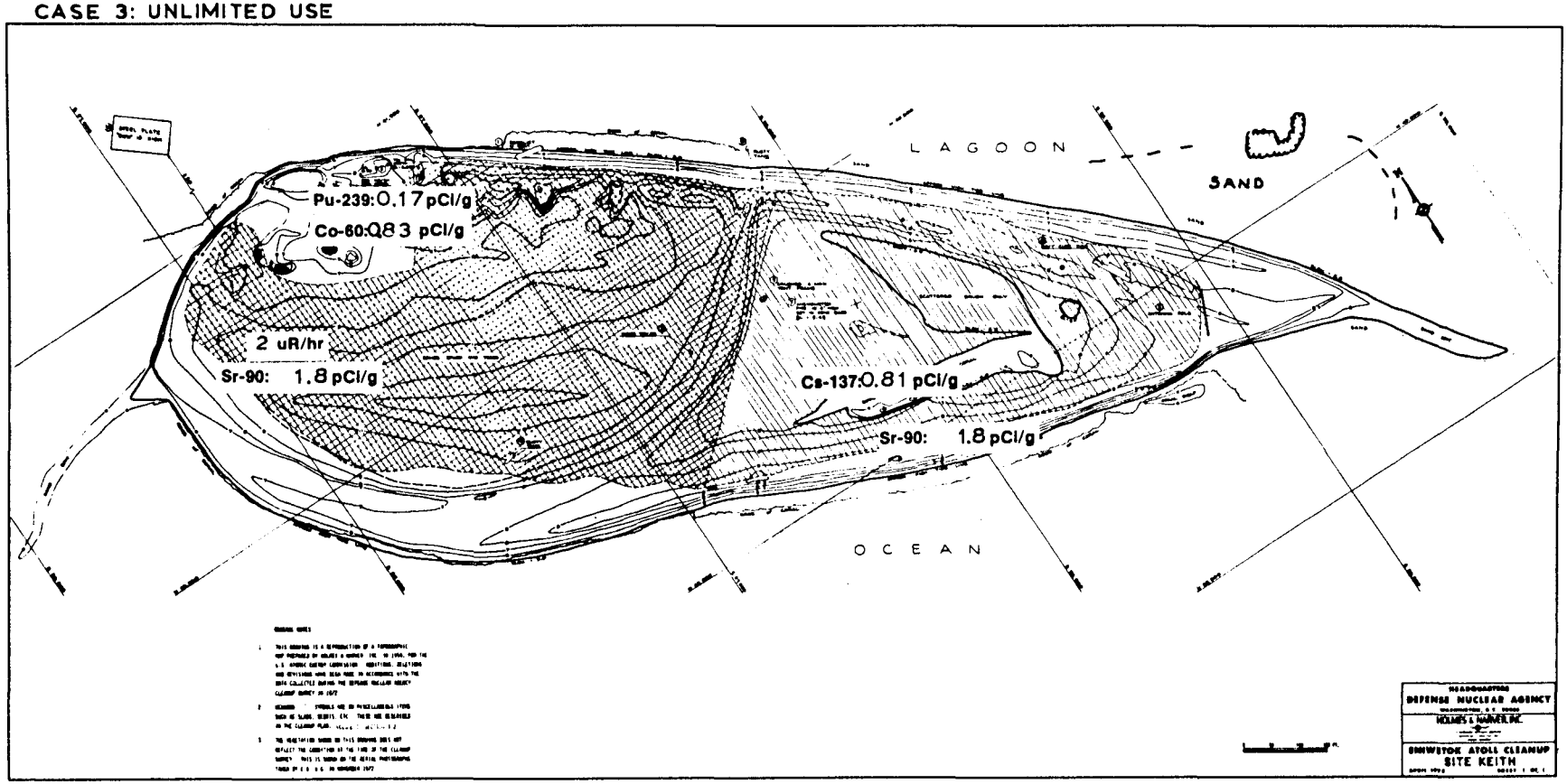

FIGURE 137. SITE KEITH

CASE 3: UNLIMITED USE

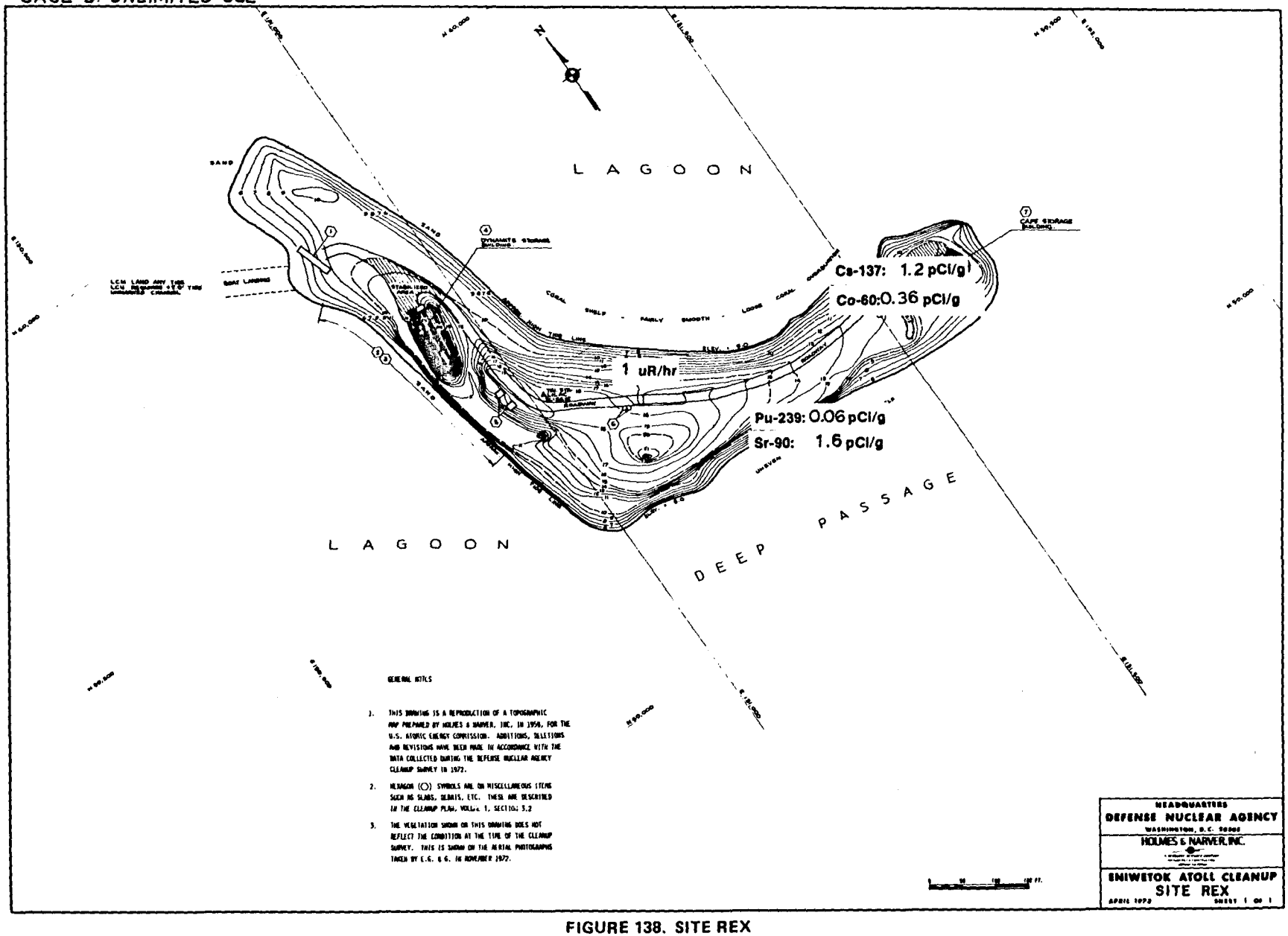

FIGURE 138. SITE REX

CASE 3: UNLIMITED USE

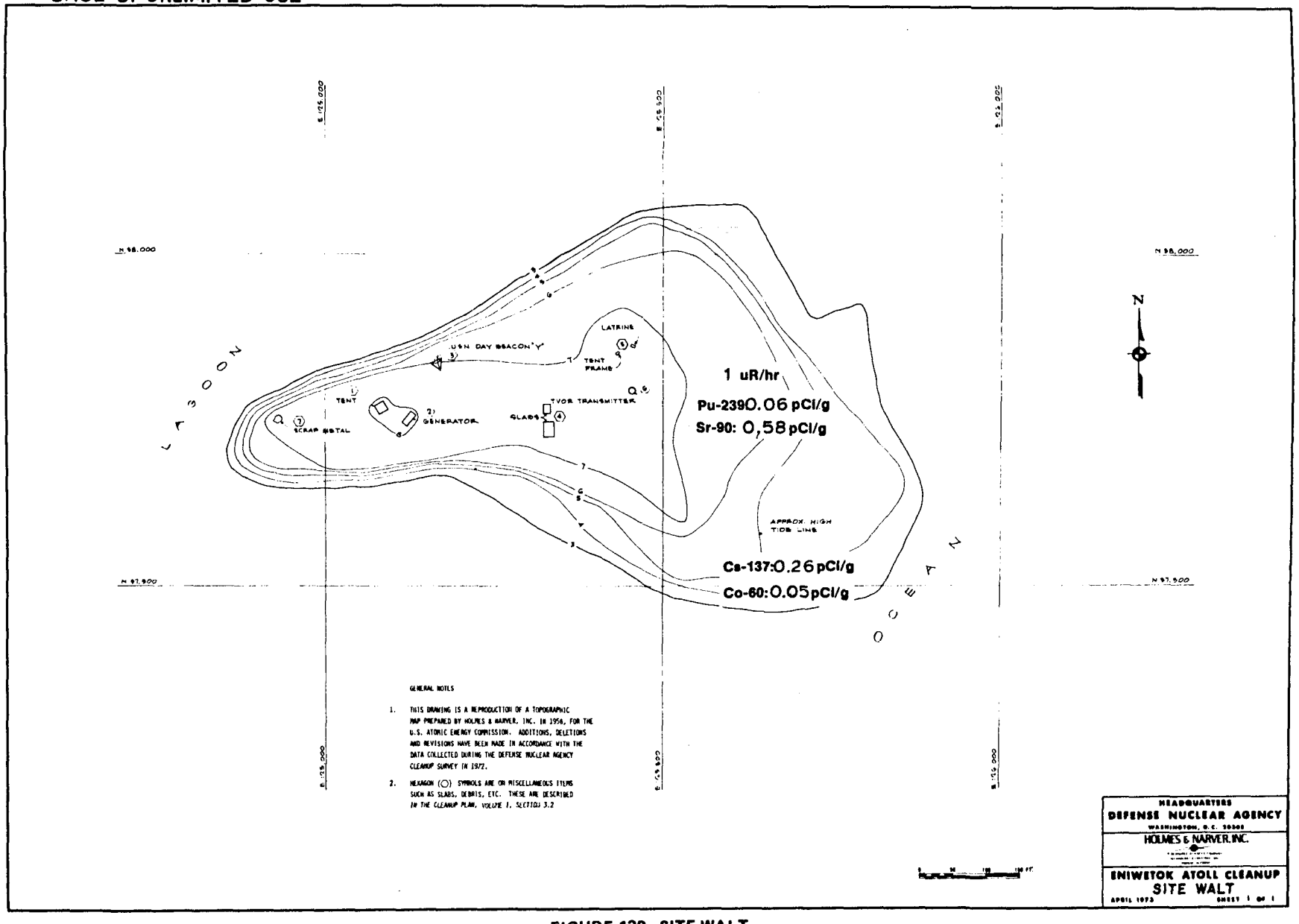

FIGURE 139. SITE WALT

August 25, 1977

Site Name: DAVID
Board of Geo.: MUTI
Marshallese: JAPTAN

DAVID is located in the southeast quadrant of Enewetak Atoll adjacent to the Deep Entrance. It has a land area of about 79 acres (32 hectares). Coconut trees remain from a nineteenth century German plantation and numerous installations remain from U. S. operations. (Figure 140) The island was first used by the U. S. to house animals used in nuclear test effects research. During OPERATION CASTLE, DAVID was the site of an electromagnetic diagnostic station. Later, during OPERATION REDWING, it became the radio receiver site for the Atoll with a 20-man permanent camp. Following the termination of nuclear testing at Enewetak, the Atoll became a down-range target area for the Navy's Pacific Missile Range and the Air Force Western Test Range. A 3000 square-foot concrete building was constructed to house the Missile Impact Locating System — Building 2182. DAVID was also used as a recreational area during nuclear test operations.

Some 50 - 75 Enewetak people returned to DAVID in March 1977 and currently reside there.

The radiological condition of DAVID is good. The accumulated H+1 hour gamma exposure rate contributed by three nuclear tests is 1 R/h. The maximum gamma exposure rate measured in 1972 was 5 uR/h. The mean and range of values for the prevalent radionuclides in surface soil samples were:

Radionuclide	Activity (pCi/g)		
	Mean	Range	
^{90}Sr	0.55	0.08 -	2.6
^{137}Cs	0.39	0.03 -	1.0
^{239}Pu	0.05	0.004 -	0.23
^{60}Co	0.03	0.009 -	0.14

No zero points, radioactive material burials, or other radiological hazards are known to exist on DAVID. Cleanup activities will include removal of physical hazards and structures as specified in the Engineering Plan.

CASE 3: UNLIMITED USE

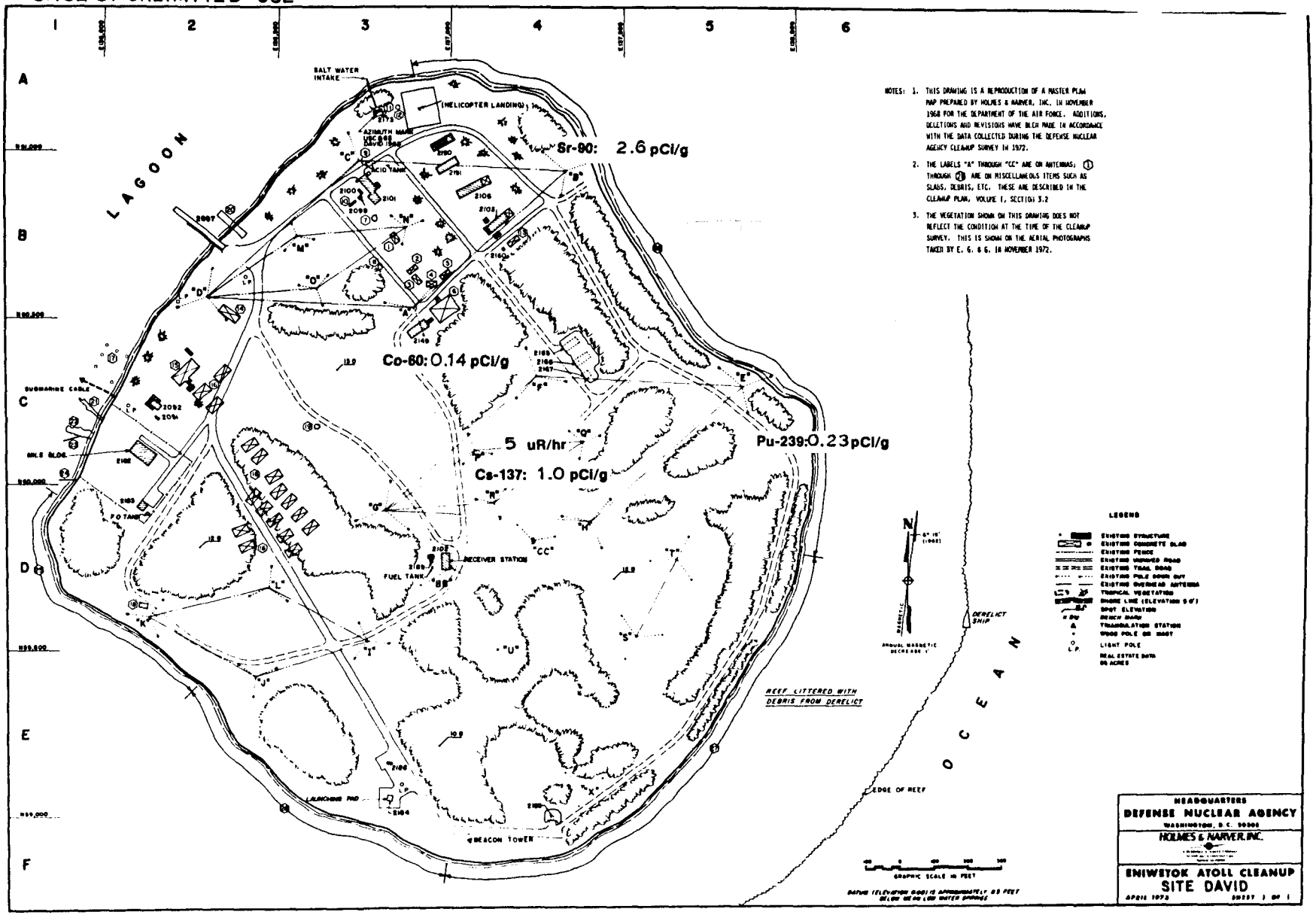

FIGURE 140. SITE DAVID

Site Name: ELMER
Board of Geo.: PARRY
Marshallese: MADRIN or MEDREN

ELMER is located in the southeast quadrant of Enewetak Atoll and has an area of about 200 acres (81 hectares).

ELMER was the support island used by the AEC and the scientific groups during the nuclear testing program. At its peak, it held facilities to house, feed and generally support up to 3000 people. Figure 141 is the Plot Plan of facilities at the end of testing. Some of the facilities have been removed, but many remain as indicated in the detail drawings in Figures 142-152. Almost half of the noncontaminated metal debris and concrete rubble on the Atoll is located on ELMER.

Along with DAVID and FRED, ELMER is one of the three islands which have been selected as residential sites by the Enewetak people.

ELMER has no surface zero points and accumulated H+1 hour exposure rates from 5 events resulted in a total of 2.6 R/h exposure to the island. The highest exposure rate measured with a hand-held survey instrument in 1972 was 7 uR/h. This reading was perhaps influenced by a Co source, and if so would indicate that 2 uR/h is the maximum background exposure rate. The concentrations of radionuclides in surface soil samples were measured to be:

Radionuclide	Activity (pCi/g)	
	Mean	Range
^{90}Sr	0.77	0.02 - 5.1
^{137}Cs	0.32	0.01 - 1.2
^{239}Pu	0.22	0.008 - 5.5
^{60}Co	0.06	0.01 - 0.88

The higher values in this table were influenced by the decontamination area shown in Figure 145. This area was used for all manners of decontamination including heavy machinery and materials shipped from Bikini Atoll. During periods of high use, the ball field north of the decon pad was also used to store contaminated materials. The ball field was not extensively sampled according to NVO-140. The ball field as well as the decon area are shown on Figure 145. It has been verbally reported that some contaminated pipe exists in the decon area. Further, it would be advisable to check the drain outfall from this area for residual contamination. Various cleaning agents were used in the decontamination which may have suspended contamination for removal. These agents may have become ineffective when mixed with the seawater and resulted in a local concentration of contamination near the drain outfall. Similar examination of the facilities used for storage and decontamination for CASTLE and REDWING may be in order (see Figures 148 and 150).

Reportedly, there are some hemispherical objects near the north end of the island which showed 80 uR/h and 0.5 mR/h radiation levels with scintillation and GM survey meters. Specific identification or locations have not been noted.

Similarly, some old shielding in the laboratory building showed 400 uR/h and 0.3 mRad/h, some fiberglass material in the chillhouse showed 2-3 uR/h, and 4 uR/h was measured in the IBM building. The first warrants removal as contaminated material. The other locations should be checked to assure that no overlooked sources or contaminated areas exist. A ^{60}Co source was found on ELMER but has since been disposed of at the Nevada Test Site.

NVO-140 shows two areas on ELMER with elevated radiation levels as measured by the aerial survey. The Task Group Recommendations suggest that these may be shallow burials. Based on the reports and opinions researched for this material, these areas are not burials but may be areas of higher residual fallout. During fallout periods and thereafter, water washing as well as rain was used to remove fallout from the immediate work and residential areas. Various designs of gutters and runoff catchments were used to aid fallout removal. An example case would be the fallout from the TEWA SHOT on Bikini which resulted in a 1.2 Rad exposure to ELMER. The fallout occurred over a period of several hours.

An incident occurred on ELMER which involved a ruptured foil containing plutonium. All materials contaminated were either successfully decontaminated or poured in concrete and buried at sea.

CASE 3: UNLIMITED USE

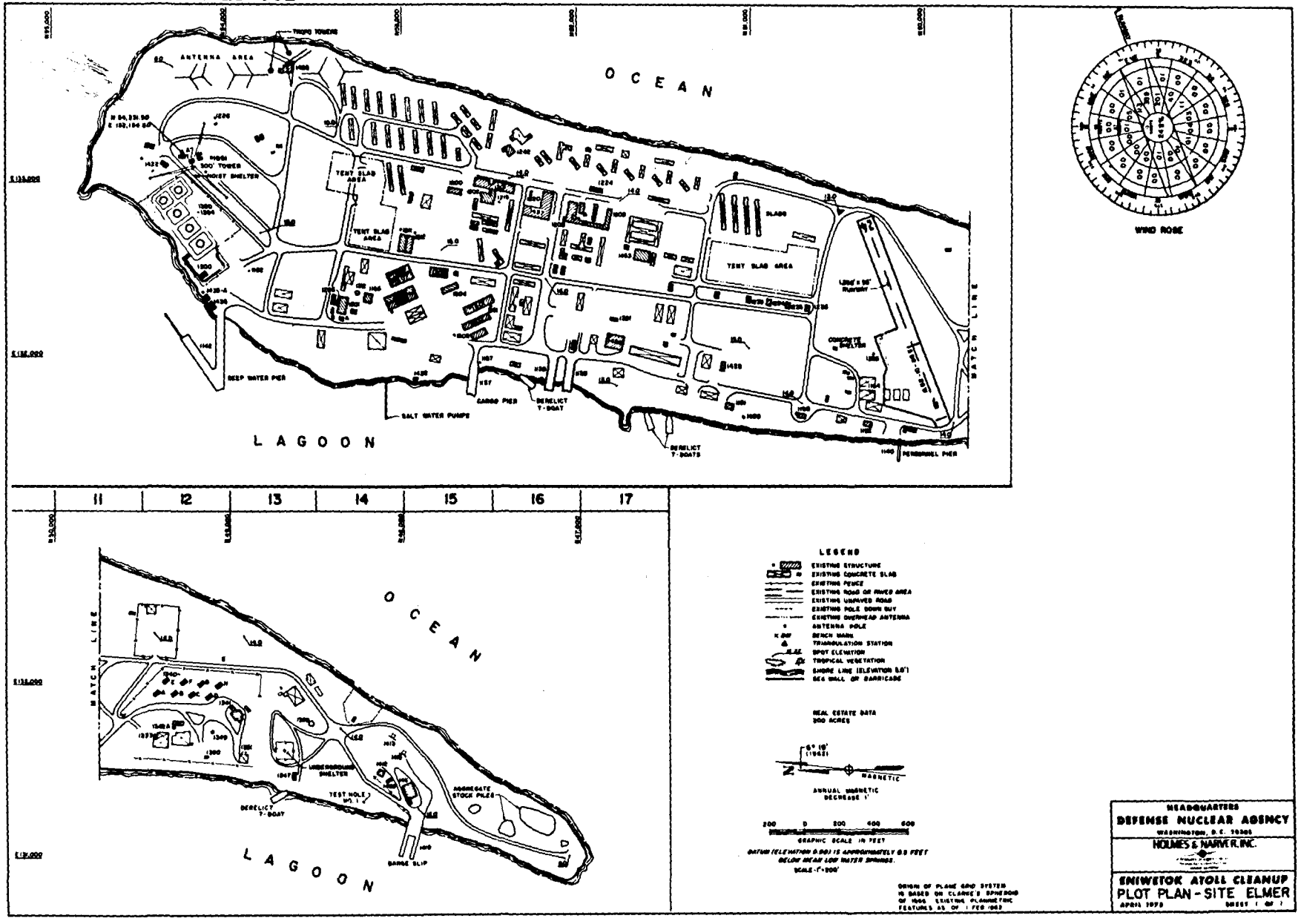

FIGURE 141. SITE ELMER, PLOT PLAN

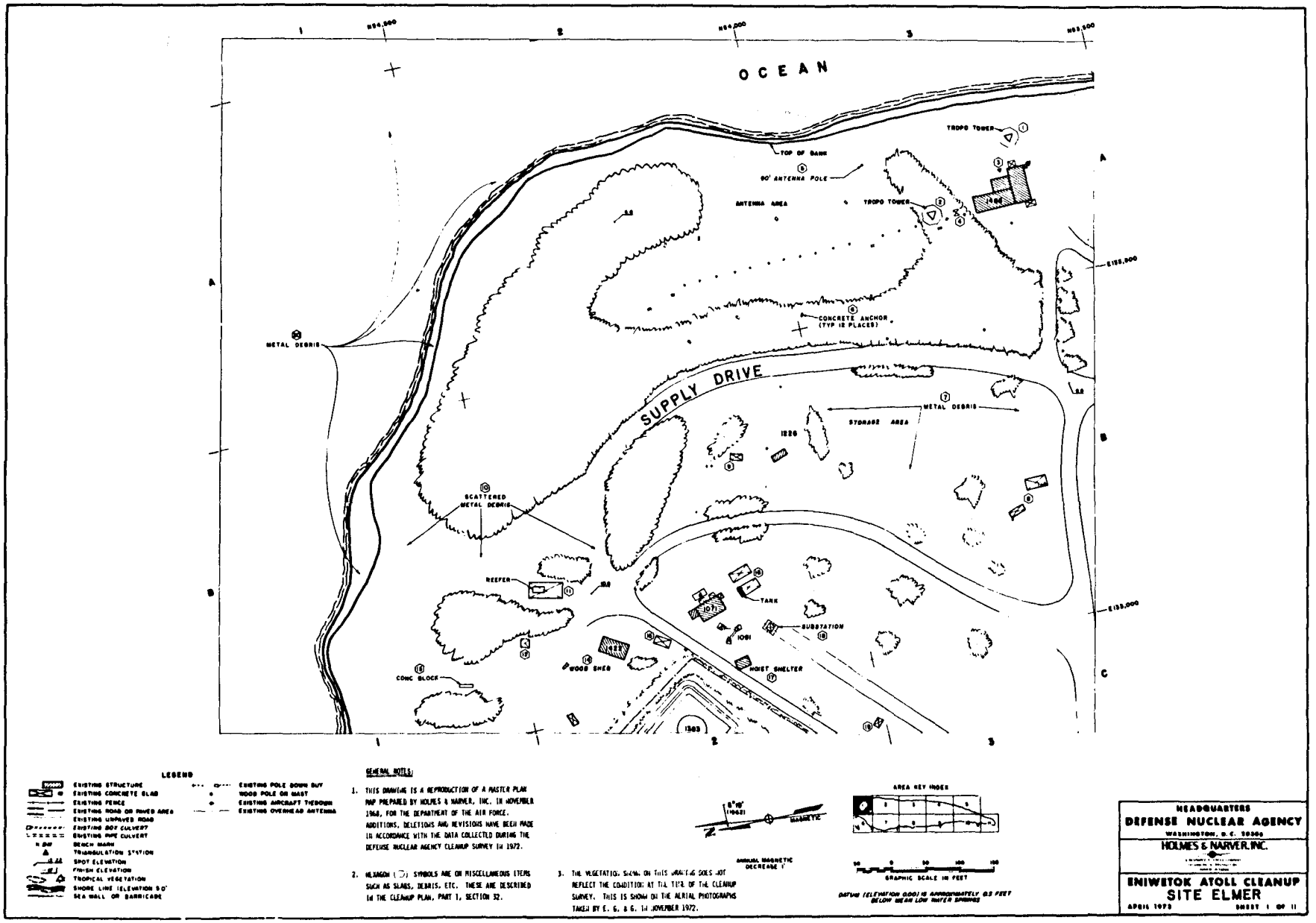

FIGURE 142. SITE ELMER, SHEET 1 OF 11

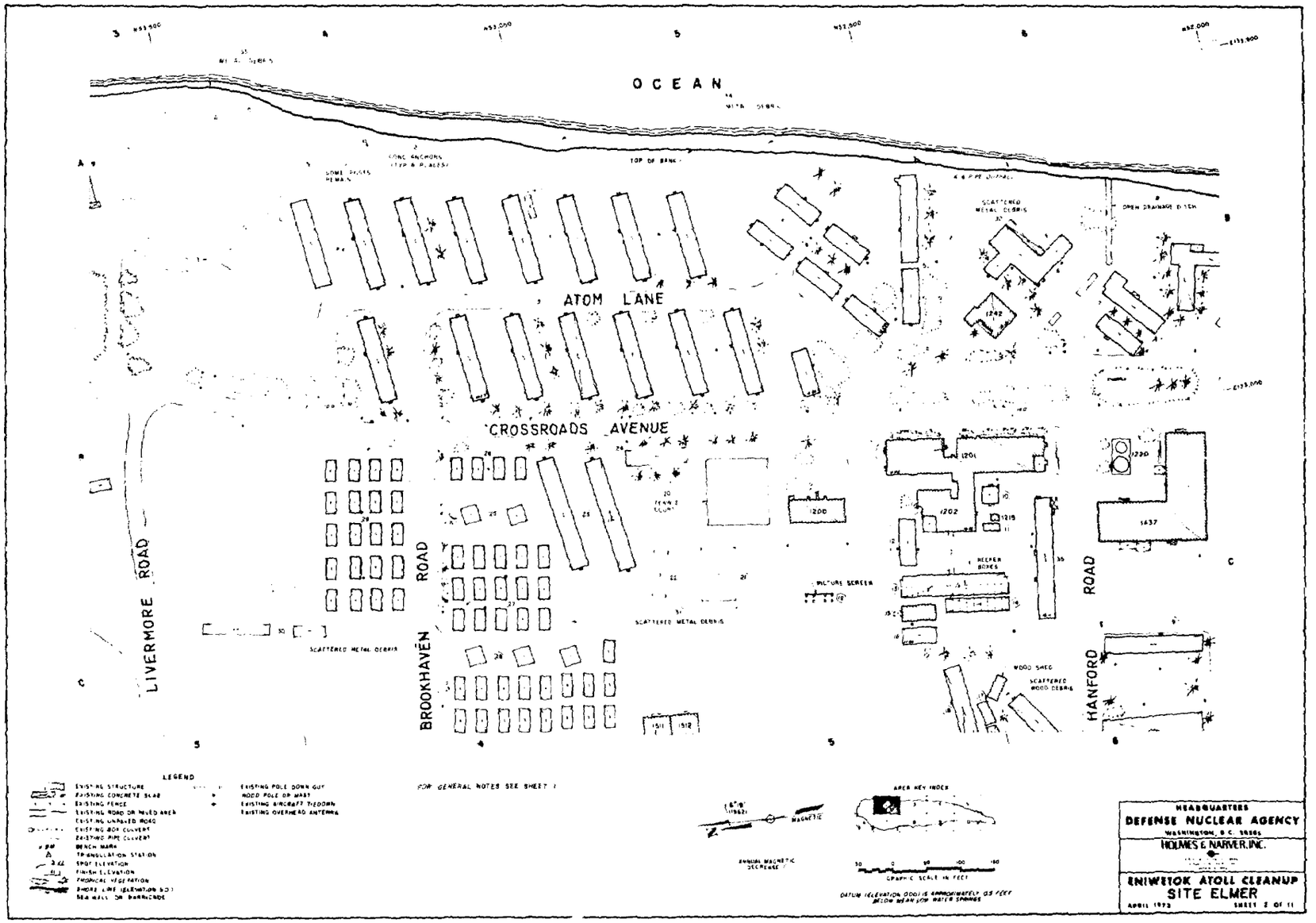

FIGURE 143. SITE ELMER, SHEET 2 OF 11

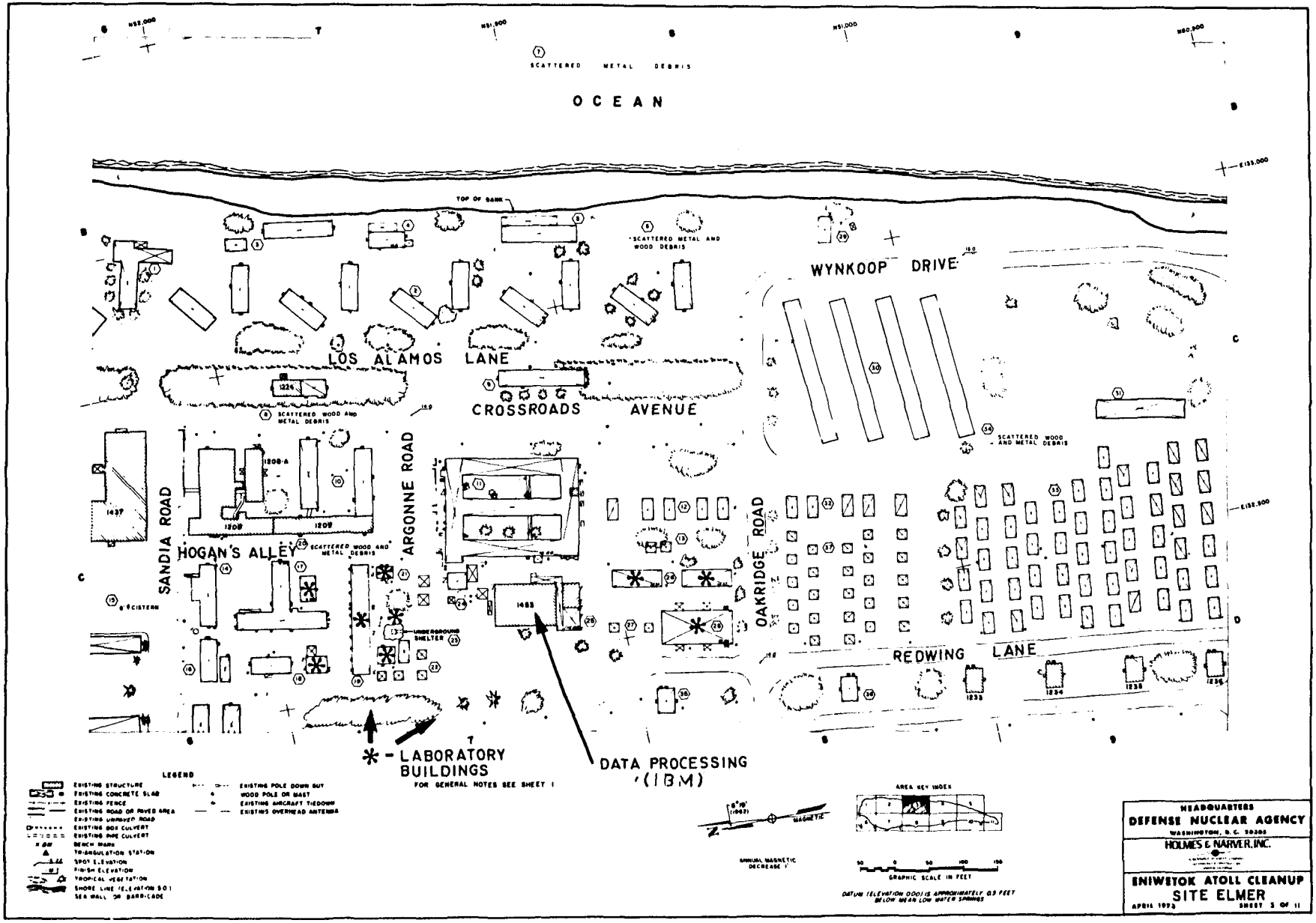

FIGURE 144. SITE ELMER, SHEET 3 OF 11

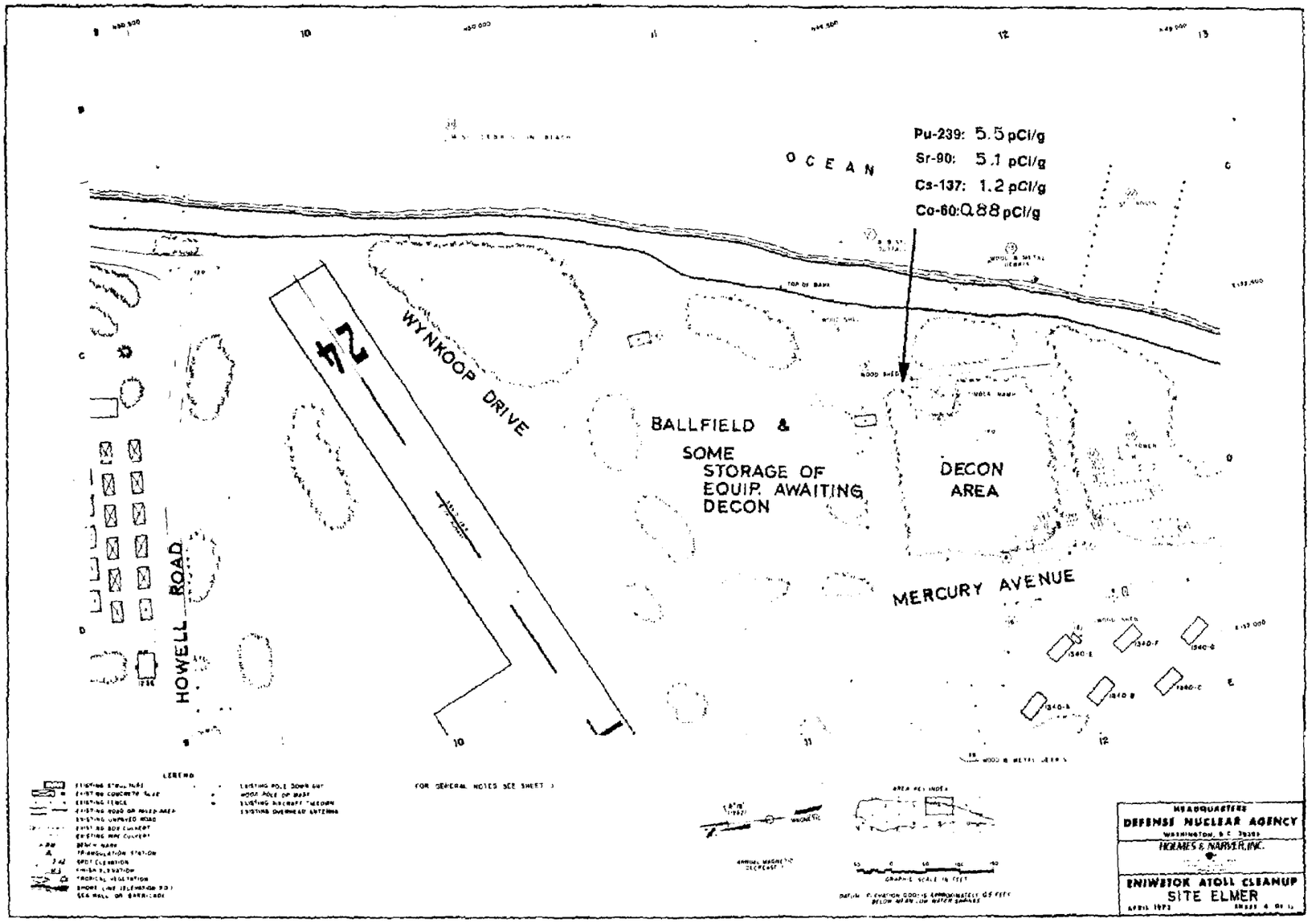

FIGURE 145. SITE ELMER, SHEET 4 OF 11

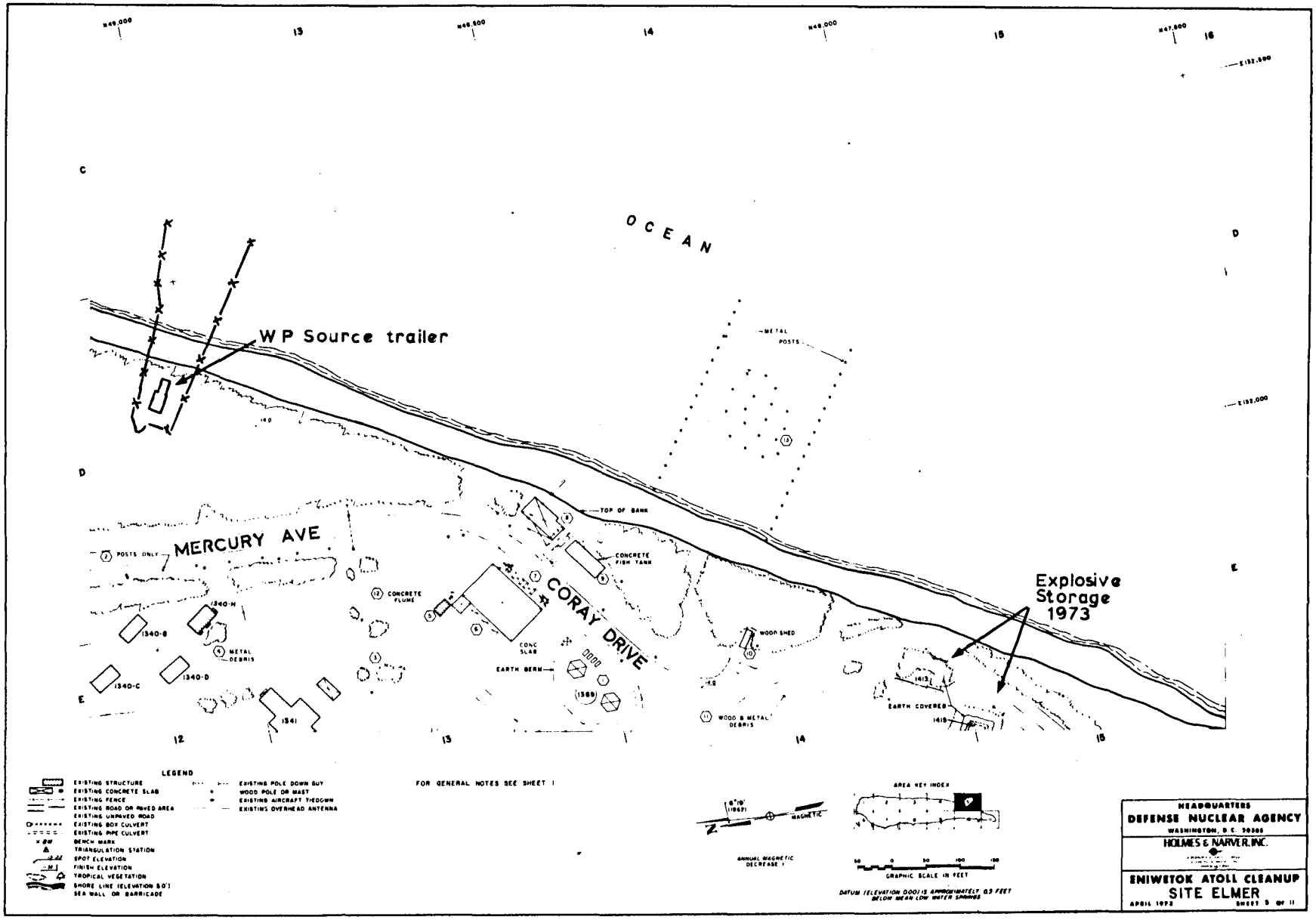

FIGURE 146. SITE ELMER, SHEET 5 OF 11

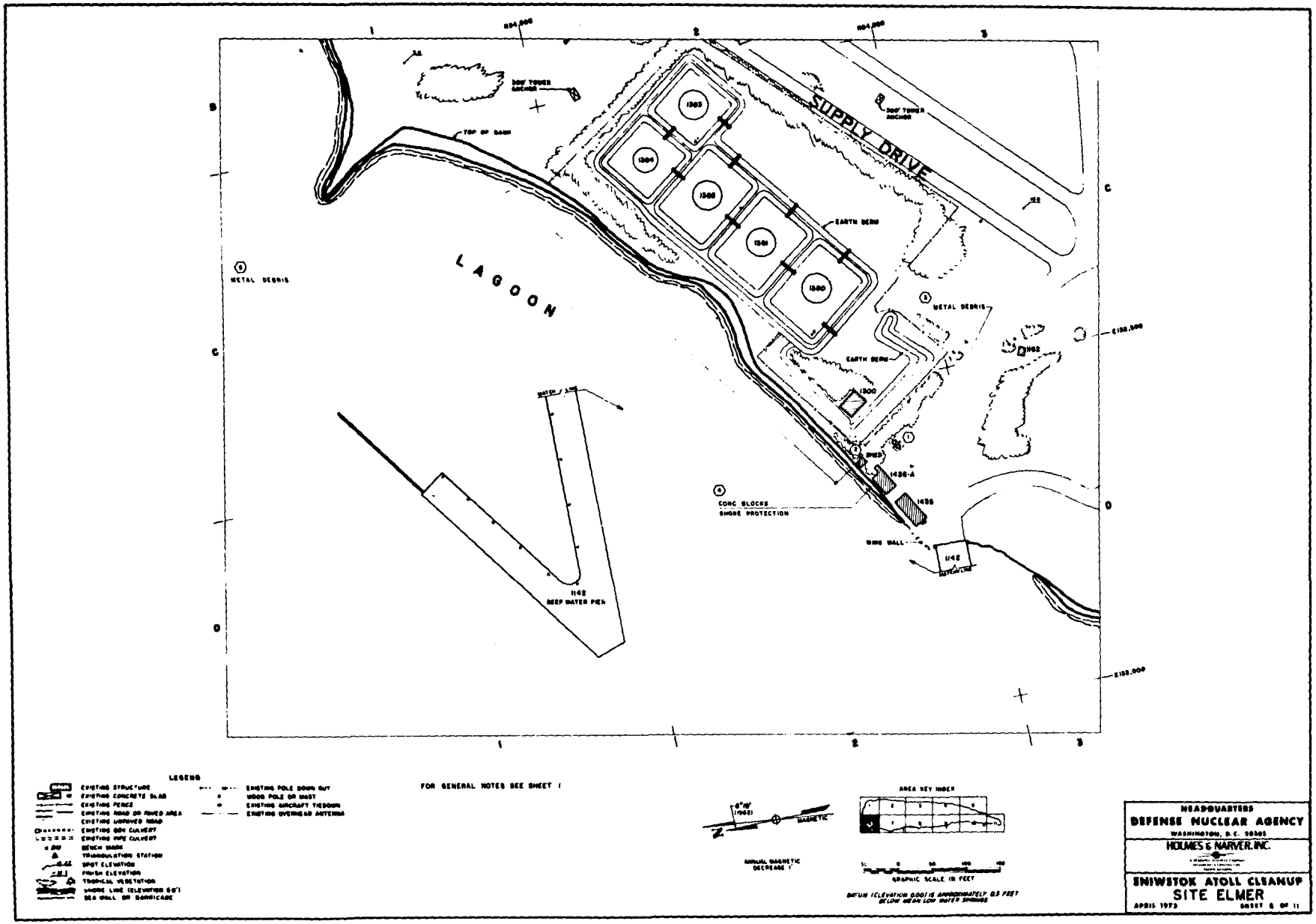

FIGURE 147. SITE ELMER, SHEET 6 OF 11

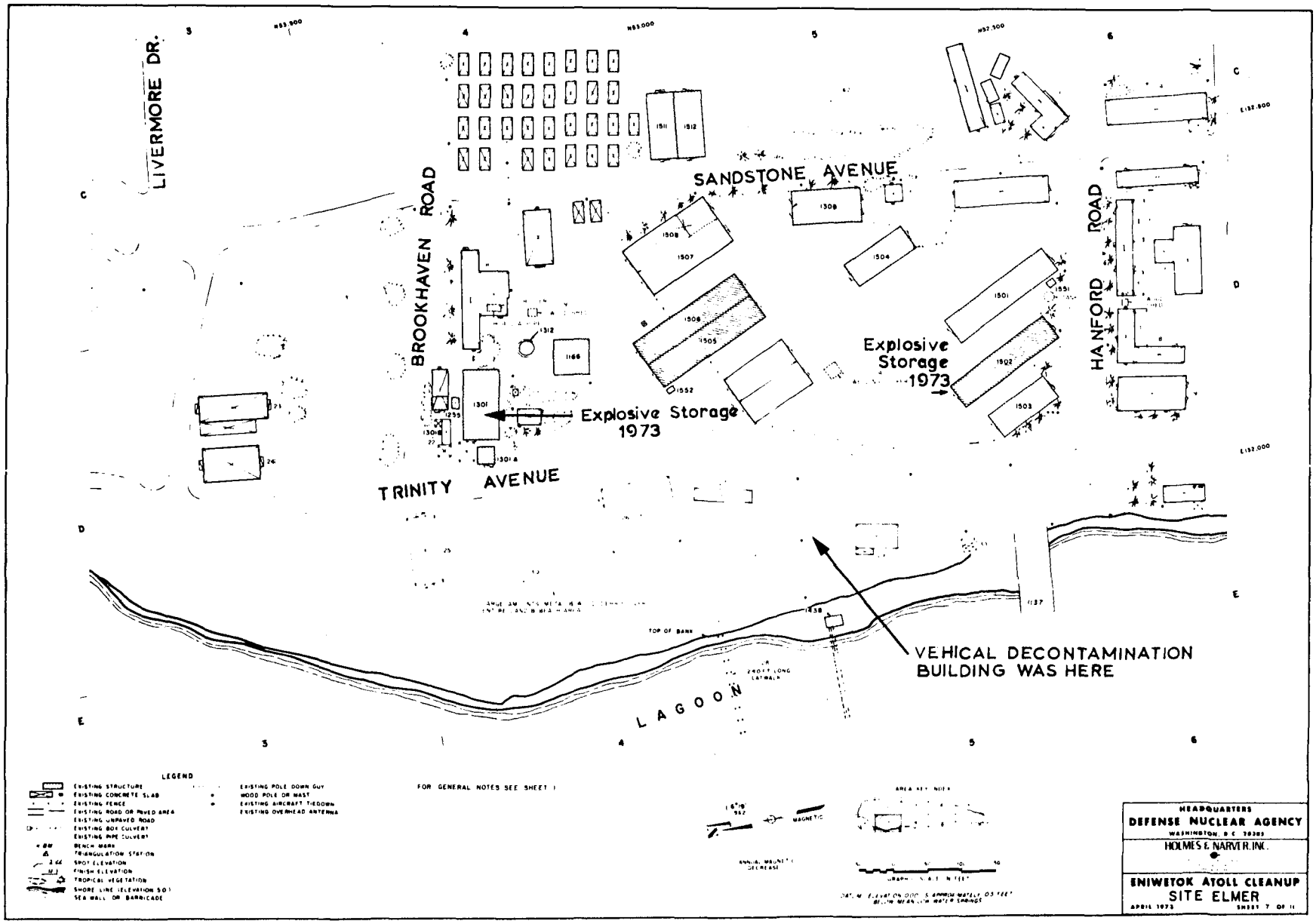

FIGURE 148. SITE ELMER, SHEET 7 OF 11

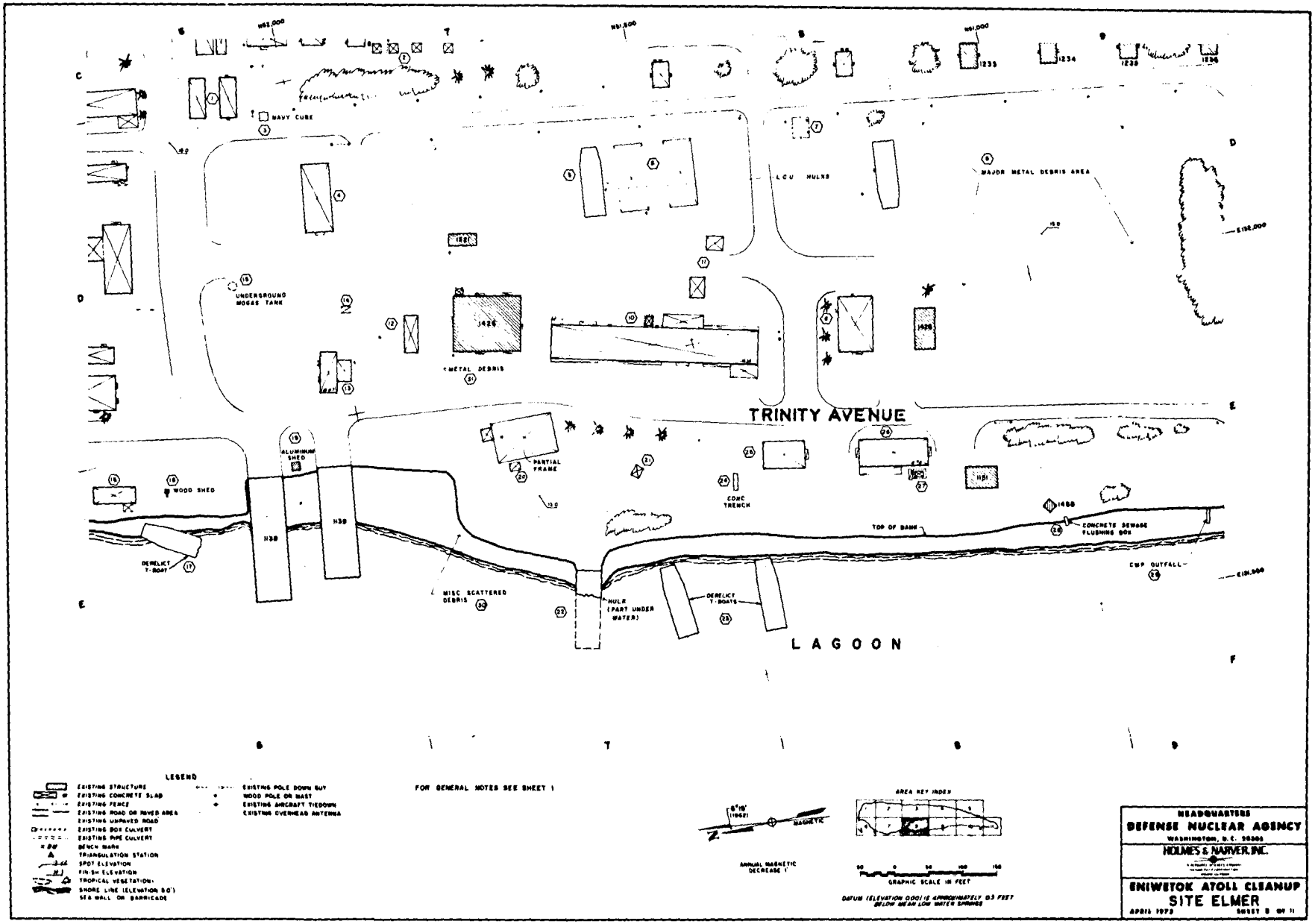

FIGURE 149. SITE ELMER, SHEET 8 OF 11

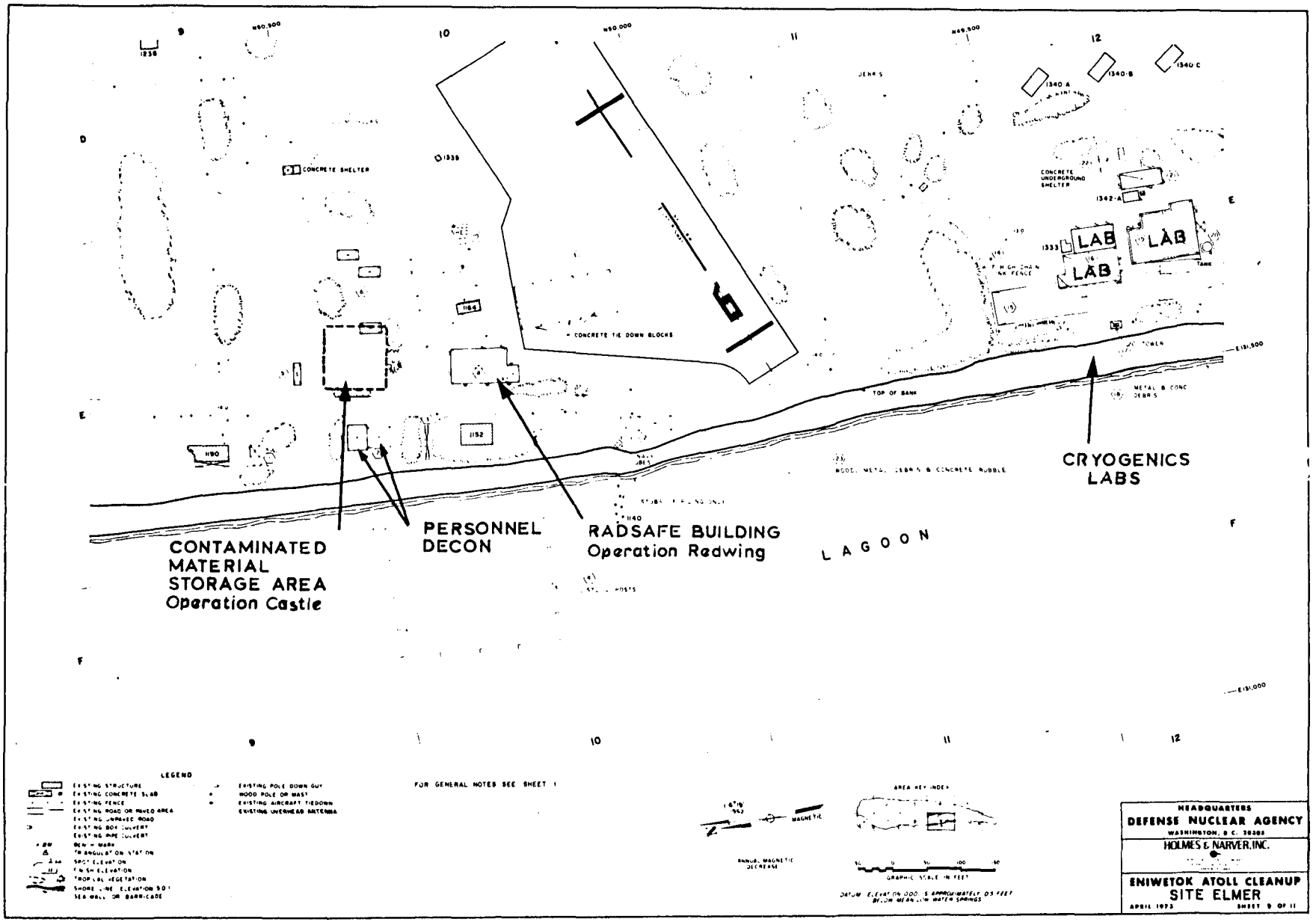

FIGURE 150. SITE ELMER, SHEET 9 OF 11

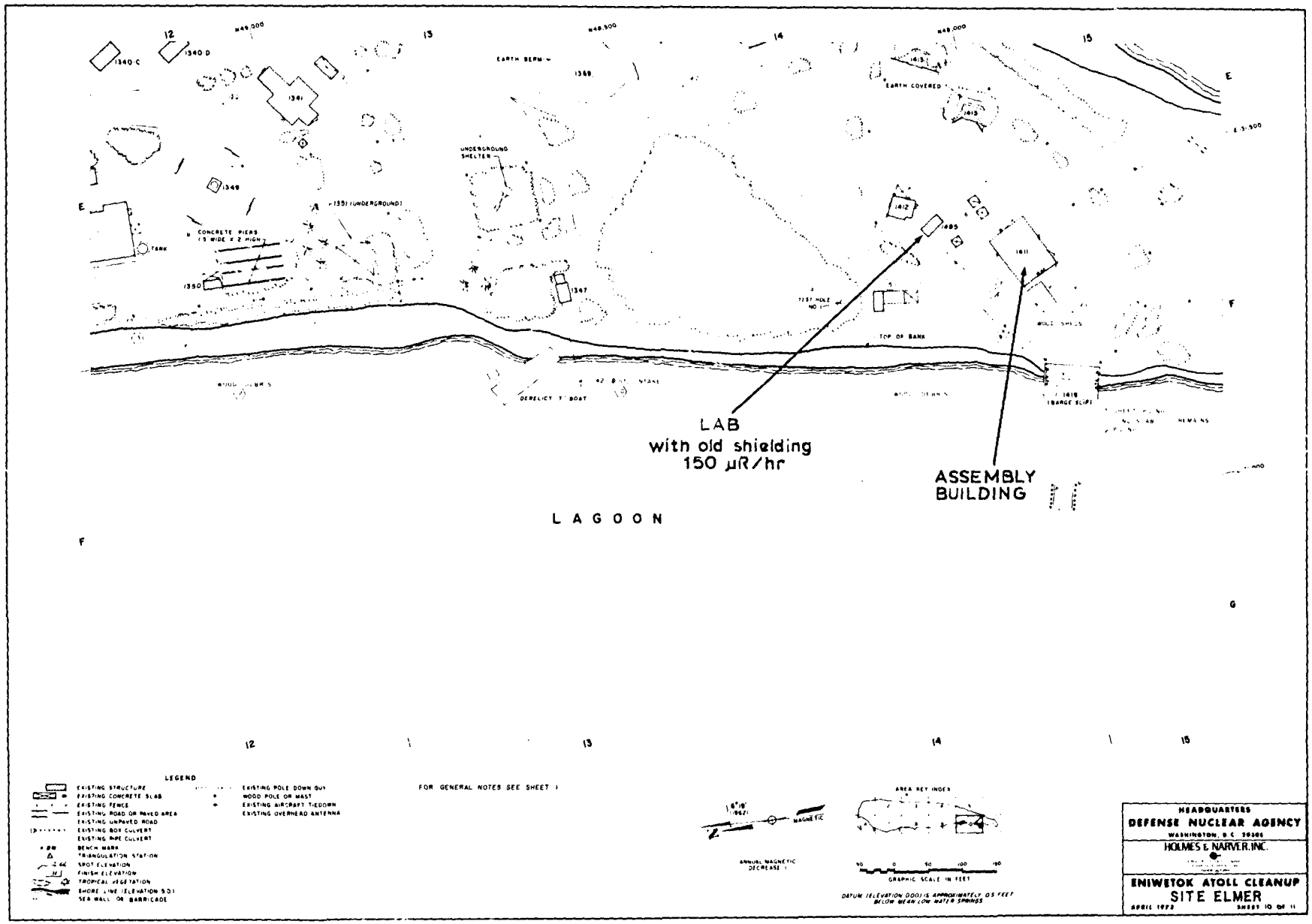

FIGURE 151. SITE ELMER, SHEET 10 OF 11

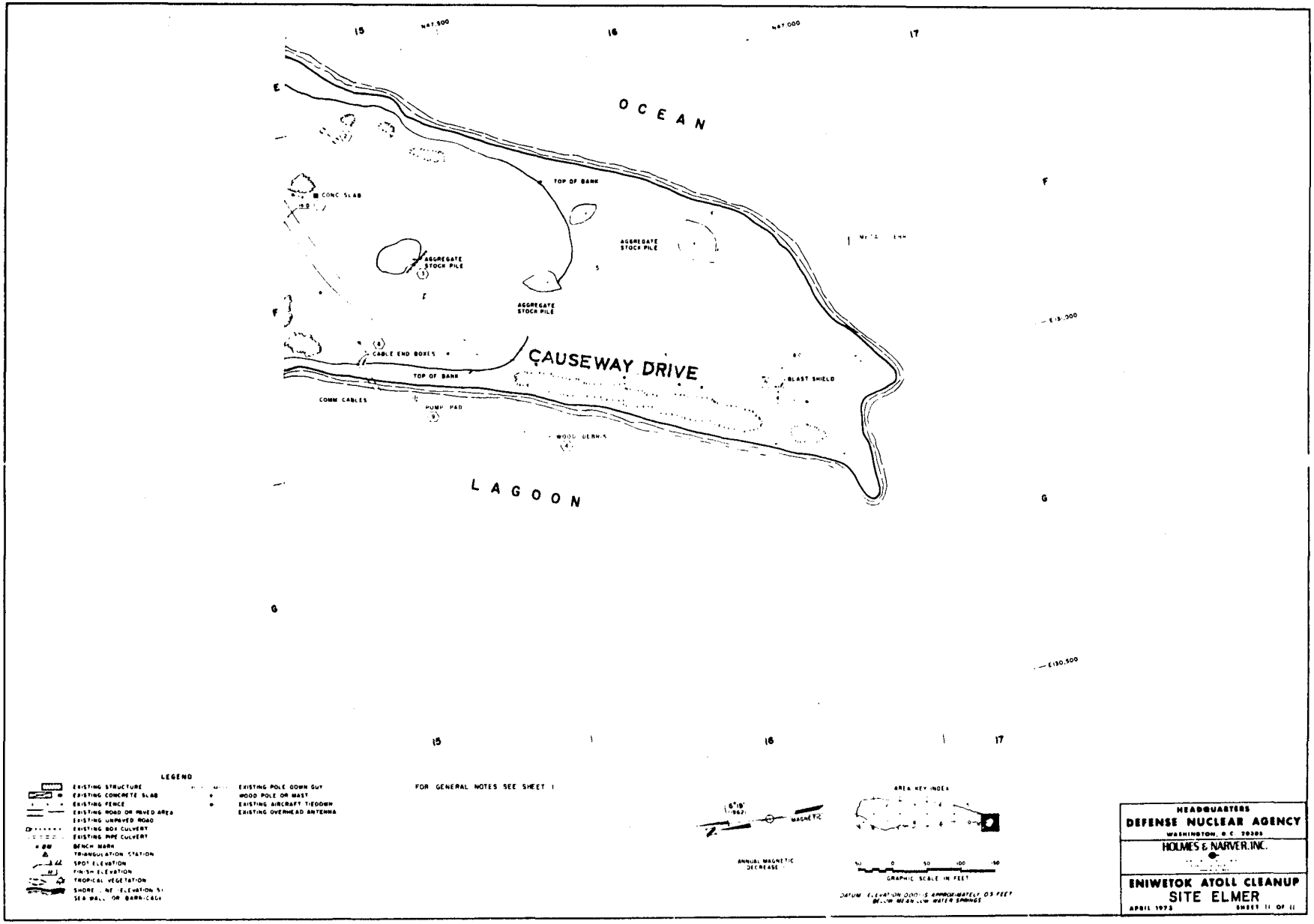

FIGURE 152. SITE ELMER, SHEET 11 OF 11

August 29, 1977

Site Name: FRED
Board of Geo.: ENIWETOK
Marshallese: ENEWETAK

FRED is located in the southeast quadrant of Enewetak Atoll and has an area of about 322 acres (130 hectares). FRED is the largest island in the Atoll. It was the support base for the military segment of the nuclear test operations as well as support island for the Pacific Missile Range and the Air Force Western Test Range following nuclear testing. It has been selected as a residential island for the returning Enewetak people and will be the main support base for cleanup operations. Many structures are present on FRED, including an airport capable of handling large jet aircraft. Figure 153 is the Plot Plan of facilities at the end of testing. Details appear in Figures 154 through 171.

FRED has no zero points and radiation levels are low on the island. Accumulated H+1 hour exposure from 4 nuclear events on the Proving Ground totalled 2.6 R/h. The maximum 1 meter exposure rates measured in 1972 were 1 uR/h. Radionuclide concentrations in surface soil samples were measured to be:

Radionuclide	Activity (pCi/g)	
	Mean	Range
^{90}Sr	0.61	0.16 - 1.5
^{137}Cs	0.25	0.02 - 2.1
^{239}Pu	0.08	0.02 - 0.31
^{60}Co	0.04	0.02 - .15

During the buildup, roll-back and interoperational periods of nuclear testing, FRED was the site of numerous construction programs. These may have altered radiation distributions on the island, however, the levels were low and may not be detectable at this time. One example is currently known as Parking Apron 2 at the airport (2400 feet from the approach end of runway 6). It is suspected that this area may have been used for aircraft decontamination during OPERATION CASTLE (based on aerial photo). If so, this area was altered prior to OPERATION HARDTACK when the runway was refurbished and lengthened on both ends. The areas routinely used for aircraft decontamination are labeled on Figures 167 and 168. The larger of the two concrete pads was constructed early in the testing program and the second was added later — for REDWING or HARDTACK. As suggested for SITE ELMER, the drains and drain outfalls from these areas should be rechecked to assure no accumulation of radioactivity remains from decontamination activities.

Other references have been found which refer to decon areas on FRED; one was called Decon Area 117. The location of these areas were not given. Due to the low radiation levels measured on the island, these are not of great concern. They also may be the same locations as the aircraft decon pads mentioned above.

Cleanup activities on FRED will involve only physical hazards unless the above areas or resurvey indicates otherwise.

CASE 3: UNLIMITED USE

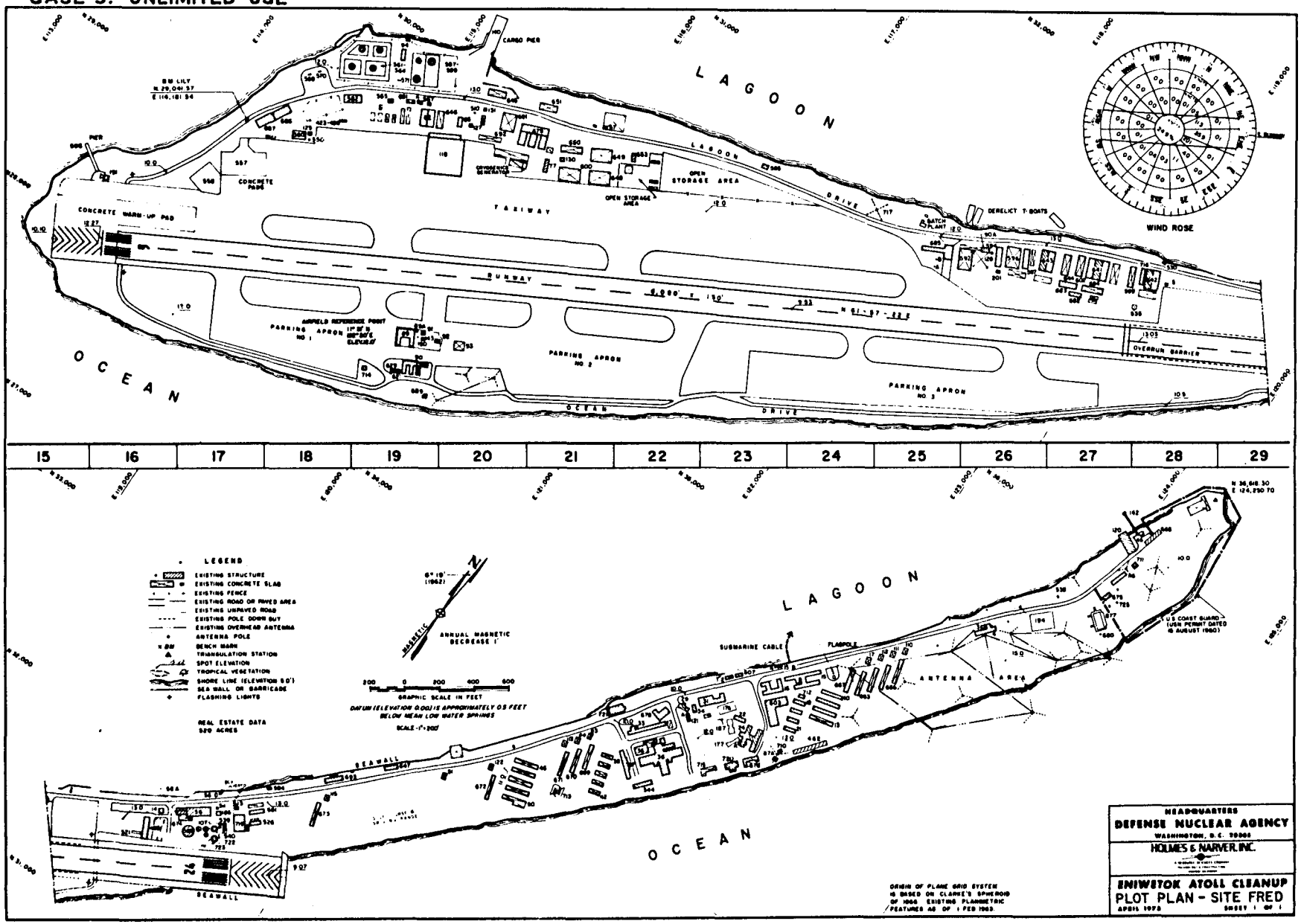

FIGURE 153. SITE FRED, PLOT PLAN

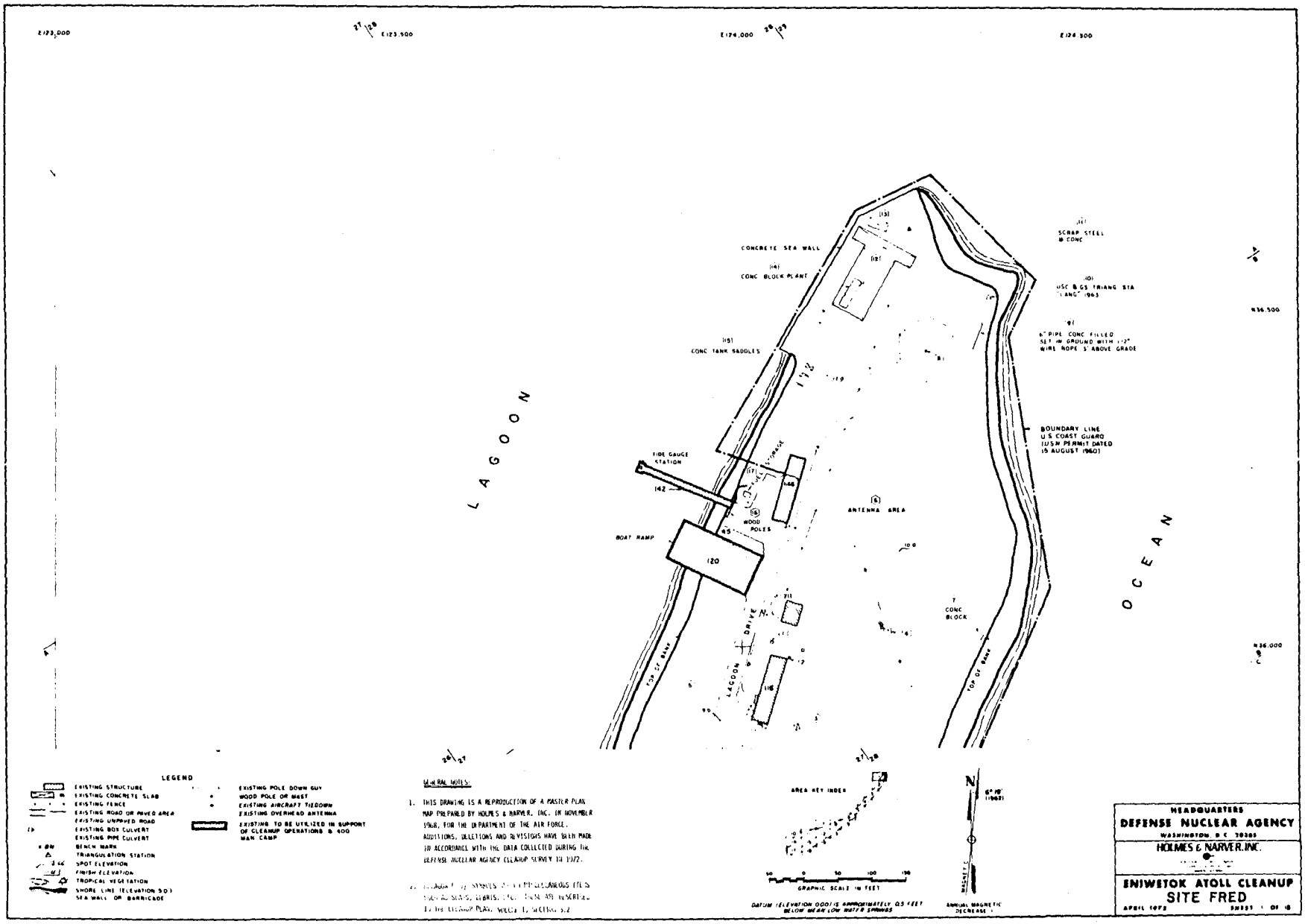

FIGURE 154. SITE FRED, SHEET 1 OF 18

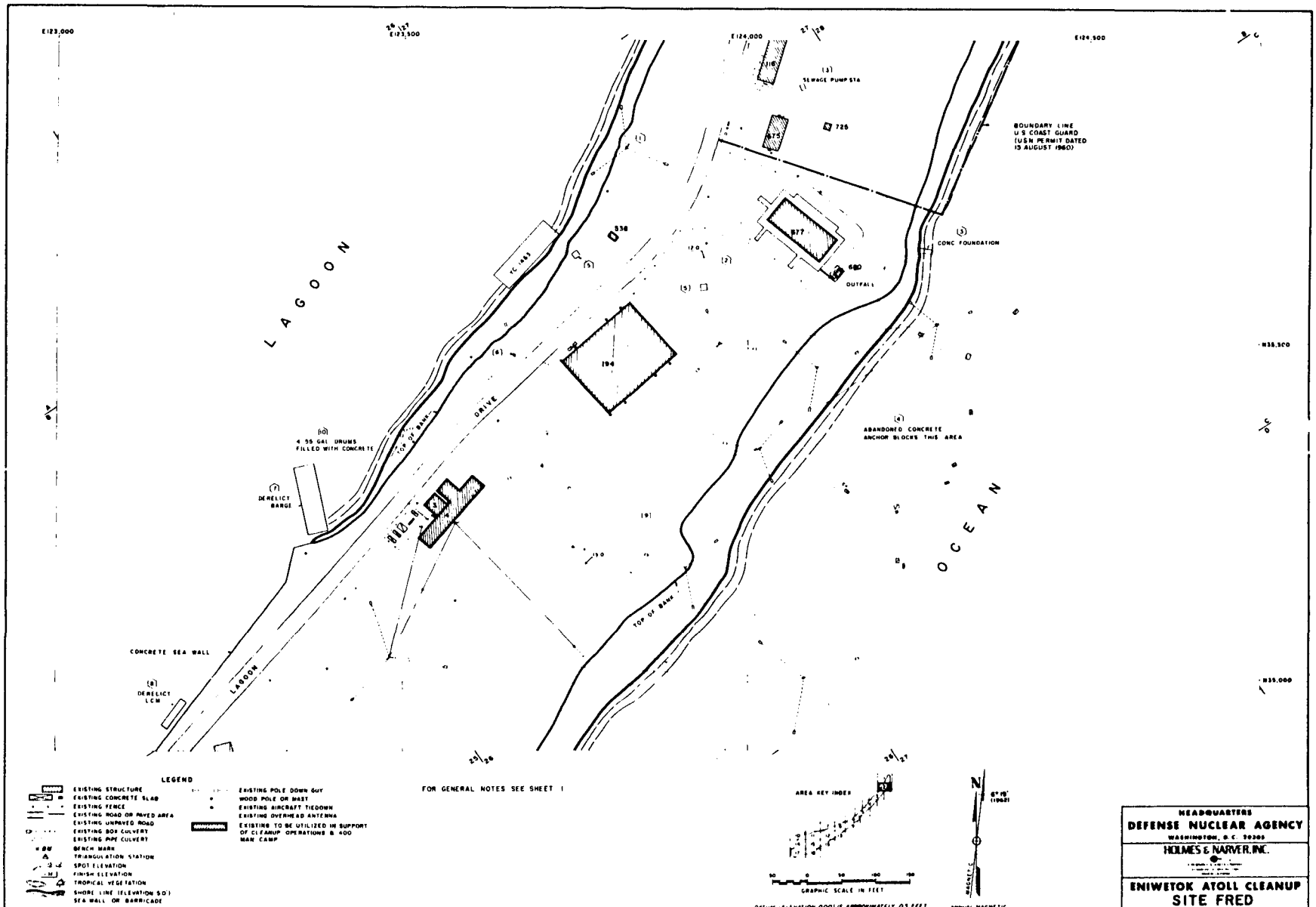

FIGURE 155. SITE FRED, SHEET 2 OF 18

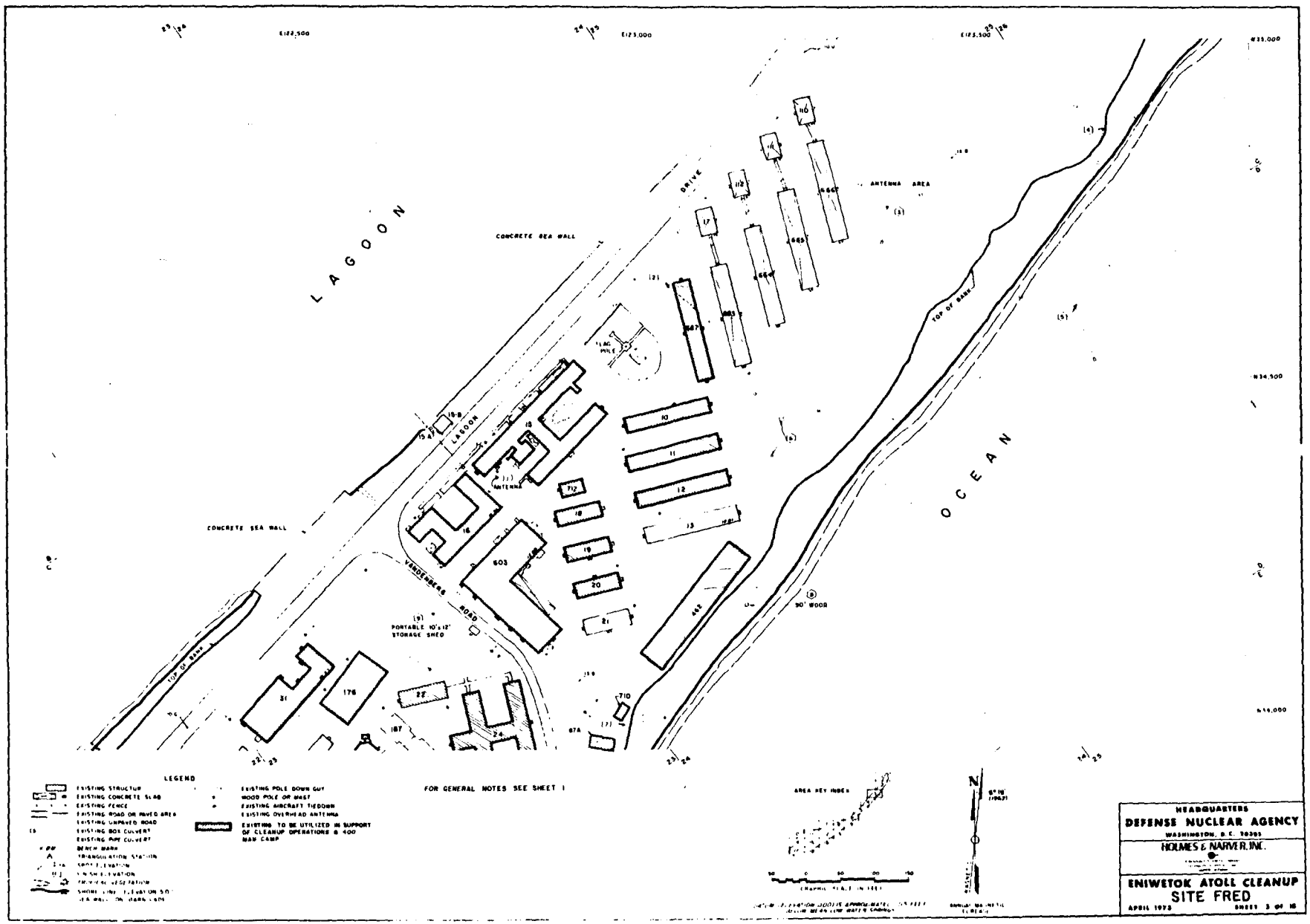

FIGURE 156. SITE FRED. SHEET 3 OF 18

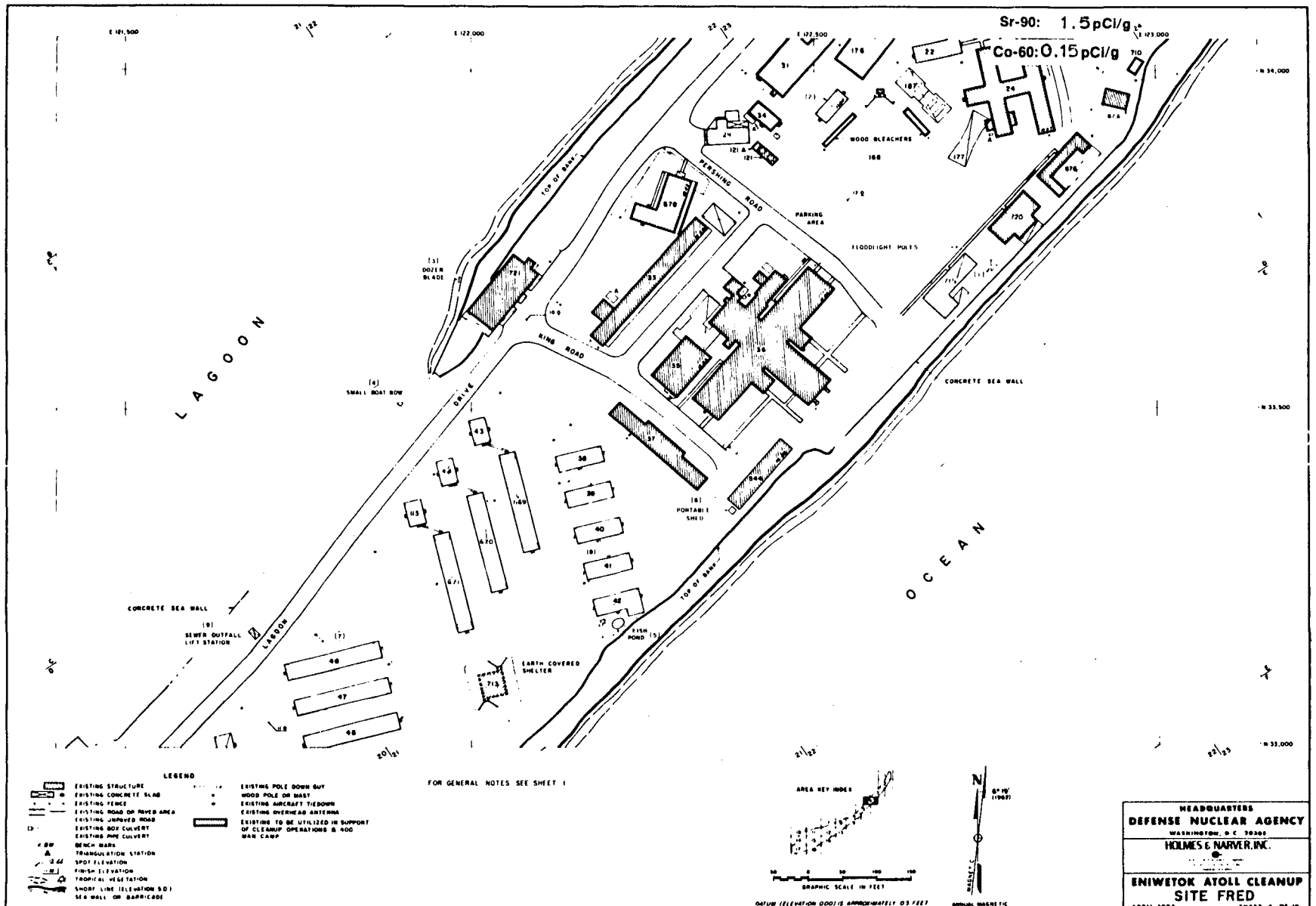

FIGURE 157. SITE FRED, SHEET 4 OF 18

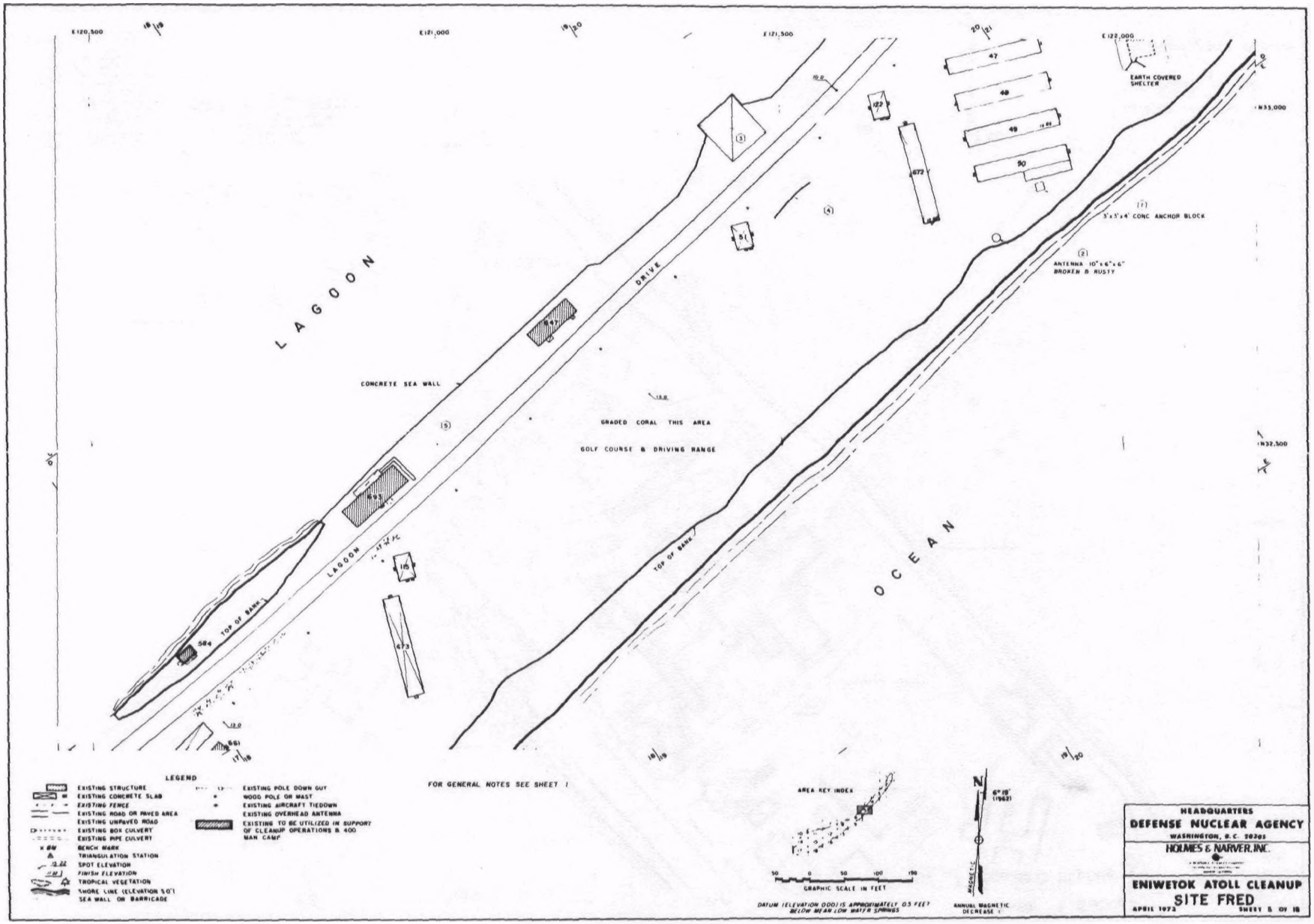

FIGURE 158. SITE FRED, SHEET 5 OF 18

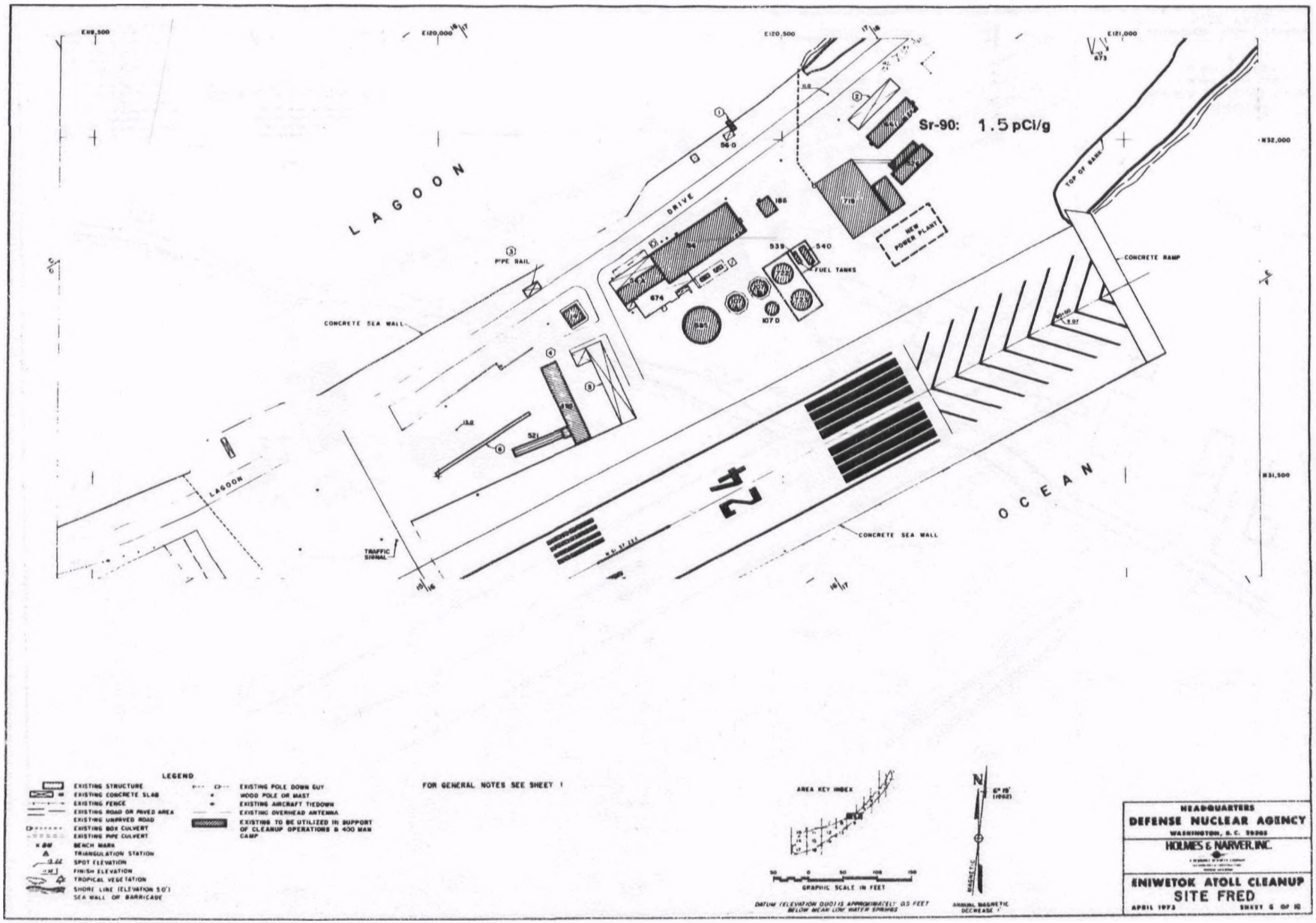

FIGURE 159. SITE FRED, SHEET 6 OF 18

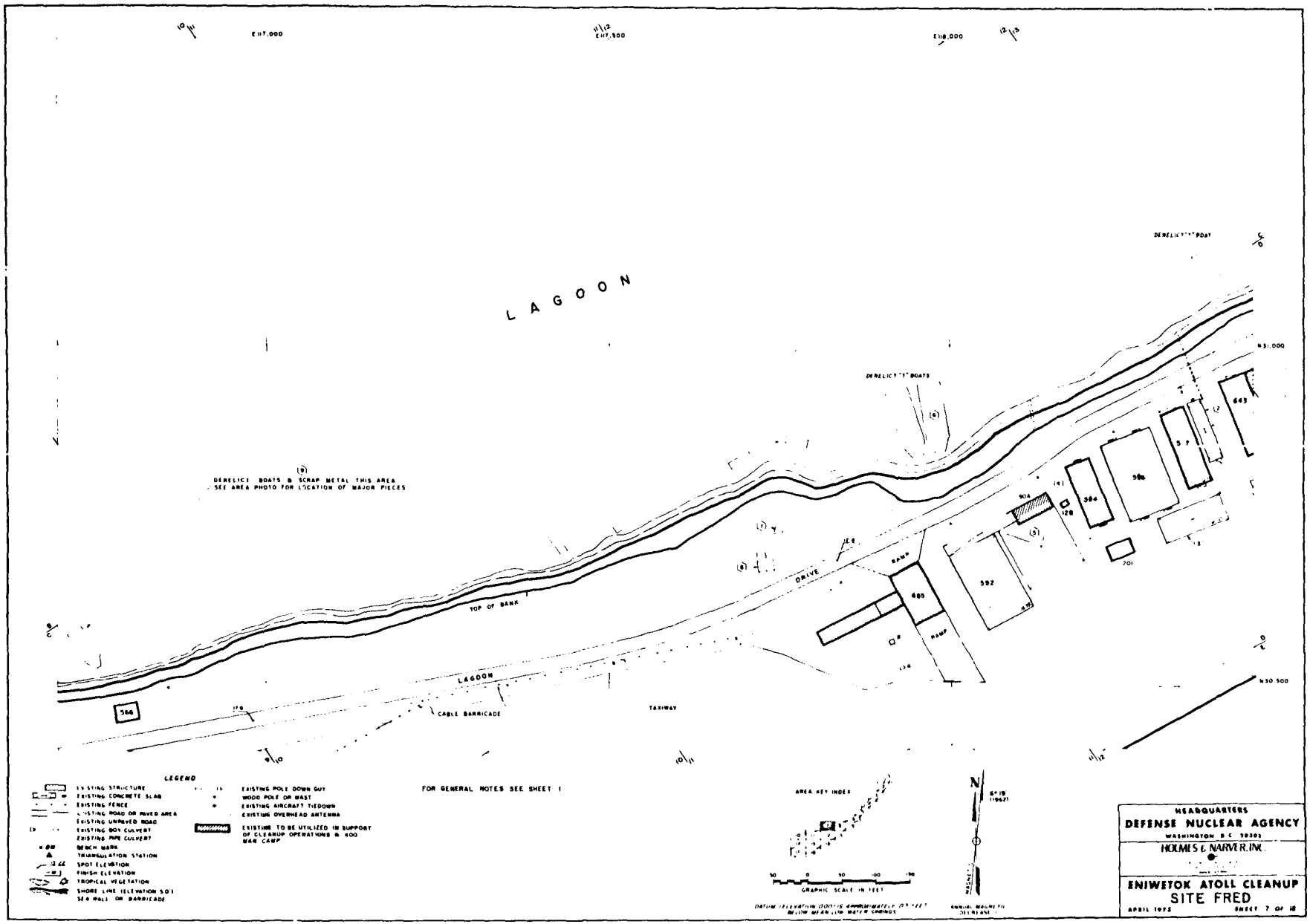

FIGURE 160. SITE FRED, SHEET 7 OF 18

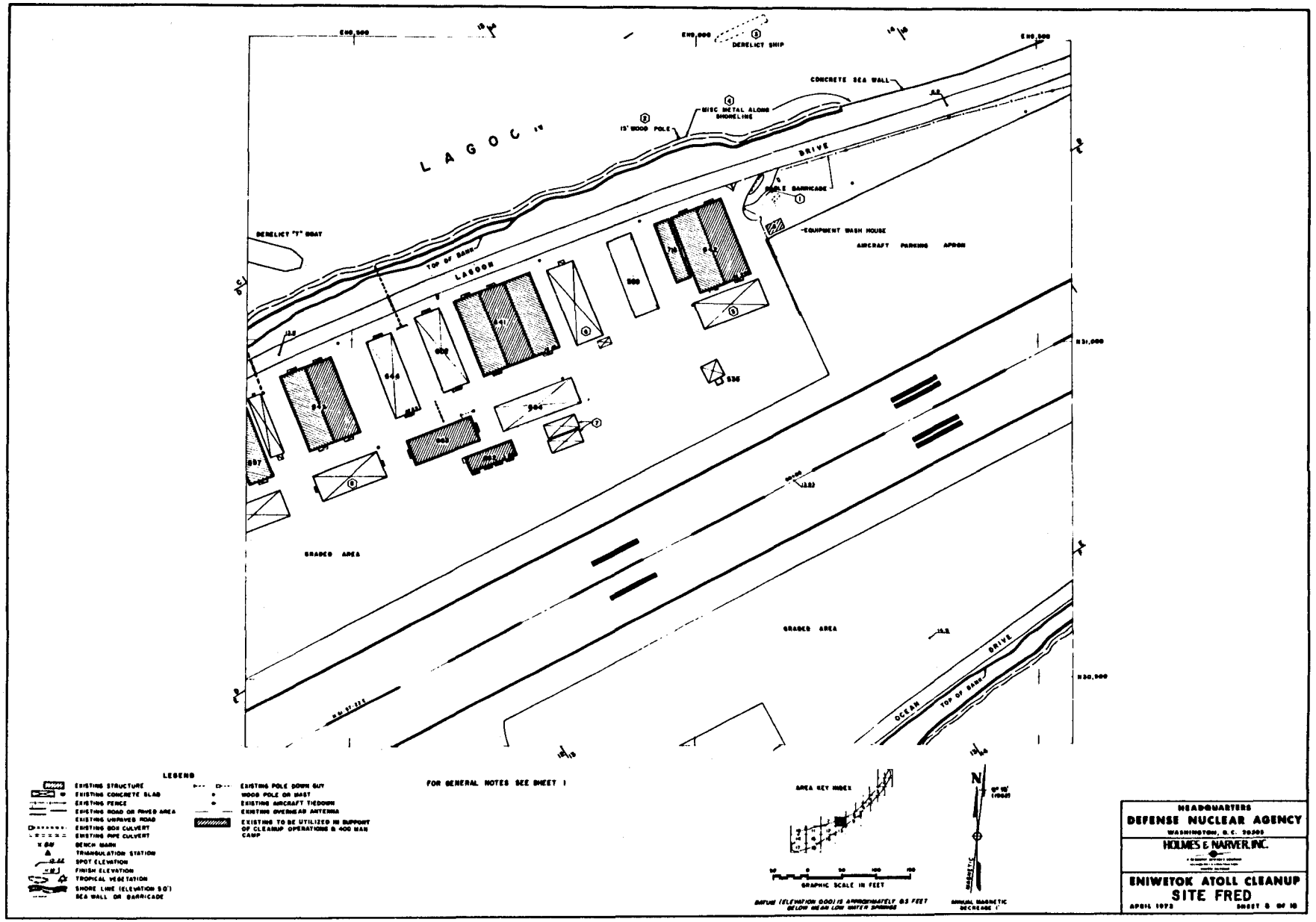

FIGURE 161. SITE FRED, SHEET 8 OF 18

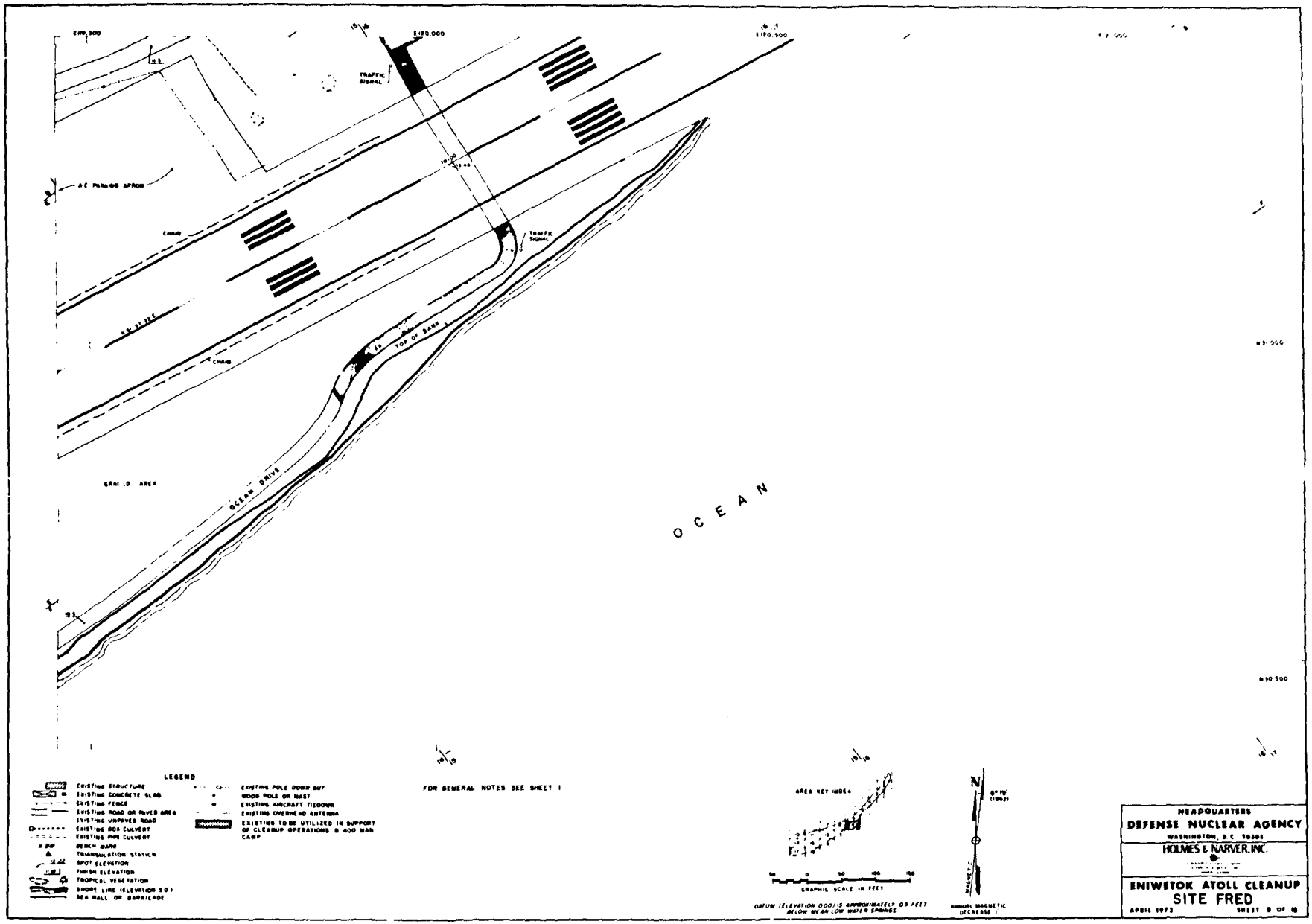

FIGURE 162. SITE FRED, SHEET 9 OF 18

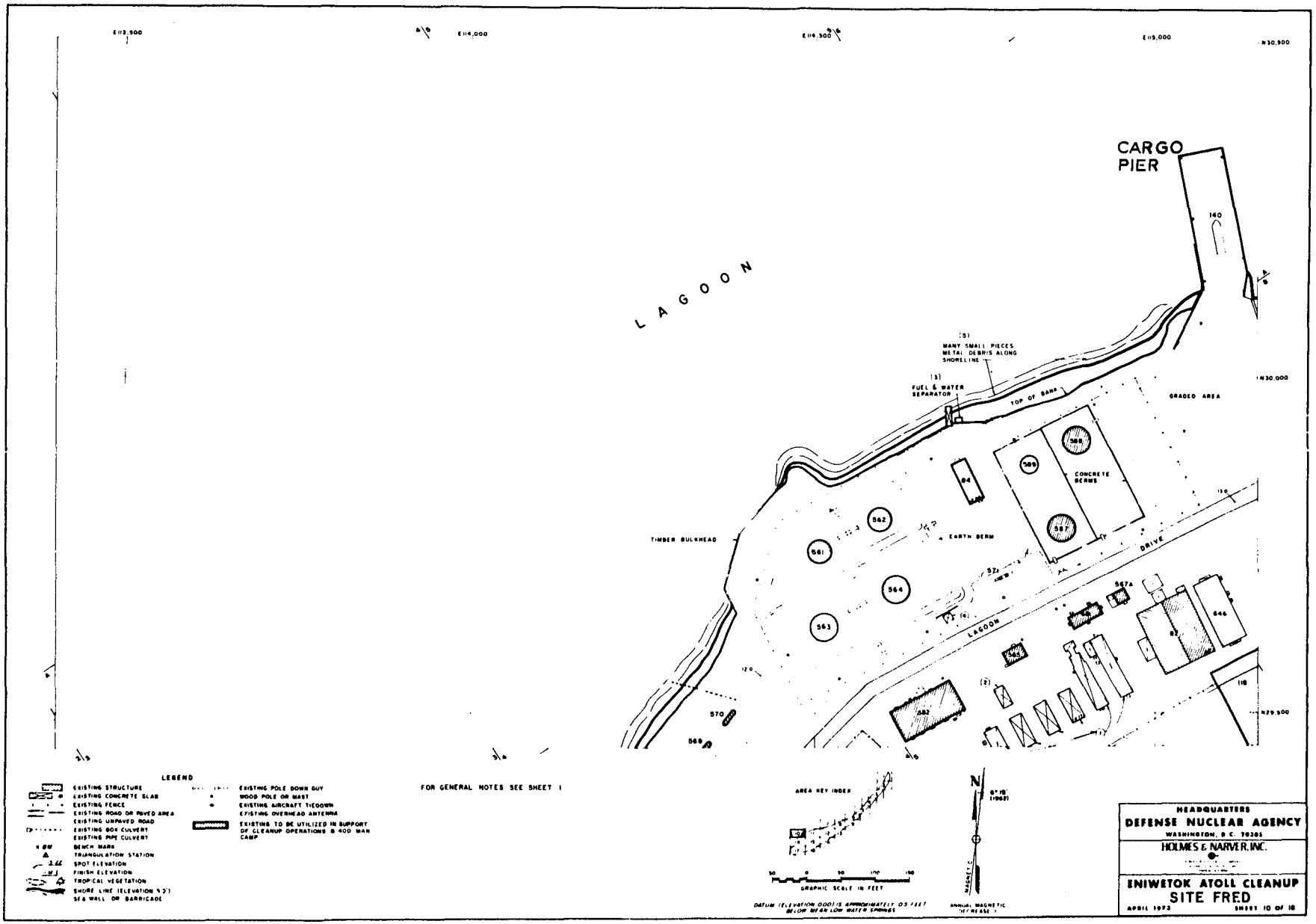

FIGURE 163. SITE FRED, SHEET 10 OF 18

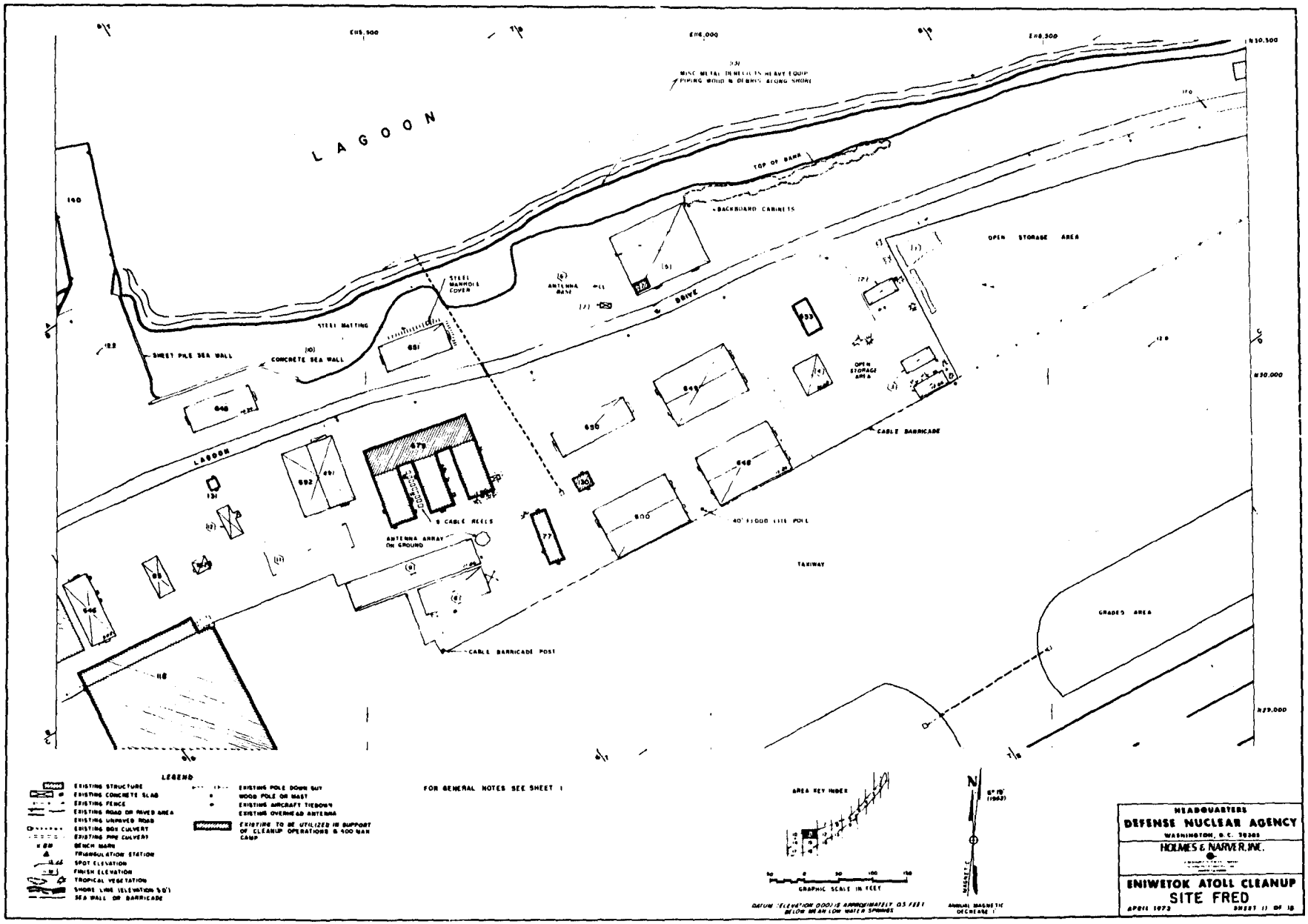

FIGURE 164. SITE FRED, SHEET 11 OF 18

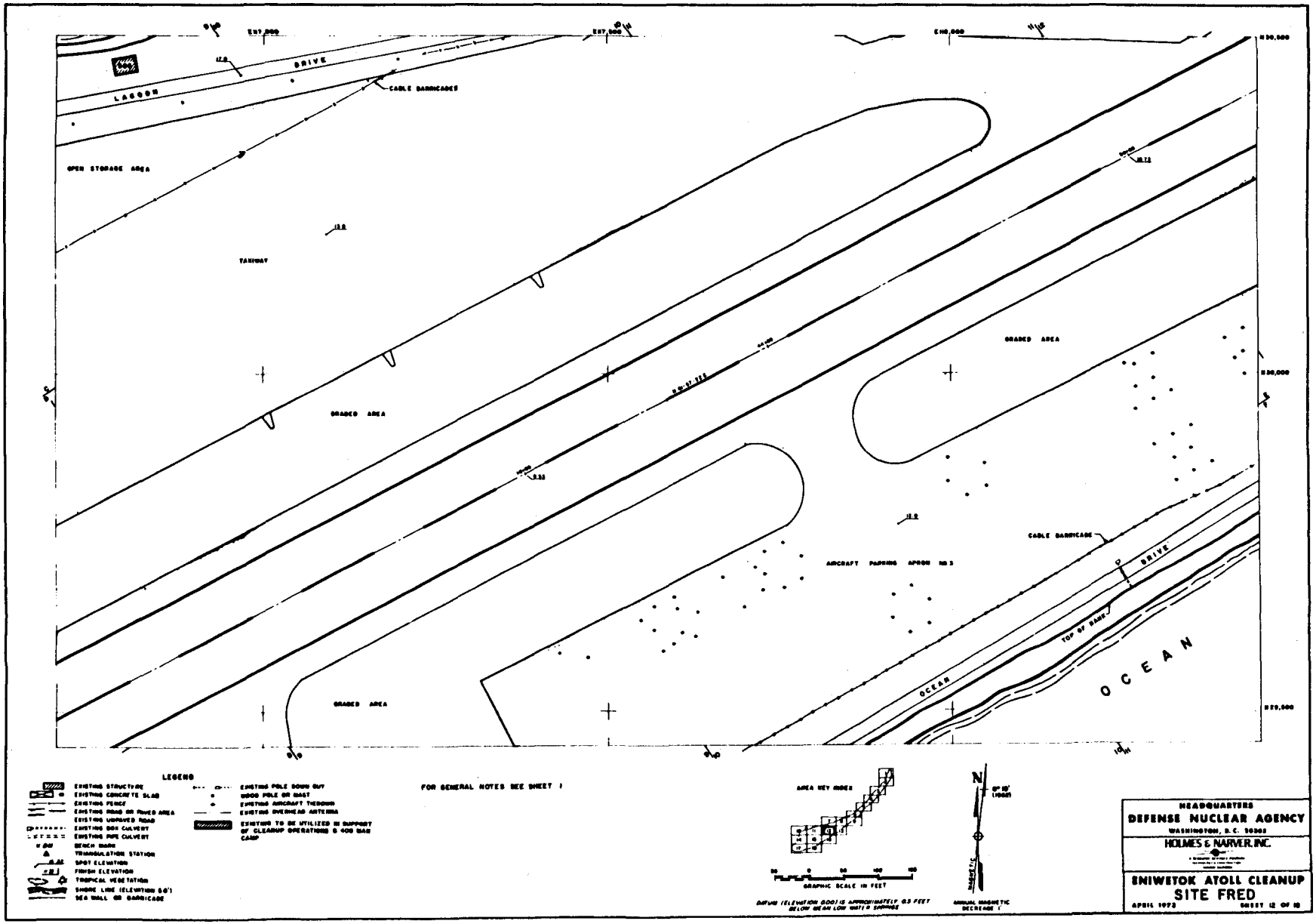

FIGURE 165. SITE FRED, SHEET 12 OF 18

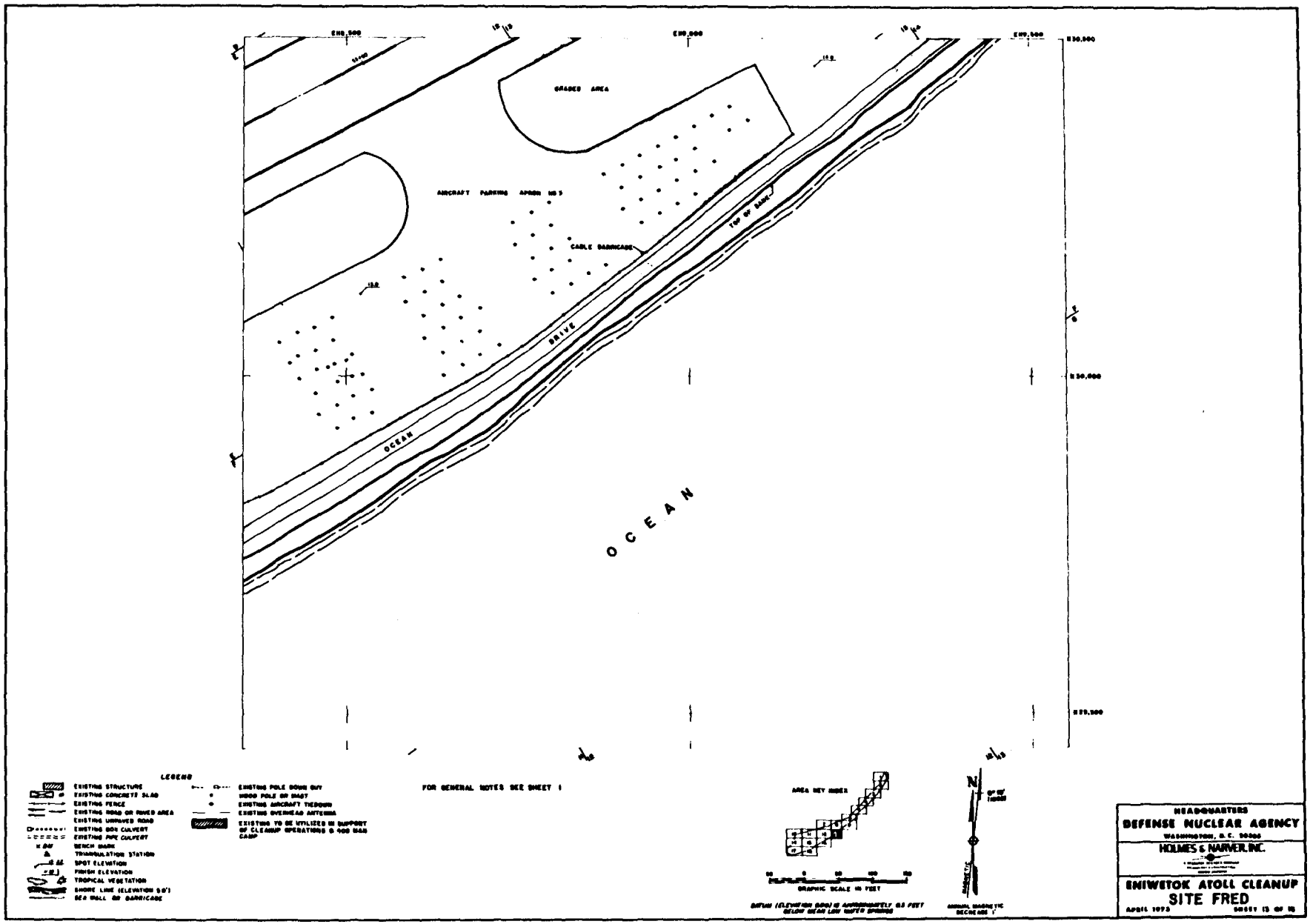

FIGURE 166. SITE FRED, SHEET 13 OF 18

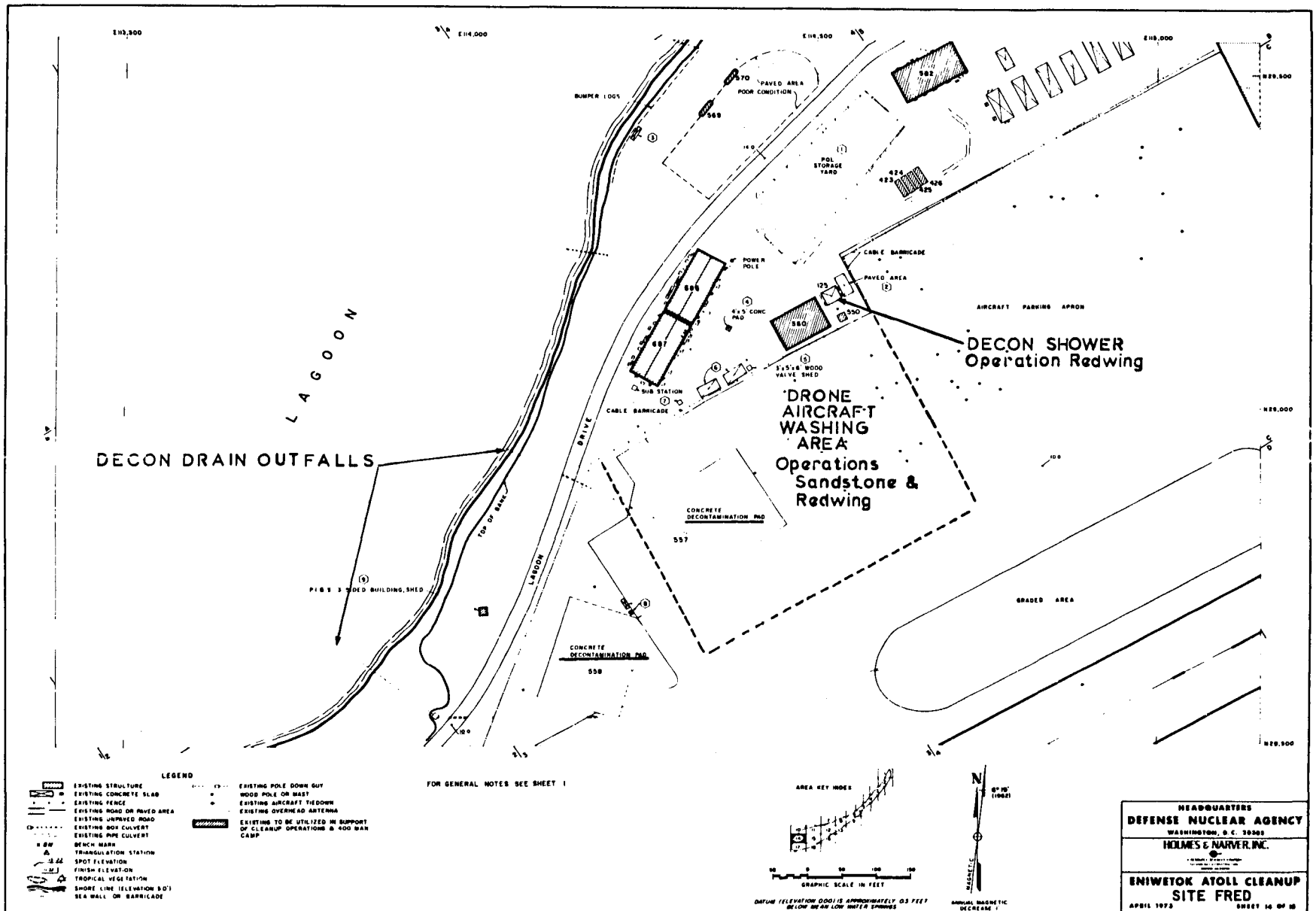

FIGURE 167. SITE FRED, SHEET 14 OF 18

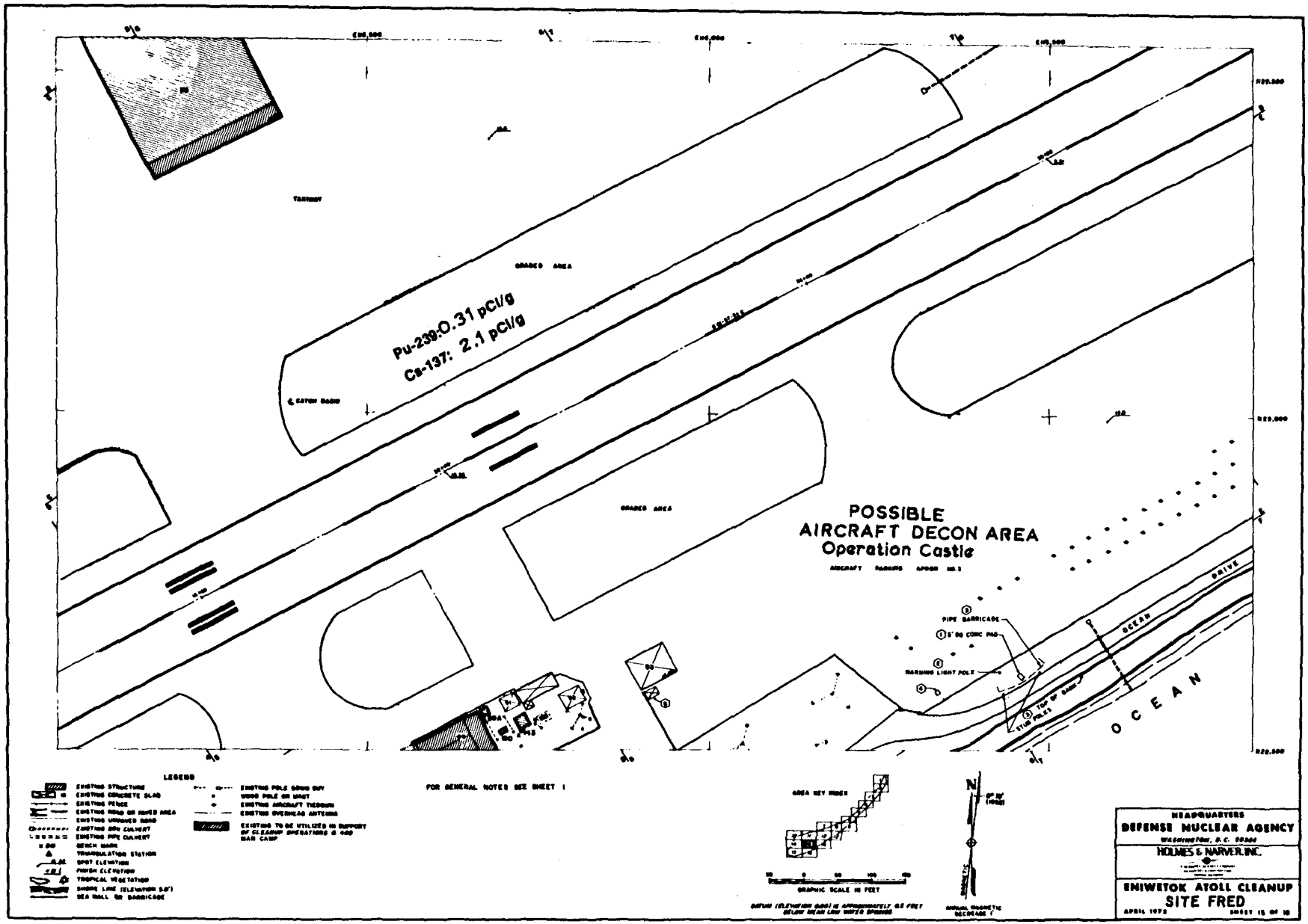

FIGURE 168. SITE FRED, SHEET 15 OF 18

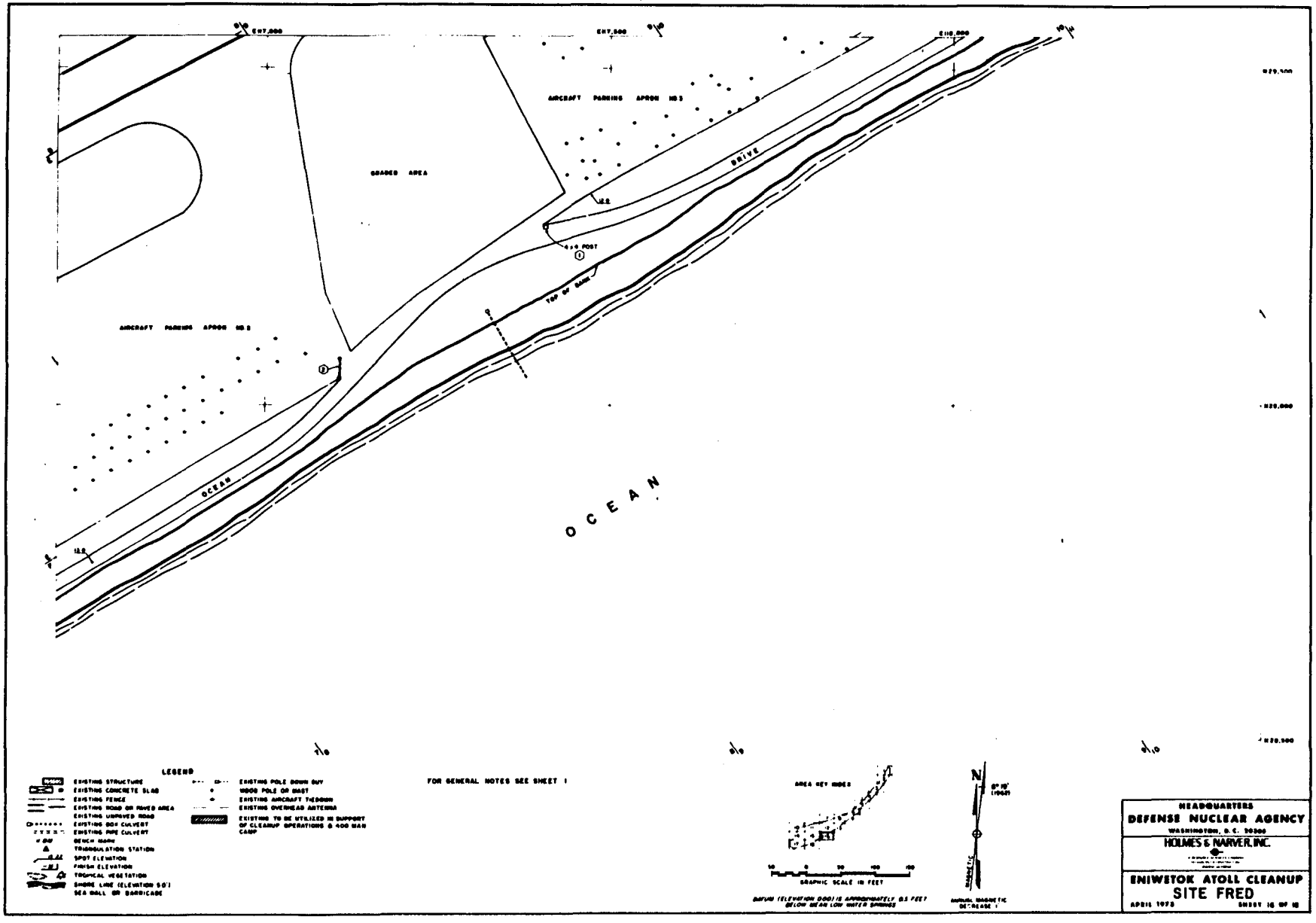

FIGURE 169. SITE FRED, SHEET 16 OF 18

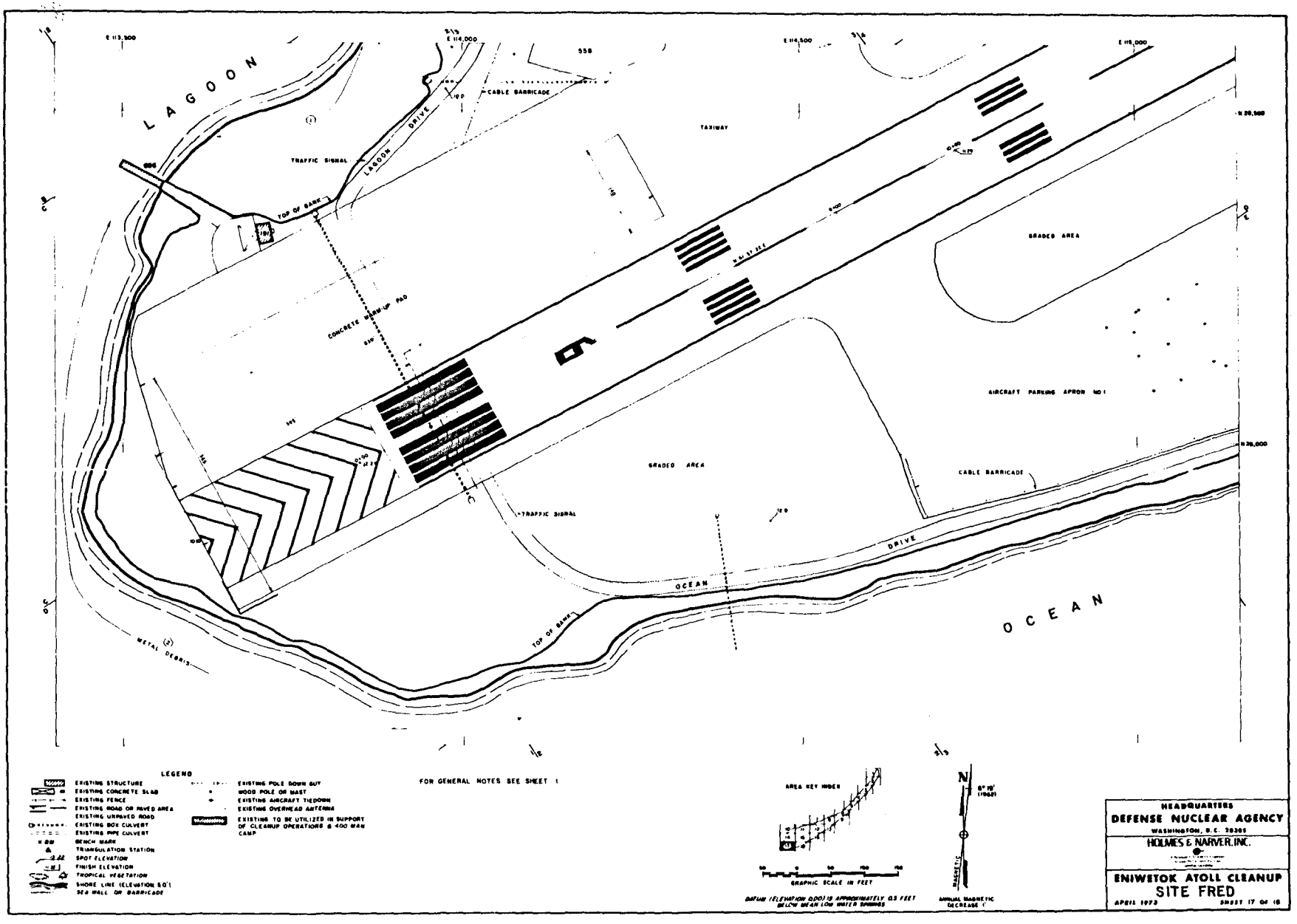

FIGURE 170. SITE FRED, SHEET 17 OF 18

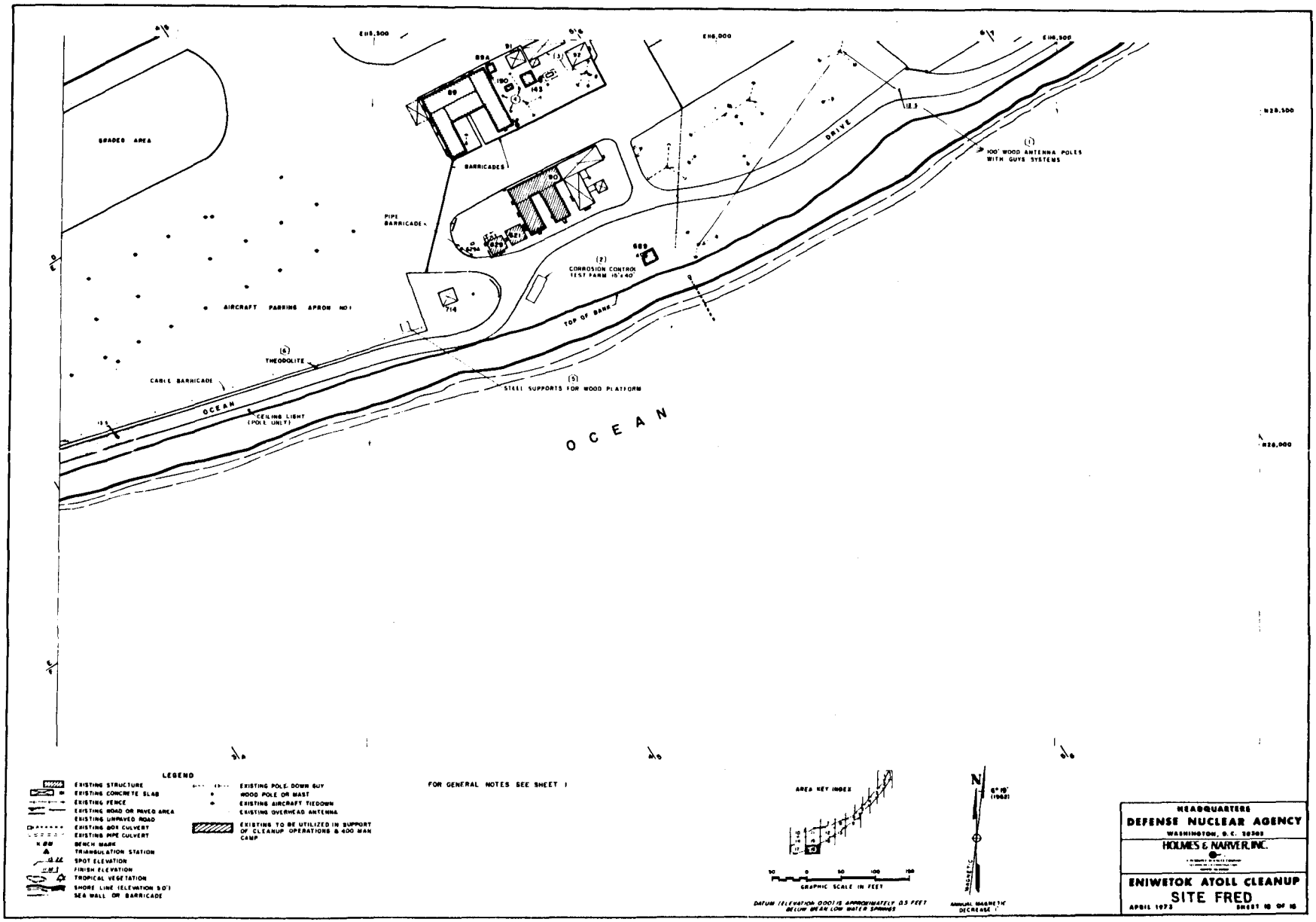

FIGURE 171 SITE FRED, SHEET 18 OF 18

Site Name: LEROY
Board of Geo.: RIGILI
Marshallese: BIKEN

LEROY is the western-most island of Enewetak Atoll. It is situated north of the Southwest Passage and has an area of about 13.6 acres (5.5 hectares). The entire island is overgrown with brush, trees and some coconut palms except for some clearings on the lagoon side. LEROY was used during three of the nuclear test operations for scientific purposes including fallout collection.

LEROY has no surface zeroes. It received fallout from 13 events, which ranks it 23rd of the islands in the Atoll for accumulated H+1 hour exposure rate received with 235 R/h. This is reflected by the background gamma exposure rates and soil samples collected there for the radiological survey in 1972. The maximum 1-m exposure rate was 8 uR/h in the area indicated on Figure 172. Furthermore, the island's dense vegetation probably tends to inhibit dilution of the radioactivity by environmental processes.

The activities obtained from the 15-cm deep surface soil samples were:

Radionuclide	Activity (pCi/g)	
	Mean	Range
^{90}Sr	11	1.6 - 34
^{137}Cs	3.2	0.5 - 10
^{239}Pu	0.63	0.02 - 2.0
^{60}Co	0.58	0.04 - 5.0

These mean activities are about ten times greater than those observed on the other islands in the southern part of the Atoll. The depth distributions of activity measured at three locations within the interior of the island exhibit very gradual decreases in activity with depth. Relaxation lengths of 10 cm or greater are typical.

No radioactive material burials are known to exist on LEROY.

CASE 3: BIRDS, EGGS, PICNIC

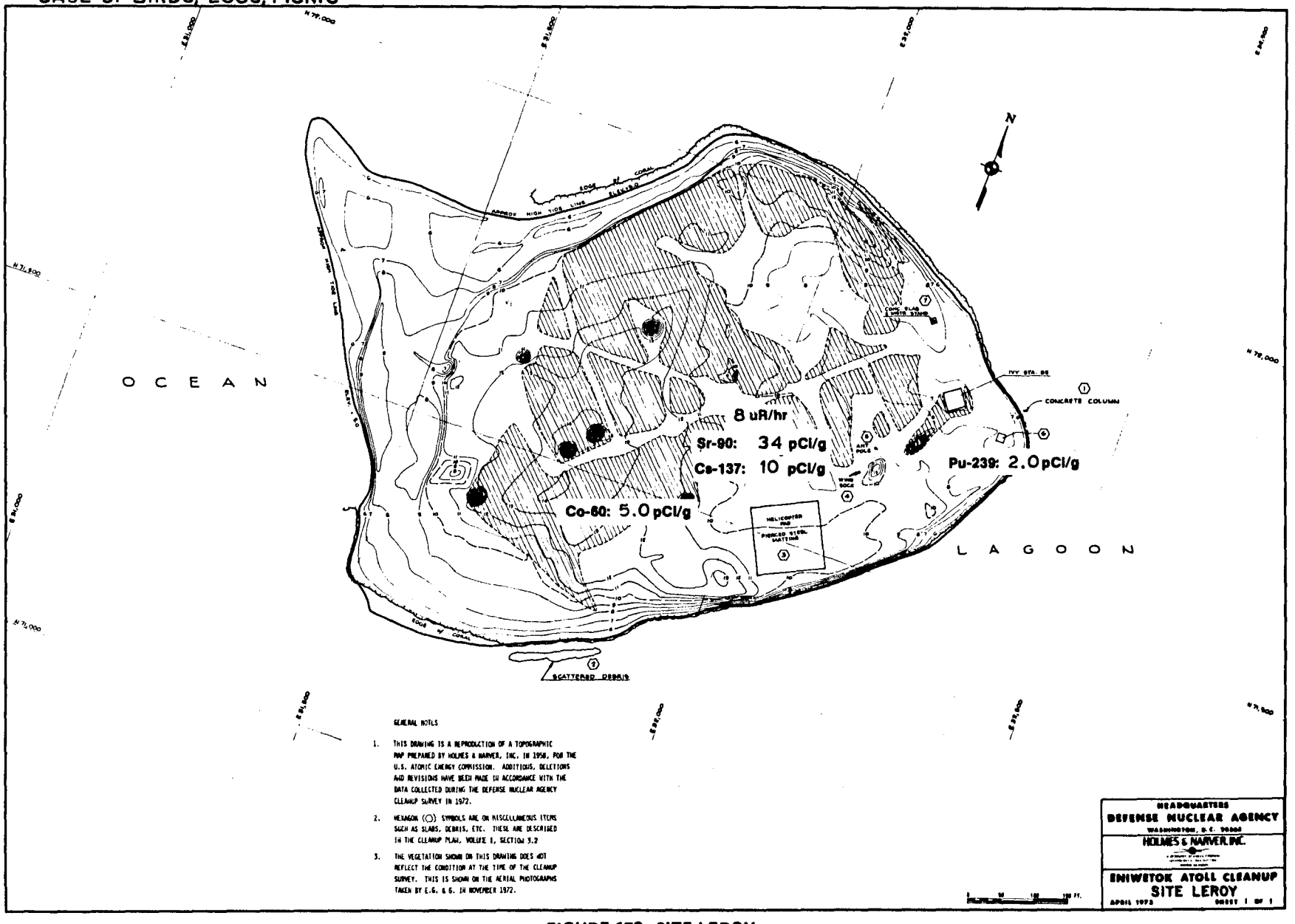

FIGURE 172. SITE LEROY

EPILOGUE

ENEWETAK FACT BOOK

WAYNE A. BLISS

The Fact Book has undergone minor editing for final printing. No changes were made other than format and grammar. The Fact Book was prepared prior to cleanup to be used as an informative guide. That premise has not changed nor has it been compromised by this editing.

The following information is included to expand or clarify the Fact Book. As the cleanup proceeded, discoveries were made, new questions asked, and the Fact Book questioned. This author and others responded to each incident to develop the best possible information base to assure cleanup.

As mentioned by footnote in the text, the AEC Task Group recommended criteria were, by design, general in nature. Soil concentrations in the range of 40-400 pCi Pu/gm were to be treated on a case-by-case basis. In OPLAN 600-77, an intermediate level of 100 pCi/gm was used to define a Condition B which might be applicable to an agricultural island. This served for planning purposes and for the development of methodology. The Enewetak Advisory (Bair) Committee came forth, on April 28, 1978, with its recommended levels of 40, 80, and 160 pCi/gm (total transuranium elements) for residence, agricultural and food gathering islands, respectively. Thenceforth these levels were used as guidance for cleanup decisions and certification.

The Fact Book treatment of YVONNE mentioned a jar of highly contaminated sand buried near the door to HARDTACK Station 1310. The mention was made based on the personal recall of a visitor there in 1971 and 1972. Investigation during cleanup showed the supposed burial area to be underlain with concrete. The mention was in error and the jar found in the 15 x 15-ft. wire enclosure is most probably the same as the one supposedly buried.

The Fact Book did not specify the land areas of sites FLORA and GENE which were destroyed by nuclear testing. Holmes & Narver has estimated that FLORA had an area of about 35 acres (14 hectares) and GENE had an area of about 23 acres (9.4 hectares).

During a precleanup radiation survey on ELMER, an area near coordinates N49,200 and E132,400 was found to have higher than expected levels of ^{60}Co in soil. Although of no great hazard, this area had not been previously identified. No reason for its existence was found.

Rumor of a plutonium incident on ELMER resulting in onsite burial arose during cleanup. Investigation concluded that the incident rumored was the same as the plutonium foil incident mentioned in the Fact Book and that no onsite burial occurred.

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