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LABORATORY  
OF THE UNITED STATES  
DEPARTMENT OF ENERGY



AN AERIAL RADIOLOGICAL AND PHOTOGRAPHIC SURVEY  
OF ELEVEN ATOLLS AND TWO ISLANDS WITHIN THE

# NORTHERN MARSHALL ISLANDS

DATES OF SURVEYS: JULY - NOVEMBER 1978

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### ABSTRACT

An aerial radiological survey was conducted over eleven atolls and two islands within the northern Marshall Islands between September and November 1978. This survey was part of a comprehensive radiological survey, which included extensive terrestrial and marine sampling, to determine possible residual contamination which might remain as a result of the United States nuclear testing program conducted at Bikini and Enewetak Atolls between 1946 and 1958. A similar survey was conducted at Enewetak Atoll in 1972.

The present survey covered those atolls known to have received direct fallout from the Bravo event, conducted in March 1954 at Bikini Atoll. These included Bikini, Rongelap, Rongerik, Ailinginae, Bikar, Taka, and Utirik Atolls. In addition, several atolls and islands which might have been at the fringes of the Bravo fallout were also surveyed, including Likiep and Ailuk Atolls, Jemo and Mejit Islands, and Wotho Atoll. Ujelang Atoll, which lies approximately 200 km southwest of Enewetak, was also surveyed.

The aerial survey employed a large array of NaI (TI) detectors mounted externally on a Navy SH-3G helicopter. Results were processed to obtain total terrestrial exposure rate values, as well as the individual contributions and associated soil concentration values for  $^{137}\text{Cs}$  and  $^{60}\text{Co}$ . Results are presented in the form of island-averaged terrestrial exposure rate and soil concentration values, as well as detailed radiation contour maps.

Island-averaged terrestrial exposure rates in the range of 30-50  $\mu\text{R/h}$  were observed over parts of Bikini Atoll, including Bikini Island, and over the northern part of Rongelap Atoll. Levels over southern Rongelap and over Rongerik Atoll ranged from 4-7  $\mu\text{R/h}$ . Levels were somewhat lower at Ailinginae Atoll (approximately 2  $\mu\text{R/h}$ ) and at Utirik Atoll (approximately 0.7  $\mu\text{R/h}$ ). The variations observed were consistent with what might be expected from the fallout pattern of the Bravo event. Levels at Ailuk, Likiep, Wotho and Ujelang Atolls and at Mejit and Jemo Islands were consistent with  $^{137}\text{Cs}$  activity, due to worldwide fallout, observed within the United States and at other locations in the central Pacific. These four atolls and the two islands, therefore, do not appear to have received any significant direct contamination from the Bravo event or the other tests conducted at Bikini and Enewetak Atolls.

A detailed aerial photographic survey using a large format aerial mapping camera was also conducted between July and September 1978 in order to obtain photographs for use in the radiation survey. These photographs were used as base maps for presenting the radiation contour data and were used to generate photomosaics for each of the atolls surveyed. A special four-camera array was also employed to obtain photographs covering several different optical wavelength regions of the electromagnetic spectrum. This multispectral imagery can be used for a variety of purposes, including such things as a determination of the type and vigor of vegetation on each island, a determination of the percent cover of the various types of vegetation, estimation of water depth around each island and a study of island usage by the inhabitants.



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## 1.0 INTRODUCTION

During the period from 1946 to 1958 the United States conducted a number of nuclear weapons related tests in the Pacific at Enewetak and Bikini Atolls. These atolls, which lie approximately 4000 km southwest of Honolulu, are part of the northern Marshall Islands. After World War II a United Nations trusteeship was established over a portion of the Pacific that included the Marshalls. This trusteeship is presently administered by the United States Government through the Department of the Interior (DOI), Office of the Trust Territory of the Pacific Islands (TTPI).

Forty-three tests were conducted at Enewetak and 23 at Bikini. Radioactive contamination from these tests was generally confined to local areas within the two atolls. Because of the prevailing winds in the northern Marshalls, radioactive clouds created by the tests were generally blown in a westerly direction over open ocean.

In March 1954 the second U.S. test of a thermonuclear device was conducted at Bikini. This test, code named Bravo, resulted in a yield of approximately 15 megatons. The radioactive cloud from the test reached an altitude of 30 km (100,000 feet), where winds were blowing in an easterly direction. The unexpected wind change in the upper atmosphere resulted in heavy radioactive fallout over the northern part of Bikini Atoll (including Bikini Island) and over parts of Rongelap, Rongerik, and Ailinginae Atolls located to the east. Significant fallout occurred as far east as Bikar and Utirik Atolls, approximately 500 km east of Bikini. This event was responsible for most of the contamination on Bikini Island and on atolls other than Bikini and Enewetak which occurred as a result of the U.S. Pacific nuclear testing program.

Since 1958 numerous radiological surveys have been conducted in the northern Marshalls to assess the impact of the U.S. nuclear testing program.<sup>1-4</sup> The most extensive survey was conducted at Enewetak Atoll in 1972.<sup>5</sup> In this survey, detailed terrestrial and marine sampling was combined with data obtained from an airborne gamma ray detector system to provide a comprehensive assessment of the radiological conditions throughout the atoll. A cleanup plan was developed for Enewetak based on the data obtained during this survey. The actual cleanup occurred between 1977 and 1979.<sup>10</sup> A rehabilitation program was initiated while the cleanup was in progress; in April 1980 the Enewetak people officially returned to Enewetak Atoll. Although some restrictions on land use were recommended for the northern part of the atoll, where the testing actually took place, the southern half was certified for unrestricted use by the Enewetak people.

A cleanup and rehabilitation program was also started on Bikini Atoll in 1969. Although a partial resettlement occurred, studies performed between 1974 and 1977 indicated that the residual radiation levels on Bikini Island were still too high to allow a safe permanent resettlement. In August 1978 the Bikinians who had resettled on Bikini were returned to Kili Island.

Since the 1954 Bravo event, periodic routine medical studies have been performed at Rongelap and Utirik Atolls. Radiation surveys have also been performed at these atolls, as well as at other atolls in the northern Marshalls.<sup>7-9</sup> None of these radiation surveys, however, has been as complete or thorough as the 1972 Enewetak survey. The United Nations trust agreement is presently scheduled to end in 1981. It was felt that a complete and comprehensive radiological survey was required, prior to the termination of the agreement, over those atolls known to have been, or suspected of having been, contaminated during the U.S. Pacific testing program. Such a survey would be the basis for a radiation dose assessment of the inhabitants.

The Department of the Interior (DOI) received funding through an FY78 supplement to cover the logistical support costs for the survey. Logistical support was provided by the Department of Defense (DOD) through the Department of the Navy (DON). Technical direction and support were provided by the Department of Energy (DOE).

The field portion of the northern Marshall Islands survey was conducted in two separate phases. The first, which took place between July and September 1978, was a photographic survey; detailed aerial photographs were obtained for most of the atolls and islands within the northern Marshalls. These photographs were used to support the second phase, the radiation survey, which occurred between September and November 1978. This survey covered all the atolls known to have been contaminated by the Bravo fallout: Bikini itself, Rongelap, Rongerik, Ailinginae, Bikar, Utirik, and Taka Atolls. In addition, several atolls and islands which might have been at the fringes of the fallout pattern were also surveyed, including Likiep and Ailuk Atolls, Jemo and Mejit Islands, and Wotho Atoll. Ujelang Atoll, which lies approximately 200 km southwest of Enewetak, was also surveyed.

The radiation survey was similar in scope to that performed in 1972 at Enewetak Atoll. An aerial radiological survey was combined with an extensive terrestrial and marine sampling program. The aerial survey provided complete coverage of the terrestrial gamma ray activity over all land masses within each atoll. These results were used to derive external dose assessments. In the terrestrial and marine programs

numerous soil and vegetation samples were obtained, as well as samples of water, marine life, and other food sources. These results were used to derive internal dose assessments.

The present report describes the photographic survey and the aerial radiological survey. These surveys were performed by the U.S. Department of Energy Remote Sensing Laboratory, which is operated for the DOE by EG&G. The results of the terrestrial and marine sampling programs, as well as the dose assessments derived from the complete radiological survey, are discussed in separate reports.<sup>11</sup>

## 2.0 PHOTOGRAPHIC SURVEY

### 2.1 Introduction

Detailed aerial photography of the majority of the islands in the northern Marshalls was obtained between mid-July and mid-September 1978. Photography was done at a variety of scales using several different optical wavelength regions of the electromagnetic spectrum. All islands were photographed in the atolls of Ailinginae, Ailuk, Bikar, Bikini, Enewetak, Lae, Likiep, Rongelap, Rongerik, Taka, Ujae, Ujelang, Utirik, and Wotho. The individual islands of Jemo and Mejit were also photographed.

The purpose of the photographic survey was two-fold. First, it was necessary to obtain photographs for use as photo maps during the radiation survey and as underlays for the radiation data. Second, acquisition of detailed optical spectral information was necessary for further study. Photography for both requirements was successfully completed. In addition, oblique photographs were obtained of the majority of the larger populated islands.

The photographic survey was accomplished by seven EG&G technicians using DOE/EG&G photographic equipment mounted in a U.S. Navy EC-121 aircraft. An operational base was established at Kwajalein Island in the Kwajalein Atoll. Daily missions were flown to the outlying atolls from Kwajalein. Midday landings were made only at Enewetak Island on the four missions flown to that atoll.

Certain films were processed at Kwajalein to verify proper coverage and to produce photo maps for use as navigational aids on succeeding photographic flights. Film processing was done by EG&G personnel using DOE/EG&G processing and printing equipment set up within the base photographic laboratory on Kwajalein. The majority of the film records were sent for processing to EG&G, Las Vegas.



Twelve to fifteen U.S. Navy personnel supported the effort by providing flight personnel. Dynalectron, a contractor to the U.S. Navy, provided aircraft maintenance support with a crew of eight to ten. Additional support was provided by personnel from the the base photographic laboratory operated on Kwajalein by Kentron.

## 2.2 Photographic Instrumentation and Methods

### 2.2.1 Camera Systems

Two photographic camera systems were used.

- 1) A Wild RC-10 aerial mapping camera that produces 228mm x 228mm negatives provided very detailed photographs of the islands for use by the radiation survey crew.
- 2) A four-camera system of Hasselblad EL-70 cameras aligned on parallel optical paths recorded information from different portions of the optical spectrum by utilizing a different film and optical filter combination in each camera.

The two aerial camera systems were installed in the bottom of the EC-121 aircraft prior to deployment to the islands. Two optical windows were installed in the fuselage of the aircraft so that the camera systems, mounted immediately above, would view directly out the bottom of the aircraft. The camera systems were installed on adjustable mounts to permit manual leveling of the cameras. For the purpose of guiding the aircraft over the target, a navigation sight, which allowed the camera operator to view in a forward and downward direction, was installed in the bottom of the fuselage.

An additional optical window was installed on the left side of the aircraft forward of the engines to allow oblique photography of the islands out of the side of the aircraft. Hand-held Hasselblad EL-70 cameras were used for this photography.

Figures 1 and 2 show the EC-121 aircraft and the camera mounting arrangement inside the aircraft.

### 2.2.2 Film Types

Different film types were used to suit specific missions. In the RC-10 mapping cameras, Kodak type 2445 Aerocolor negative film was used for all missions. This is a color negative film designed specifically for aerial mapping purposes; it is suitable for printing on positive film or paper. Large photographs having excellent color rendition and detail are printed from negatives of this film.



**Figure 1.** U.S. NAVY EC-121 AIRCRAFT USED FOR THE AERIAL PHOTOGRAPHIC MISSIONS. Both aerial camera ports and the navigation sight were mounted in the fuselage forward of the engines.

The four-camera system was configured with different film types depending on the mission requirements. On the initial missions the film and filter combinations were:

|          | Film Type                                                | Filter                                      |
|----------|----------------------------------------------------------|---------------------------------------------|
| Camera 1 | Kodak Vericolor II<br>Color Negative Film<br>5025 Type-S | Wratten 2-A<br>(Haze)                       |
| Camera 2 | Kodak Aerochrome<br>Infrared Film<br>Type 2443           | Wratten 12<br>(Yellow)<br>CC 30 B<br>(Blue) |
| Camera 3 | Kodak Plus-X Film<br>Type 2402                           | Wratten 12<br>(Yellow)                      |
| Camera 4 | Kodak Plus-X Film<br>Type 2402                           | Wratten 12<br>(Yellow)                      |

Kodak Vericolor film is a color negative film with an integral color mask. This film can be used to make color prints having excellent color rendition and fidelity. Optical information over the region of 400nm to 700nm is recorded on this film.

Kodak Aerochrome Infrared Type 2443 is a "false color" transparency film which records optical information

between 400nm and 900nm. When used with color-correcting filters this wavelength range is reduced to approximately 500nm to 900nm. The color produced on the final transparency is not the one that the film is sensitive to, thus the term "false color". Green portions of the spectrum produce a blue image; red portions produce a green image; and near-infrared portions produce a red image. The combination of the three images into an integral transparency has specialized use in the detection and interpretation of vegetation and underwater areas. High quality color prints having the "false colors" of the original transparency can be made by use of an internegative.

Kodak Plus-X film type 2402 is a panchromatic film that produces black and white negatives which can be made into detailed black and white prints. When used in conjunction with a Wratten 12 yellow filter the resulting black and white negatives and prints will have a tonal rendition that closely resembles the tonal values seen by the human eye. The optical portion of the spectrum covered by this film and filter combination is approximately 500nm to 700nm.

For the primary data collection system the filter on camera 3 was changed from a Wratten 12 (yellow) filter to a Wratten 25 (red) filter. This film and filter combination



records the optical portion of the spectrum between 600nm and 700nm. The configuration for camera 3 on the primary missions was:

|          | Film Type                      | Filter              |
|----------|--------------------------------|---------------------|
| Camera 3 | Kodak Plus-X Film<br>Type 2402 | Wratten 25<br>(Red) |

Camera 4 was also reconfigured for the primary data collection missions. Plus-X film was changed to Kodak Infrared film type 2424. A Wratten 89B (infrared) filter was used in place of the Wratten 12 (yellow) filter. This combination of film and filter results in a recording of only the near-infrared portions of the spectrum between 700nm and 900nm. The configuration for camera 4 on the primary missions was:

|          | Film Type                        | Filter                    |
|----------|----------------------------------|---------------------------|
| Camera 4 | Kodak Infrared Film<br>Type 2424 | Wratten 89B<br>(Infrared) |

On some missions the complement of films and filters used in the four-camera system was varied to meet a specific requirement. Complete technical details of each of the films used and the specific Wratten filter absorption curves can be found in Appendix A.

Kodak Vericolor II 5025 Type-S film was used for all oblique photography.

### 2.2.3 Conduct of the Missions

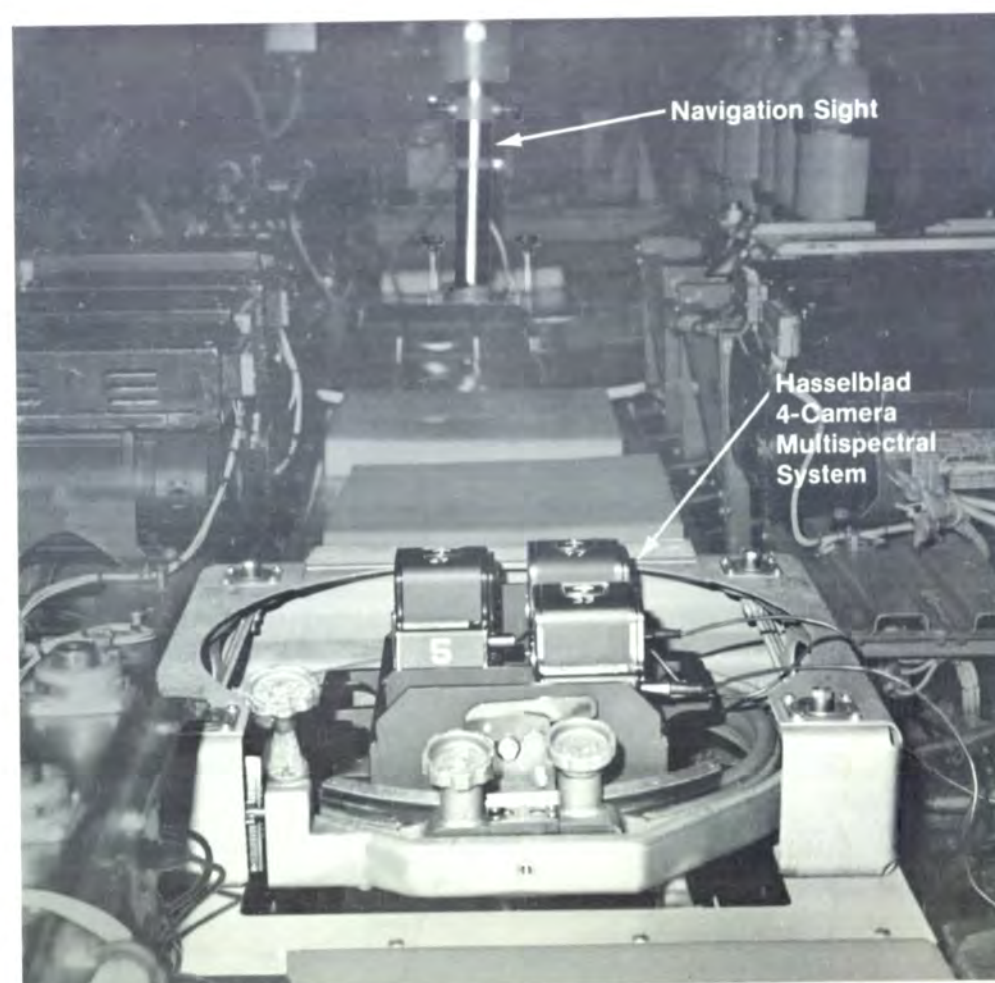
Missions were flown to meet specific requirements. On the initial missions photographs were taken which provided the following information: number of land areas in each atoll, size and shape of each island, and shape of the atoll and reef area. The imagery was processed and produced at the base laboratory in the form of a black and white uncontrolled mosaic of each atoll. The mosaic made possible accurate flights of succeeding data missions. The initial missions were flown at 4,600 meters altitude. The initial flights were flown using 80% forward

overlap. Each frame overlaps the preceeding frame by 80% in the direction of the aircraft flight.

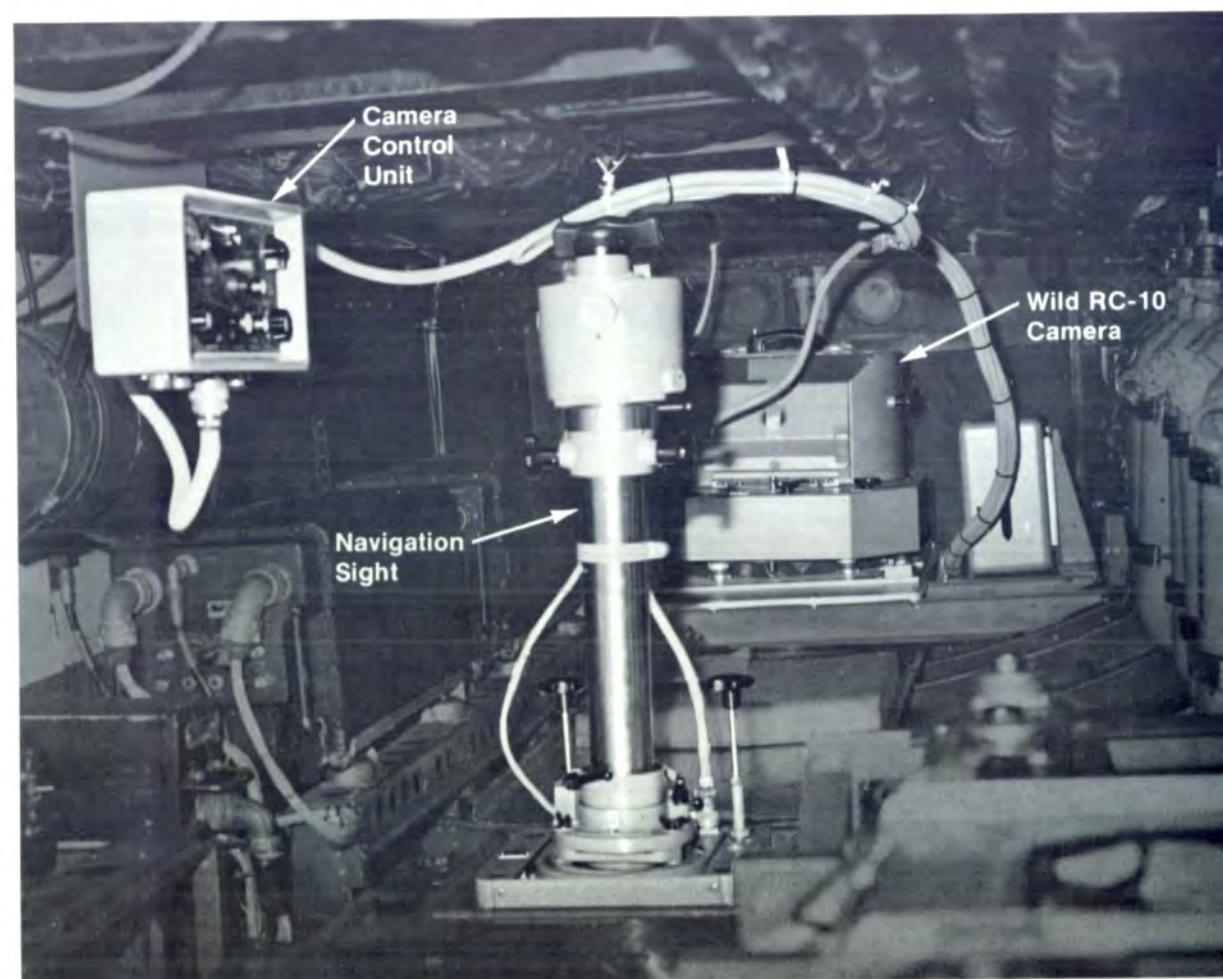
Primary photo missions were of two types. In the first, large-format cameras were used to produce a precise, detailed photograph of each island or land mass. In the second, four 70mm-format cameras were used to provide photographs of each island or land mass in four optical portions of the spectrum. By comparing data from radiation survey flights with the photographs described above, the scientists were able to correlate radiation anomalies with terrain features. The primary-data missions were flown at altitudes ranging between 300 meters and 4,600 meters. The aircraft altitude on the primary-data missions was adjusted to image a single island on a full frame.

### 2.2.4 Operational Considerations

The major determinants for mission planning were weather, tide, and sun angle. If any one factor was



**Figure 2A.** FOUR-CAMERA HASSELBLAD SYSTEM MOUNTED IN THE EC-121 AIRCRAFT. The camera system was manually levelled and initiated. The navigation sight used to guide the aircraft over the target is shown forward of the camera system.



**Figure 2B.** RC-10 CAMERA SYSTEM AND NAVIGATION SIGHT MOUNTED IN THE EC-121 AIRCRAFT. The camera was levelled and initiated by the navigation sight operator.



unsatisfactory, the mission was postponed, cancelled, or halted.

#### Weather

Clear, cloud-free weather was a requirement for all photography: photography was not acceptable that had cloud shadows on the imagery. In all cases this requirement was met.

#### Tide

Low tide was the optimum time for photography because maximum land area was then uncovered. However, it was not always possible to take the photographs at low tide. Operational constraints made it impractical to adhere strictly to this requirement. Nevertheless, the majority of missions were flown within plus or minus 3 hours of low tide.

#### Light Window

When performing photography over water another major consideration was the light window available for reflection-free photography. The optimum light window was determined from information about the sun angle and the angular coverage of the lens systems.

### 2.3 Results

Although there are approximately 300 islands in the fourteen atolls photographed, over 20,000 photographs were obtained. Many of the islands were photographed several times as a result of multiple passes over the atolls.

Photographs obtained during the initial missions, flown at high altitude, resulted in uncontrolled mosaics (Figure 3). These were produced from one record from the four-camera system. After assembly of the mosaic all land areas were identified by an alphanumeric identifier. The primary-data missions were then flown from this mosaic.

The RC-10 camera, operated simultaneously with the four-camera system, produced the result shown in Figure 4.

The typical results from a primary data mission are shown in Figures 5 and 6. Figure 5 is a detailed RC-10 photograph of Aerik Island in Rongelap Atoll taken at 900 meters altitude. Figure 6 shows a detailed four-camera record of Pigowak Island in Utirik Atoll photographed from 1800 meters altitude.

Semi-controlled mosaics were made from the RC-10 imagery for each atoll that was photographed. These show accurately the shape of the atoll and some underwater details of the reef area of the atoll. These mosaics also show the proper relationship of the islands. An example is shown in Figure 7 for Utirik Atoll.

Appendix B is a tabulation of the date, scale, and type of coverage for each island in the fourteen atolls and the two islands of Mejit and Jemo. The photographs tabulated in Appendix B were selected using the following criteria: island centered in the frame, proper film density, minimum surface reflections off water areas, lowest tide, and absence of cloud shadows. This Appendix also lists the date on which oblique coverage was obtained.

### 2.4 Suggested Uses of the Imagery

The imagery of the islands is useful for a variety of purposes beyond those of this project. The large format color photography can be used for viewing stereo images of the islands. One use of the stereo images is estimation of the depth of underwater areas surrounding the islands and the reef area between the islands. The height of trees and vegetation ground cover can also be estimated.

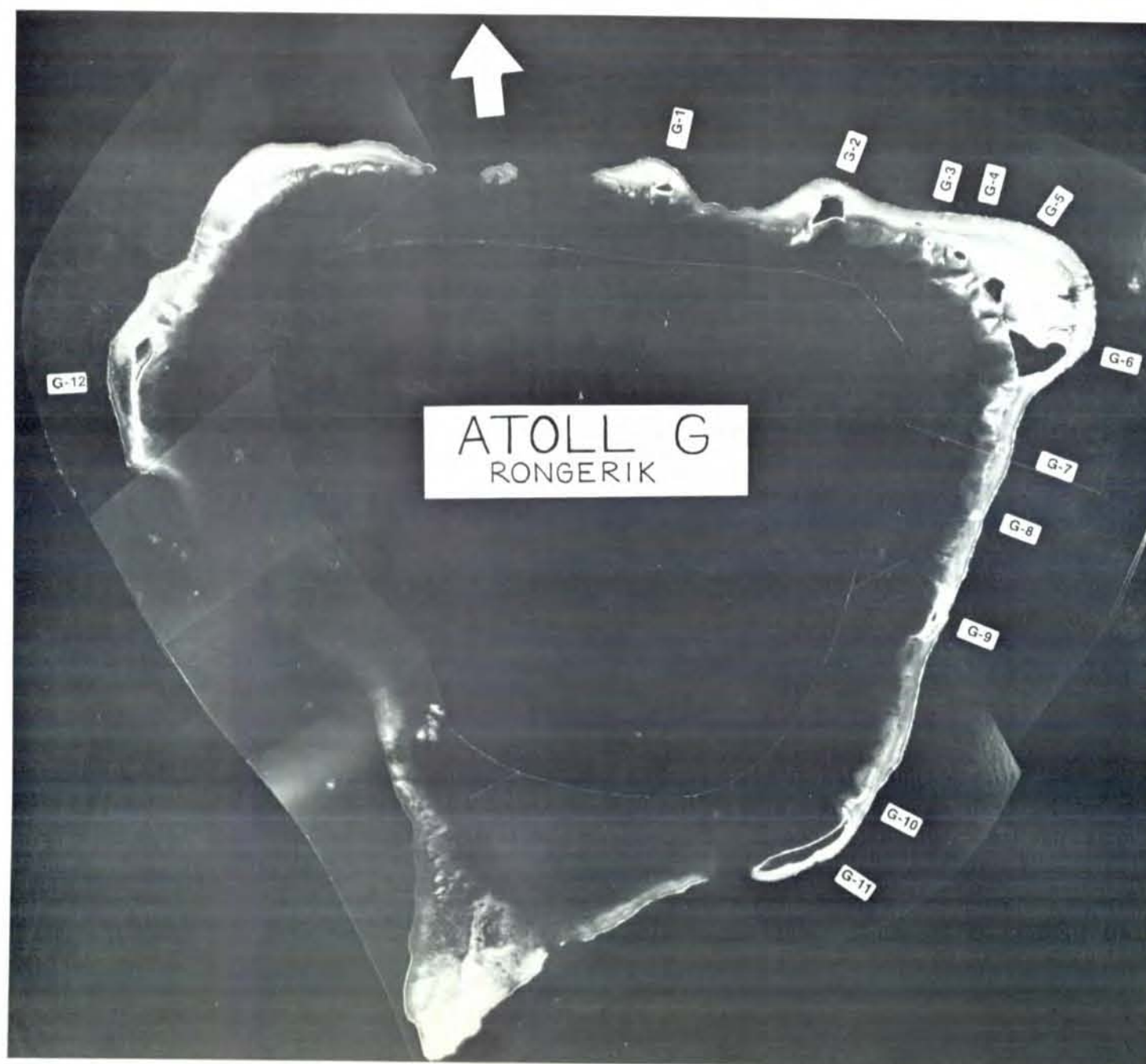


Figure 3. UNCONTROLLED MOSAIC OF RONGERIK ATOLL PREPARED FROM 70mm BLACK AND WHITE IMAGERY OBTAINED ON THE INITIAL MISSIONS. Alpha-numeric indicators were assigned to all land masses that were visible on the photographs.





**Figure 4.** HIGH ALTITUDE RC-10 PHOTOGRAPH OF A PORTION OF LIKIEP ATOLL TAKEN ON ONE OF THE INITIAL MISSIONS AT AN AIRCRAFT ALTITUDE OF 4500 METERS



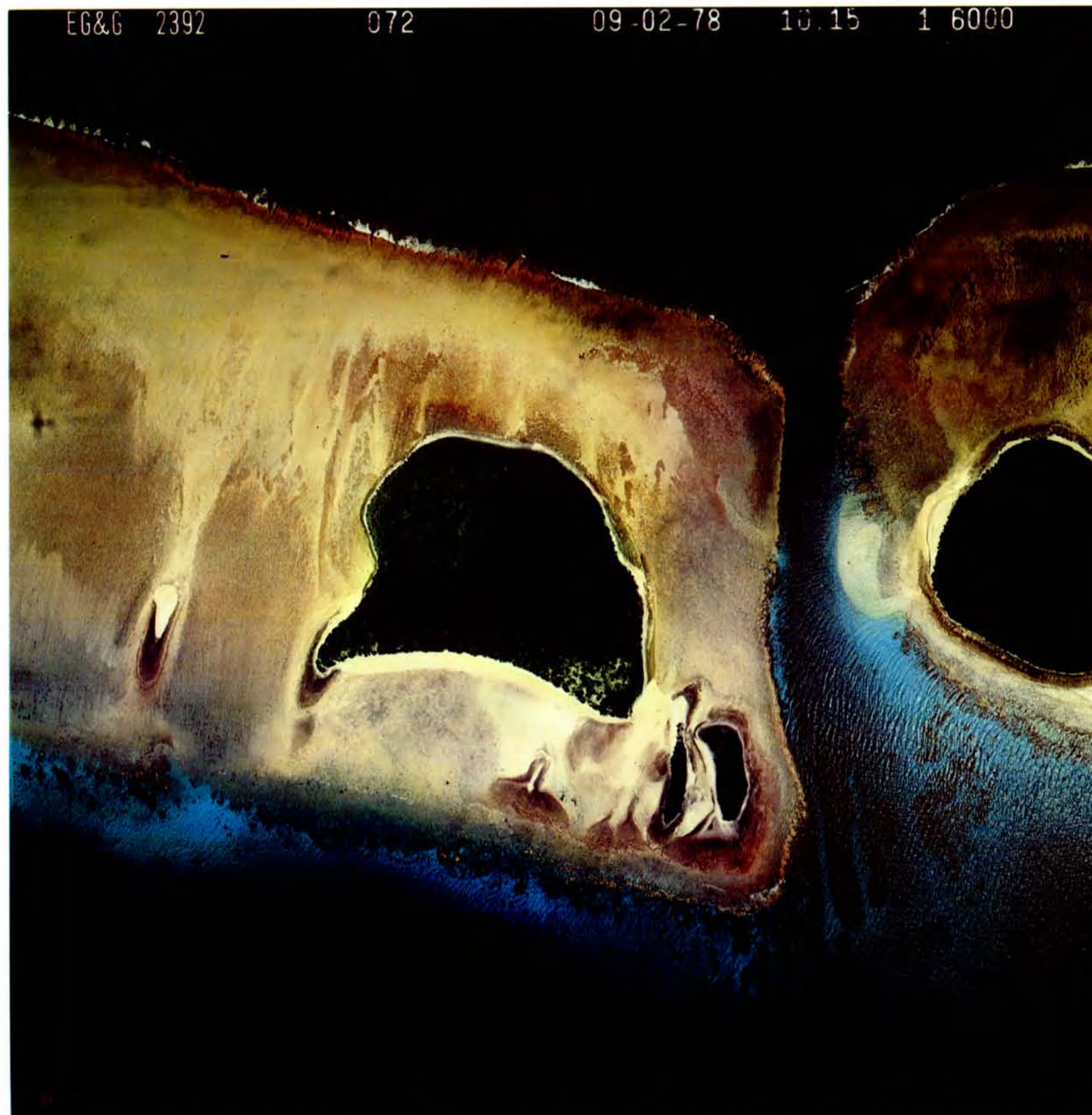


Figure 5. LOW ALTITUDE RC-10 PHOTOGRAPH OF AERIK ISLAND IN THE RONGELAP ATOLL TAKEN AT 900 METERS ALTITUDE





Normal color photographic record of the wavelength region between 400 nm and 700 nm. Colors shown are an accurate representation of the original scene.



Infrared or "false" color photographic record of the wavelength region between 500 nm and 900 nm.



Black and white photographic record of the wavelength region between 600 nm and 700 nm.



Infrared black and white photographic record of the wavelength region between 700 nm and 900 nm.

**Figure 6.** FOUR-CAMERA HASSELBLAD PHOTOGRAPHS OF PIGOWAK ISLAND IN THE UTIRIK ATOLL TAKEN AT 1800 METERS ALTITUDE. The four photographs show different optical portions of the electromagnetic spectrum from 400 nm to 900 nm.



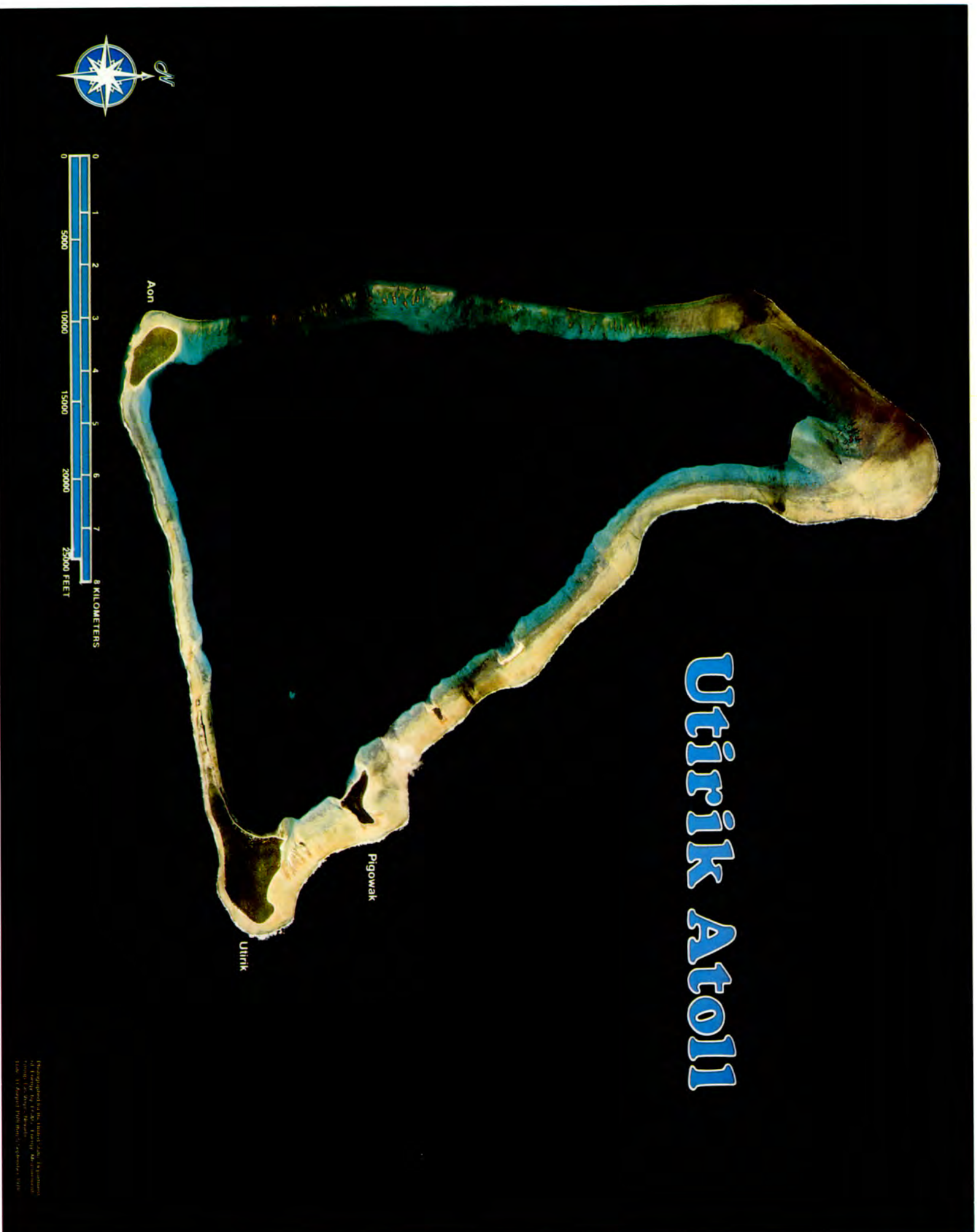


Figure 7. SEMI-CONTROLLED MOSAIC OF UTIRIK ATOLL



A wealth of additional information is contained in the four-camera film records. The coverage can be used in a variety of analysis applications that are beyond the scope of this report. Much work has been done by NASA and other agencies to utilize multispectral imagery of this type. Some of the more common applications are:

- 1) Determination of the type and vigor of vegetation on each island. Actual tree counts can be made.
- 2) Determination of the percent cover of the various vegetation types on each island.
- 3) Definition of the water/land interface for a particular tide period when each photo was taken.
- 4) Estimation of water depths along the shoreline of each island.
- 5) Estimation of the percentage of the islands used for various activities by the inhabitants.
- 6) Categorization of the man-made structures and changes.

To perform these analyses several methods can be used:

- 1) A detailed study of a four-camera image set provides a wealth of information not obtainable from a single-camera aerial photograph.
- 2) Use of optical-mechanical viewing aids, such as stereo viewers or zoom transfer scopes, enhances the viewer's ability to extract information from the photographs.
- 3) Utilization of specialized photographic printing techniques, such as high contrast or color enhancement, may provide information that is not visible through normal printing techniques.
- 4) Computer analysis of the imagery involves digitization of the images followed by manipulation of one or several of the images in the computer. This technique offers the most powerful tool for complete analysis.

### 3.0 RADIATION SURVEY

#### 3.1 Logistics

The radiation portion of the northern Marshall Islands survey was conducted between mid-September and mid-November 1978. Logistical support for the survey was provided by the USNS WHEELING (Figure 8), a missile tracking ship operated by the Pacific Missile Test Center (PMTTC) based at Point Mugu, California. Two U.S. Navy SH-3G helicopters were deployed with the ship. One



Figure 8. THE USNS WHEELING: SUPPORT VESSEL FOR THE RADIATION SURVEY

helicopter was used as a platform for the aerial radiological survey. The second helicopter was used to provide logistical support for all groups involved in the radiation survey—primarily transportation of equipment and personnel between the ship and shore. Helicopter support was provided by the U.S. Navy HC-1 Helicopter Squadron, San Diego, California.

A total of eleven atolls and two islands were surveyed. They are listed in Table 1 along with the actual dates on which the aerial surveys were conducted. The total survey was split into three parts, with a crew change at Kwajalein Atoll after the completion of the Ailinginae survey and another after the completion of the Wotho survey.

#### 3.2 Survey Equipment and Procedures

The aerial survey was conducted with an array of forty 12.7-cm diameter by 5.1-cm thick sodium iodide (NaI)

Table 1. Atolls and Islands Surveyed

|            | Location         | Survey Dates         |
|------------|------------------|----------------------|
| Series I   | Rongelap Atoll   | 18-24 September 1978 |
|            | Utirik Atoll     | 25-26 September 1978 |
|            | Taka Atoll       | 27 September 1978    |
|            | Bikar Atoll      | 30 September 1978    |
|            | Rongerik Atoll   | 2 October 1978       |
|            | Ailinginae Atoll | 5-6 October 1978     |
| Series II  | Likiep Atoll     | 12-17 October 1978   |
|            | Ailuk Atoll      | 19-22 October 1978   |
|            | Jemo Island      | 22 October 1978      |
|            | Mejit Island     | 24 October 1978      |
|            | Wotho Atoll      | 27-28 October 1978   |
| Series III | Ujelang Atoll    | 2-3 November 1978    |
|            | Bikini Atoll     | 5-10 November 1978   |



scintillation detectors mounted within two pods hung externally on the helicopter (Figure 9). Signals from the detectors were combined in four 10-way summing amplifiers also located within the detector pods. Outputs from the 10-way summing amplifiers were combined in a 4-way summing amplifier located within the helicopter. The output from this amplifier was routed through an analog-to-digital converter (ADC) into a 1024 channel multichannel analyzer.

A specially designed data acquisition system, called the REDAR III (Radiation and Environmental Data Acquisition and Recorder), was used during the survey. This is a low power, lightweight system that can operate directly from the 24 V dc power available within the helicopter. The system used was a third generation version of the system originally used in the 1972 Enewetak aerial survey. This system is normally operated in a special compression mode that compresses the 1024 channels of data into 256 channels prior to storing on tape. The spectrum is divided into three groups. Data in the first group, consisting of the first 75 channels, are stored directly. Data in the second group, the next 330 channels, are summed in three channel increments, and the summed data are stored. Data in the third group, the next 612 channels, are summed in nine channel increments, and the summed data are stored. Data in the next five channels are stored in channel 254. Data in channel 1023, which records overflow counts, are stored in channel 255. Neither the original channel 1024 nor the compressed channel 256 is used.

This compression scheme is especially useful with NaI detectors because of their variation in resolution with energy. With the foregoing compression scheme and a full scale energy of 2-4 MeV, the photopeak widths are approximately the same within each group. Thus, it is possible to gain a factor of four in the amount of data storage required without compromising photopeak identification capability.

The 256 channels of compressed spectral data are recorded every second. The REDAR system has two sets of spectral memories. Each memory can accumulate four individual spectra. The two memories are operated in a flip-flop mode, every four seconds, for continuous data accumulation. While one memory is storing data, the other is being transferred to magnetic tape.

Two additional memories are used to store nonspectral data. They operate in the same flip-flop mode as the spectral memories. The nonspectral data generally include aircraft position, altitude, time of day, and special labels to code individual flight lines, as well as other parameters that might be required, such as outside air temperature and pressure.



Figure 9. A NAVY SH-3G HELICOPTER WITH GAMMA RADIATION DETECTOR PODS ATTACHED

Both gamma ray spectral and nonspectral data are acquired every one second and recorded on 4-track cassette tapes every four seconds. The REDAR system has two tape recorders. Each tape can record approximately one hour of data. At the end of the tape, the system automatically switches to the second recorder. If the first tape has been replaced, the system will automatically switch back after the second tape is full. Thus, long flights can be accomplished with very little attention to the tape recording system.

A display is available for real-time examination of the spectral data. The data can be displayed in either the linear or compressed mode. The data can be reset, added to, or subtracted from the display without affecting the recorded information on tape. This real-time display was utilized during the flights to help verify the proper operation of the system.

An energy calibration was performed prior to each flight using  $^{22}\text{Na}$  and  $^{241}\text{Am}$  calibration sources. The energy



gain could be adjusted within the 10-way summing amplifiers and the 4-way summing amplifier to normalize the output from each detector. Maintaining power to the system on a 24-hour-a-day basis helped reduce to a negligible level any gain shifts that might occur within a given flight. The system gain was adjusted for a full scale energy of 4 MeV during the Rongelap, Utirik, and Taka surveys. To help solve some low energy noise problems which developed, the full scale energy was changed to 2 MeV at Bikar and remained that way for the rest of the survey. This change had no effect on the final results since the highest gamma ray energy observed was the 1.3 MeV peak from  $^{60}\text{Co}$ .

Position data were obtained using a microwave ranging system (MRS). This system employs two remote units placed some distance apart on the ground. A master unit is carried aboard the aircraft. The distance of the helicopter from each remote unit is determined by measuring the average roundtrip time of travel for a pulsed microwave signal. These distances, which are recorded once each second, together with the measured distance between the two remote units, allow the aircraft position to be determined relative to any survey coordinate system. Because of line-of-sight requirements for the MRS it was necessary to relocate the remote units several times to completely survey most of the atolls.

Flight lines, spaced 46 m (150 feet) apart, were normally flown with the aid of a steering indicator that utilized the position data supplied by the MRS. For parts of some atolls, flight lines were flown by visual navigation using lines drawn on photographs obtained during the photographic survey. This procedure was followed for very small or very narrow islands where the setup time required for the steering indicator could not be justified. The MRS system could not be used on either Jemo or Mejit Islands—Jemo because of its small size and Mejit primarily because of the presence of tall trees throughout the island. Visual navigation was mandatory on these two islands.

Flight lines were flown at an altitude of 38 m (125 feet) with an approximate ground speed of 70 knots. Altitude data were obtained from a radar altimeter and recorded once each second. Using the on-board readout, it was possible to maintain the survey altitude to within  $\pm 5$  m.

The atolls were surveyed in sections using the RC-10 photographs as base maps. Each section generally covered a distance of 3 to 6 km. A survey baseline was established between two points, generally located near each end, which were easily identifiable from the helicopter and also on the photograph. Flight lines parallel to the baseline were then flown using the steering

indicator. All land masses within a given section could then be flown at the same time, and the radiation data could be processed to overlay a single photograph. This approach saved a lot of time, both in flying and in data processing, which would otherwise have been required if each island within an atoll had been surveyed individually.

Two complete data reduction systems were installed aboard the USNS WHEELING to support the aerial survey. One system was primarily used to perform preflight and postflight checks to verify that all data were being properly recorded on tape. This system was also used to transfer the data to 9-track magnetic tapes for long term storage. The second system was used to perform preliminary data processing while in the field. Final data processing was performed in Las Vegas after completion of the survey.

### 3.3 Data Processing Techniques

Two distinct data processing techniques were employed in analyzing the aerial radiation data. The first involved processing to obtain total terrestrial gamma ray count rate data, which were then converted to total terrestrial external exposure rate values. The second involved processing the spectral data for specific gamma ray photopeaks. The resultant photopeak count rate data were then converted to specific radionuclide concentrations in the soil and to external exposure rate values for individual radionuclides.

A typical gamma ray spectrum obtained with the airborne system consists of a terrestrial component and a non-terrestrial component. The non-terrestrial component is due to cosmic ray contributions and to small amounts of natural radioactivity within the aircraft itself. This component is generally constant within a given location and can be obtained by flying over water, well away from land. By subtracting this water background component from the total spectrum obtained over land, one obtains the net terrestrial component.

Net terrestrial gross count data were obtained by summing all the counts between 50 keV and either 2 or 4 MeV and subtracting a constant obtained by summing the counts over the same energy range for a typical nearby water background. These results were converted to external exposure rate values, in  $\mu\text{R}/\text{h}$  (microrentgens per hour) at the 1 m level, using a conversion factor of 2300 cps (counts per second) per  $\mu\text{R}/\text{h}$ . The derivation of this conversion factor is discussed in Section 3.4.

An examination of spectral data obtained during the aerial survey showed that the primary gamma ray emitting radionuclides still remaining from the nuclear testing were  $^{137}\text{Cs}$  and  $^{60}\text{Co}$ , with  $^{137}\text{Cs}$  generally dominating. Concentration values for these radionuclides, as well as their individual contribution to the external exposure rate, can be obtained from their respective net photopeak count rate data.

Procedures used to remove background contributions within the  $^{137}\text{Cs}$  or the  $^{60}\text{Co}$  photopeak window and the  $^{60}\text{Co}$  contributions in the  $^{137}\text{Cs}$  photopeak window are based on the fact that the spectral shape for any given isotope or combination of isotopes, as well as background and cosmic ray contributions, remains essentially constant over rather large variations in intensity. For this reason, the ratio between any two regions of the spectrum will remain essentially constant.

Figure 10 shows a typical spectrum containing  $^{137}\text{Cs}$  and  $^{60}\text{Co}$  superimposed on a background spectrum containing contributions from naturally occurring uranium, thorium, and potassium, as well as cosmic ray contributions. Four pulse-height windows are also shown. Window 1 (from 600 to 750 keV) is centered on the  $^{137}\text{Cs}$  photopeak. Window 2 (from 750 to 1000 keV) defines a region between the  $^{137}\text{Cs}$  and the  $^{60}\text{Co}$  photopeaks. Window 3 (from 1100 to 1400 keV) spans both photopeaks from  $^{60}\text{Co}$ . Window 4, which includes all

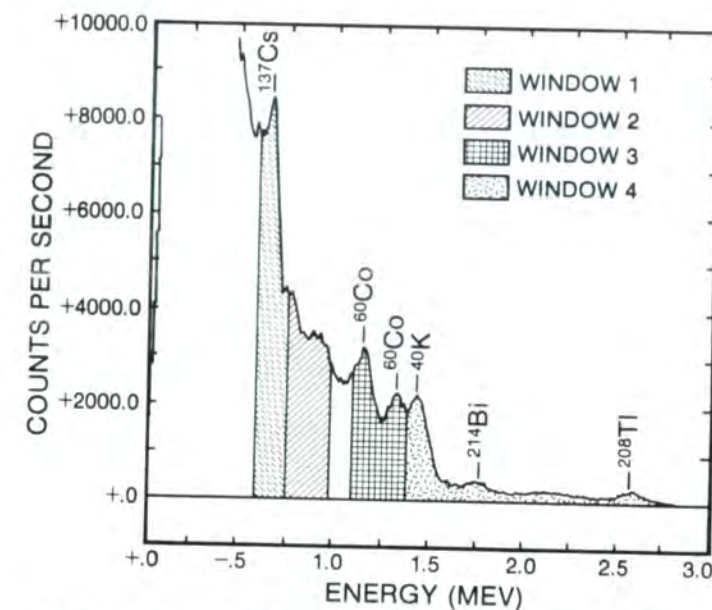


Figure 10. TYPICAL GAMMA RAY SPECTRUM FROM THE NaI(Tl) DETECTOR ARRAY SHOWING THE PULSE-HEIGHT WINDOWS USED TO EXTRACT  $^{137}\text{Cs}$  AND  $^{60}\text{Co}$  PHOTOPEAK COUNT RATE DATA



counts above 1400 keV, contains only contributions from the background. Four stripping coefficients are defined as follows:

$$\alpha = \frac{\text{Window 1}}{\text{Window 4}}, \text{ for a normal background spectrum}$$

$$\beta = \frac{\text{Window 2}}{\text{Window 4}}, \text{ for a normal background spectrum}$$

$$\gamma = \frac{\text{Window 3}}{\text{Window 4}}, \text{ for a normal background spectrum}$$

$$\delta = \frac{\text{Window 1}}{\text{Window 2}}, \text{ for a pure } ^{60}\text{Co} \text{ spectrum}$$

The  $^{60}\text{Co}$  photopeak count rate (CR) is then given by

$$\text{CR}(^{60}\text{Co}) = [\text{Cts. in 3}] - \gamma [\text{Cts. in 4}], \quad (1)$$

where the second term represents the contribution due to background gamma rays within the  $^{60}\text{Co}$  photopeak window. For  $^{137}\text{Cs}$ , both the background contributions and that due to Compton scattered gamma rays from  $^{60}\text{Co}$  must be removed from the photopeak window. Thus,

$$\text{CR}(^{137}\text{Cs}) = [\text{Cts. in 1}] - [\text{Contribution in 1 due to normal background}] - [\text{Contribution in 1 due to } ^{60}\text{Co}].$$

Using the coefficients and windows defined above, this can be written as

$$\text{CR}(^{137}\text{Cs}) = [\text{Cts. in 1}] - \alpha[\text{Cts. in 4}] - \delta [(\text{Cts. in 2}) - \beta (\text{Cts. in 4})] \quad (2)$$

In the third term, the background counts in Window 2 must first be subtracted away. The remaining counts are due to  $^{60}\text{Co}$  gamma rays. They are then used to subtract away the  $^{60}\text{Co}$  contribution within the  $^{137}\text{Cs}$  photopeak window. Equation (2) can be rewritten as

$$\text{CR}(^{137}\text{Cs}) = [\text{Cts. in 1}] - \delta[\text{Cts. in 2}] - [\alpha - \delta \beta][\text{Cts. in 4}] \quad (3)$$

Equations (1) and (3) were used to obtain photopeak count rate data for  $^{60}\text{Co}$  and  $^{137}\text{Cs}$ , respectively. Software routines were used to extract the window counts from the spectral data on a second-by-second basis. The stripping coefficients  $\alpha$ ,  $\beta$ , and  $\gamma$  were obtained from background spectra over water. To obtain the stripping coefficient  $\delta$  it was necessary to generate a pure  $^{60}\text{Co}$  spectrum, which

was done using data obtained at Bikini Atoll. Spectra were obtained over two areas containing approximately the same levels of  $^{60}\text{Co}$  but quite different levels of  $^{137}\text{Cs}$ . After subtracting the water background from each spectrum, a weighting factor was applied to one to normalize the counts in the  $^{60}\text{Co}$  photopeak window from both spectra. The normalized spectrum containing low  $^{137}\text{Cs}$  was then subtracted from the spectrum containing high  $^{137}\text{Cs}$ . This led to a pure  $^{137}\text{Cs}$  spectrum. Another area was located that contained high levels of  $^{60}\text{Co}$  and low levels of  $^{137}\text{Cs}$ . After subtracting the water background, a series of weighted pure  $^{137}\text{Cs}$  spectra was subtracted until the  $^{137}\text{Cs}$  photopeak disappeared. This procedure led to a pure  $^{60}\text{Co}$  spectrum, from which  $\delta$  could be determined. The pure  $^{137}\text{Cs}$  and  $^{60}\text{Co}$  spectra were also used in the derivation of the gross count conversion factor as discussed in Section 3.4.

Radiation data were processed using the above techniques and coordinated on a second-by-second basis with the position data obtained from the MRS. Results were processed in the form of radiation contours superimposed on aerial photographs.

Position data were scaled to a photograph using several tie-down points located within each survey area. The points chosen were prominent features on the ground that could easily be seen from the helicopter and also readily identified on the photograph. A cross type pattern, centered on each reference point, was flown with the helicopter. These flight lines were then processed and plotted so that the center of each cross coincided with the appropriate spot on the photograph. This provided the necessary scaling factor for processing the radiation data to overlay the photograph.

The radiation data were processed in the form of alphabetic symbols that designated discrete count rate intervals. An appropriate symbol was plotted at the appropriate position for each one-second data point along a flight line. Contour lines were then drawn after all flight lines had been processed. The lowest count rate interval, designated an A level, was chosen to include all the purely statistical fluctuations around zero resulting from the background subtraction procedures. All water background areas are thus represented by an A level. The magnitude of the statistical fluctuations determines the minimum detectability for the aerial system. Thus, A levels over land represent terrestrial levels that are below the detection sensitivity of the system. The count rate intervals represented by the alphabet symbols were converted to exposure rate or concentration intervals for the final data presentation.

In addition to the radiation contours generated from the aerial radiation data, an inventory routine was used to

derive island-averaged values for the larger islands within each atoll. This routine sums together the actual net counts for each one-second data point located within a selected area (generally chosen to include a single island or several islands lying close together). The total net counts divided by the total points within the island(s) leads to an island-averaged count rate. This count rate can then be converted, as appropriate, to an island-averaged exposure rate or activity level.

### 3.4 CONVERSION FACTORS

Gamma ray count rate data obtained with the airborne detector system can be used directly to determine relative activity. It is more useful, however, to convert this type of data to equivalent exposure rate values (at the 1 m level) or to specific radionuclide concentration levels in the soil. Details on the derivation of conversion factors relating photopeak count rate data to source activity in the soil are presented in Appendix C. Basically, the derivation involves a calculation of the unscattered gamma ray flux at some height above ground, for a given source distribution, combined with an experimental calibration of the detector response to a given flux.

To calculate the conversion factors, it is necessary to measure or make some assumptions about the source distribution with depth in the soil. For fallout activity the distribution after a period of time can be reasonably approximated by an exponential distribution given by:

$$S_v = S_v^0 e^{-\alpha z} \quad (4)$$

where

$S_v^0$  = the activity per unit volume at the surface  
( $\gamma/\text{sec}$ ) and  $\text{cm}^{-3}$

$\alpha$  = the reciprocal of the relaxation length ( $\text{cm}^{-1}$ ).

Figures 11 and 12 show the conversion factors for  $^{137}\text{Cs}$  and  $^{60}\text{Co}$ , respectively, relating the average concentration in the top  $z$  cm,  $S_v^z$ , to the net photopeak count rate,  $N_p$ , for a wide range of depth distributions. Conversion factors are given for the 40-detector array at a survey altitude of 38 m. The effect of the depth distribution on the conversion factor varies significantly depending on the depth over which the average is taken. For example, the conversion factor relating photopeak count rate to average activity in the top 10 cm is not nearly as sensitive to variations in the depth distribution as that for the 40 cm average.



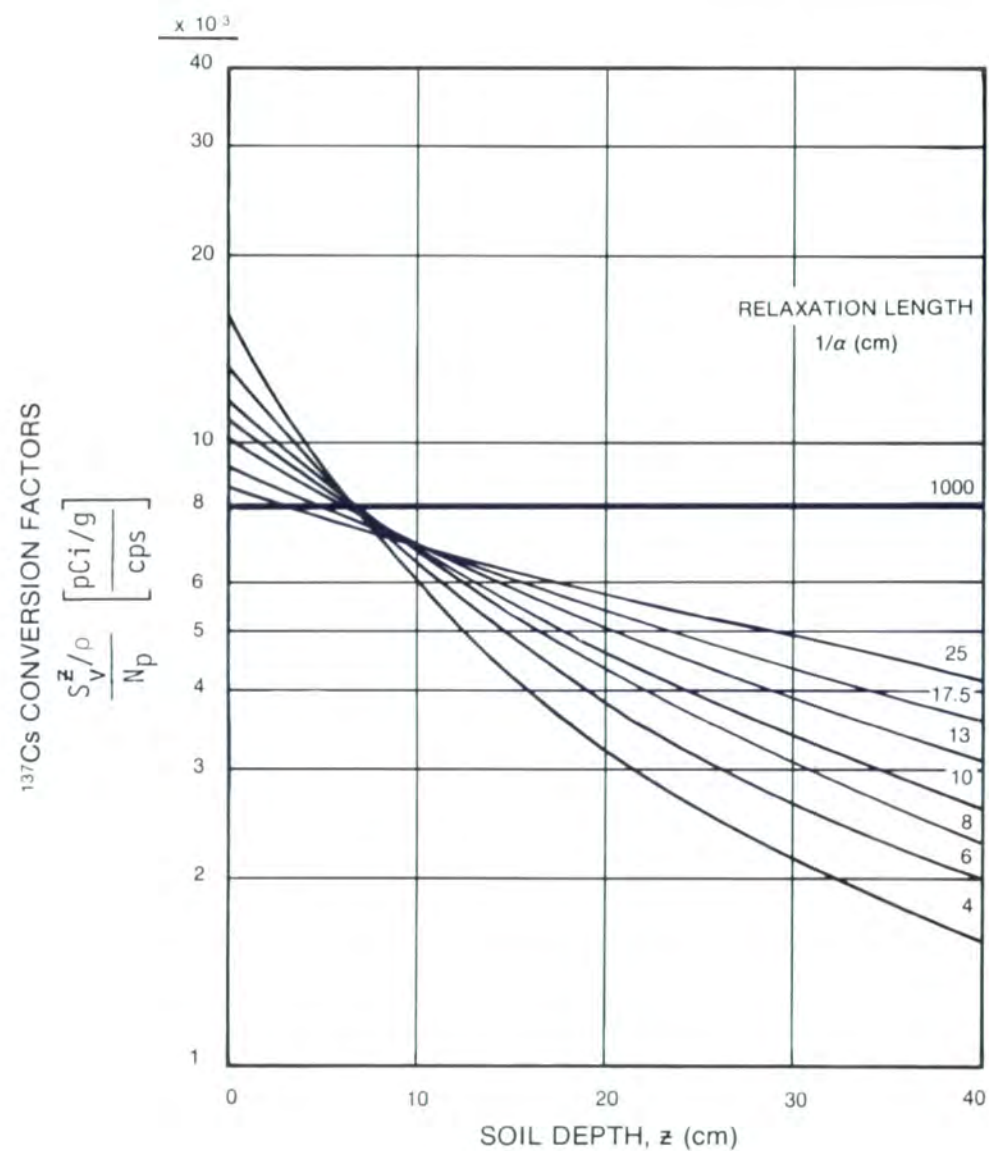


Figure 11. CONVERSION FACTORS FOR  $^{137}\text{Cs}$  GIVING AVERAGE CONCENTRATION IN THE TOP  $z$  CM AS A FUNCTION OF DEPTH DISTRIBUTION

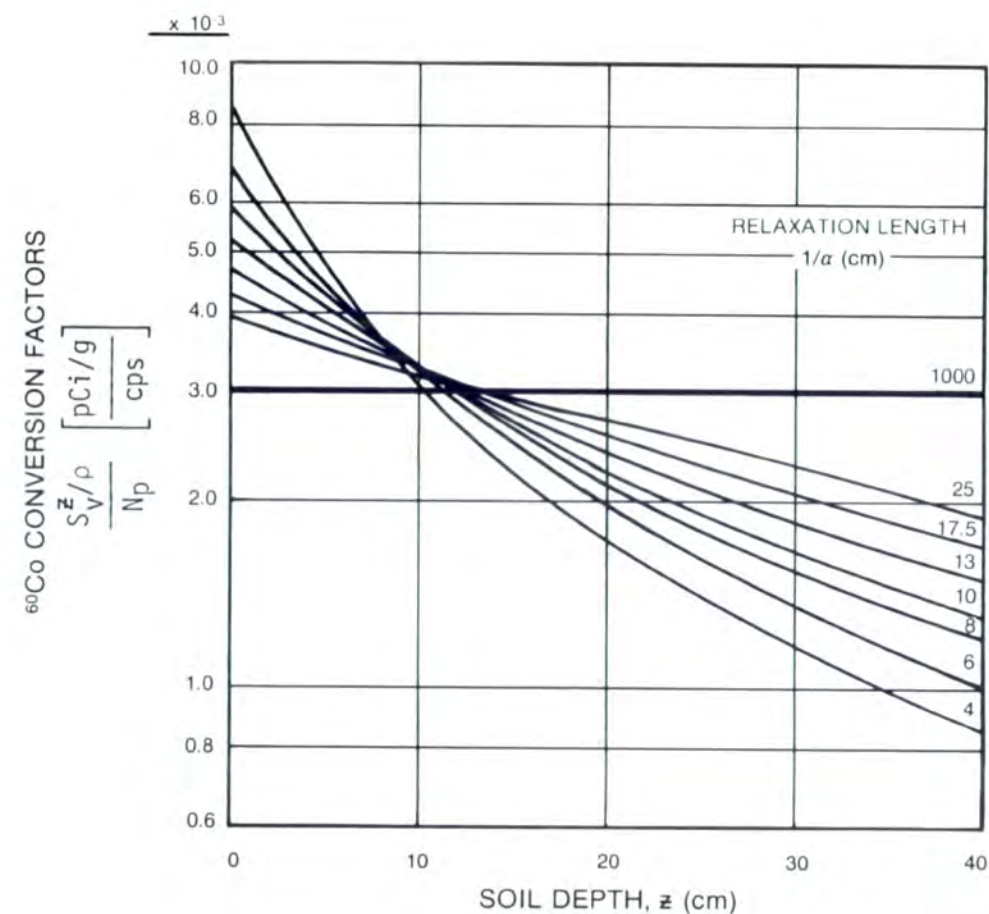


Figure 12. CONVERSION FACTORS FOR  $^{60}\text{Co}$  GIVING AVERAGE CONCENTRATION IN THE TOP  $z$  CM AS A FUNCTION OF DEPTH DISTRIBUTION



In practice, the depth distribution can vary significantly from point-to-point and from island-to-island. To obtain the "best" conversion factors for the aerial survey data, a total of 63 depth profiles for  $^{137}\text{Cs}$ , obtained on six different islands at Rongelap Atoll during the terrestrial portion of the survey, were fit to an exponential distribution. The range over which the measured depth distribution varied is shown in Table 2. These results were used to derive weighting factors which were applied to the various depth distributions shown in Figure 11 to obtain a weighted average value for the appropriate conversion factor. The results are summarized in Table 3 for several different depths of integration. Insufficient data existed to obtain similar depth distribution profiles for  $^{60}\text{Co}$ . An assumption was made that the  $^{60}\text{Co}$  depth distribution would be similar to that of  $^{137}\text{Cs}$ . Table 3 contains weighted average conversion factors for  $^{60}\text{Co}$  based on this assumption. These conversion factors assume the photopeak window includes both photopeaks from  $^{60}\text{Co}$ .

Concentration data given in Section 3.5 and in Appendix D are expressed in terms of the average concentration in the top 10 cm. Table 3 can be used to convert any of these data to average concentration over other depths. For example, it might be more useful for uptake studies to know the average  $^{137}\text{Cs}$  concentration within the top 25 cm. This average can be obtained from the 10 cm data by multiplying by 0.67, the ratio of the two appropriate conversion factors given in Table 3.

Conversion factors relating net photopeak count rate data to exposure rate can be obtained directly from the concentration conversion factors using data given by Beck et al.<sup>12</sup> This reference provides tables for various

**Table 2. Relaxation Lengths Determined by Fitting Sixty-Three  $^{137}\text{Cs}$  Depth Profiles to an Exponential Depth Distribution\***

| Relaxation Length, $1/\alpha$ (cm) | Number of Profiles | Calculated Weighting Factor (%) |
|------------------------------------|--------------------|---------------------------------|
| 3 - 5                              | 1                  | 2                               |
| 5 - 7                              | 4                  | 6                               |
| 7 - 9                              | 8                  | 13                              |
| 9 - 11                             | 9                  | 14                              |
| 11 - 15                            | 22                 | 34                              |
| 15 - 20                            | 3                  | 5                               |
| 20 - 30                            | 8                  | 13                              |
| > 30                               | 8                  | 13                              |

\*Data were obtained on six islands at Rongelap Atoll during the terrestrial portion of the survey.

**Table 3. Conversion Factors for  $^{137}\text{Cs}$  and  $^{60}\text{Co}$  Relating Net Photopeak Count Rate Data,  $N_p$ , to Average Concentration in the Top  $z$  cm,  $S_z^c$ , Using a Weighted Average to Account for Observed Variations in the Depth Distribution**

| Averaging Depth, $Z$ (cm) | Conversion Factor $\frac{S_z^c}{N_p} \left( \frac{\mu\text{Ci/g}}{\text{cps}} \right)$ |                  |
|---------------------------|----------------------------------------------------------------------------------------|------------------|
|                           | $^{137}\text{Cs}$                                                                      | $^{60}\text{Co}$ |
| 5                         | $8.2(10^{-3})$                                                                         | $3.9(10^{-3})$   |
| 10                        | $6.9(10^{-3})$                                                                         | $3.3(10^{-3})$   |
| 15                        | $5.9(10^{-3})$                                                                         | $2.8(10^{-3})$   |
| 25                        | $4.6(10^{-3})$                                                                         | $2.2(10^{-3})$   |
| 40                        | $3.5(10^{-3})$                                                                         | $1.5(10^{-3})$   |

radionuclides that relate the external exposure rate at 1 m (in  $\mu\text{R/h}$ ) to source activity in the soil as a function of source depth distribution. A weighted average was again used to account for observed variations in the depth distribution. The variation of the exposure rate conversion factors with depth distribution, however, is not nearly as great as that of the concentration conversion factors. Errors in exposure rate values due to uncertainty in depth are less than 5% even for the two extremes obtained from the Rongelap profile data given in Table 2. The final data given in Section 3.5 and Appendix D are based on a conversion factor of  $3.9(10^{-3}) \mu\text{R/h}$  per cps for  $^{137}\text{Cs}$  and  $8.1(10^{-3}) \mu\text{R/h}$  per cps for  $^{60}\text{Co}$  (assuming the photopeak window includes both photopeaks).

The photopeak exposure rate conversion factors were used to derive the total gross count conversion factor in the following manner. A pure  $^{137}\text{Cs}$  and a pure  $^{60}\text{Co}$  spectrum were derived from the aerial data at Bikini Atoll (as discussed previously). These spectra were used to obtain a ratio between the total counts and the photopeaks counts for each individual isotope. These ratios were then used to obtain a total count conversion factor from the photopeak conversion factor for each isotope. A detailed investigation of numerous spectra from Bikini, Rongelap, and Rongerik Atolls was made to determine an average value for the fraction of the total gross counts due to  $^{137}\text{Cs}$  and the fraction due to  $^{60}\text{Co}$ . These values were then used as weighting factors to derive the total gross count conversion factor.

### 3.5 RESULTS

The results of the aerial radiation survey are summarized in Figure 13. The data given represent island-averaged terrestrial exposure rate levels for selected islands within

each of the atolls surveyed. Similar data are presented in more detail in Figures 14-16 for Bikini, Rongelap, and Rongerik Atolls. These were the only atolls surveyed which showed any significant variation in radiation levels within the atoll. Letter labels were used to designate discrete exposure rate intervals. These were the same intervals chosen for producing the detailed radiation contour maps which are presented in Appendix D. An A level (less than  $0.07 \mu\text{R/h}$ ) represents typical water background. Although B levels were observed in the detailed contour maps, the lowest island-averaged values obtained were in the C level range (from  $0.14$  to  $0.30 \mu\text{R/h}$ ). Similar data are presented, for comparison, in Section 3.6.3 for the continental United States.

In order to obtain the total external exposure rate, it is necessary to include cosmic ray contributions. A value of  $3.3 \mu\text{R/h}$  has previously been assumed for this component for atolls within the northern Marshalls.<sup>5</sup>

Also shown as an insert in Figure 13 is the estimated fallout pattern from the March 1954 Bravo event conducted at Bikini Atoll.<sup>13</sup> The aerial radiation survey results correlate extremely well with the estimated fallout pattern. This supports the assumption that most of the residual terrestrial radioactivity on atolls due east of Bikini resulted from fallout from the Bravo event.

Numerical values for the island-averaged terrestrial exposure rate are given in Table 4 for selected islands within each atoll. These values were obtained by numerically averaging the individual second-by-second data points obtained over a given island. For islands having a width less than approximately 300-400 meters, a correction factor was applied to account for the large-area averaging properties of the airborne system. This is discussed in more detail in Section 3.6.1. Islands are identified using the code numbers assigned during the photographic survey (see Appendix B). Names given reflect the Marshallese spelling whenever available. Otherwise, names given are those obtained from existing navigation charts.

With the exception of Bikini Atoll, where local nuclear testing took place, the aerial data showed that changes in the average radiation levels within a given atoll occurred in a systematic manner. In fact, for most of the atolls surveyed, the island-averaged values were essentially constant throughout the atoll. Those islands specifically listed in Table 4 were selected to provide representative coverage for each of the atolls surveyed. Radiation levels on other islands can be inferred from those given in Table 4.

The summary data presented in Figure 13 and in Table 4 show that the highest levels measured during the aerial survey occurred over parts of Bikini Atoll and over the



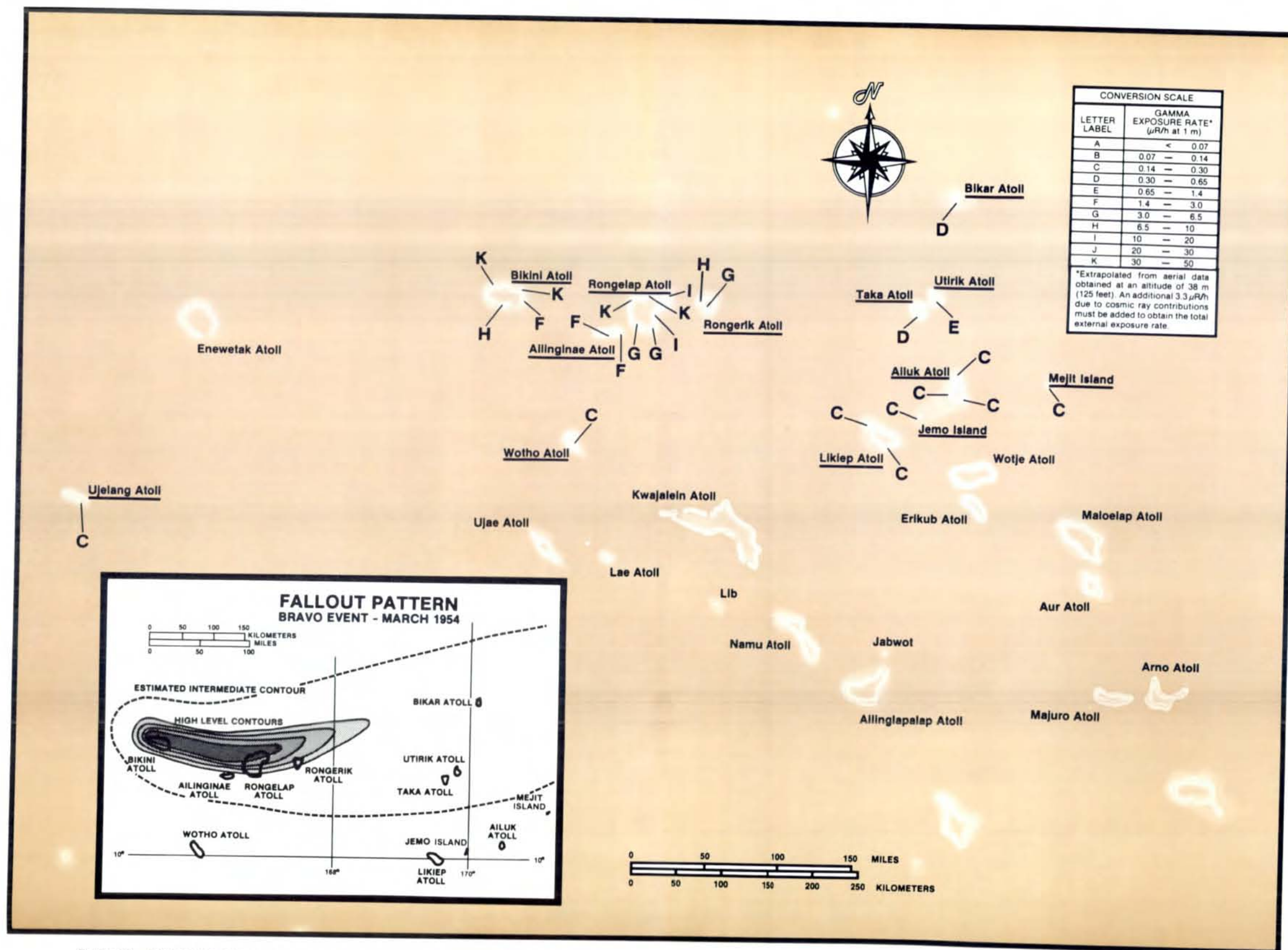


Figure 13. SELECTED ISLAND-AVERAGED TERRESTRIAL EXPOSURE RATE LEVELS FOR THE ELEVEN ATOLLS AND TWO ISLANDS COVERED DURING THE AERIAL RADIOLOGICAL SURVEY



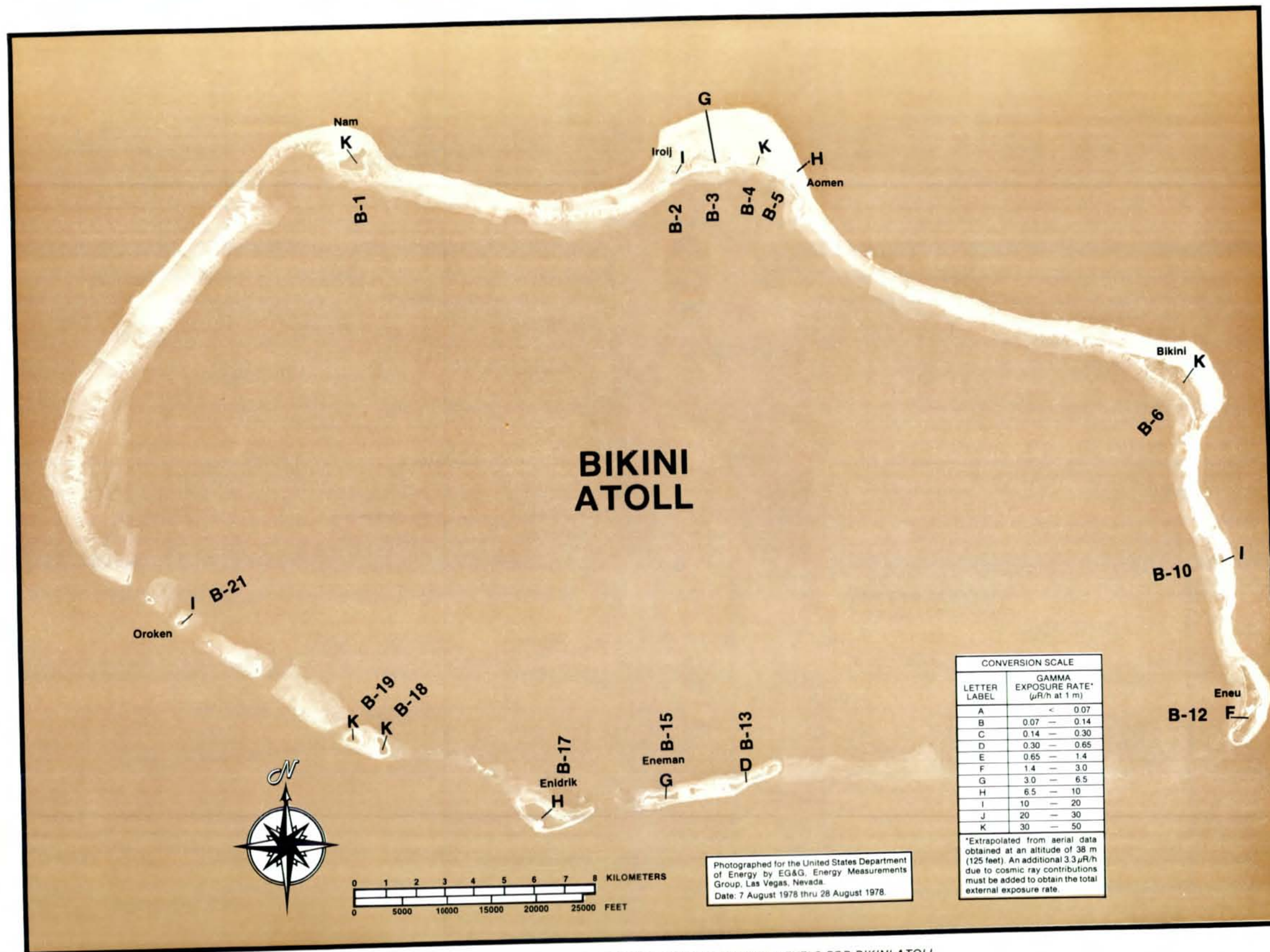


Figure 14. ISLAND-AVERAGED TERRESTRIAL EXPOSURE RATE LEVELS FOR BIKINI ATOLL



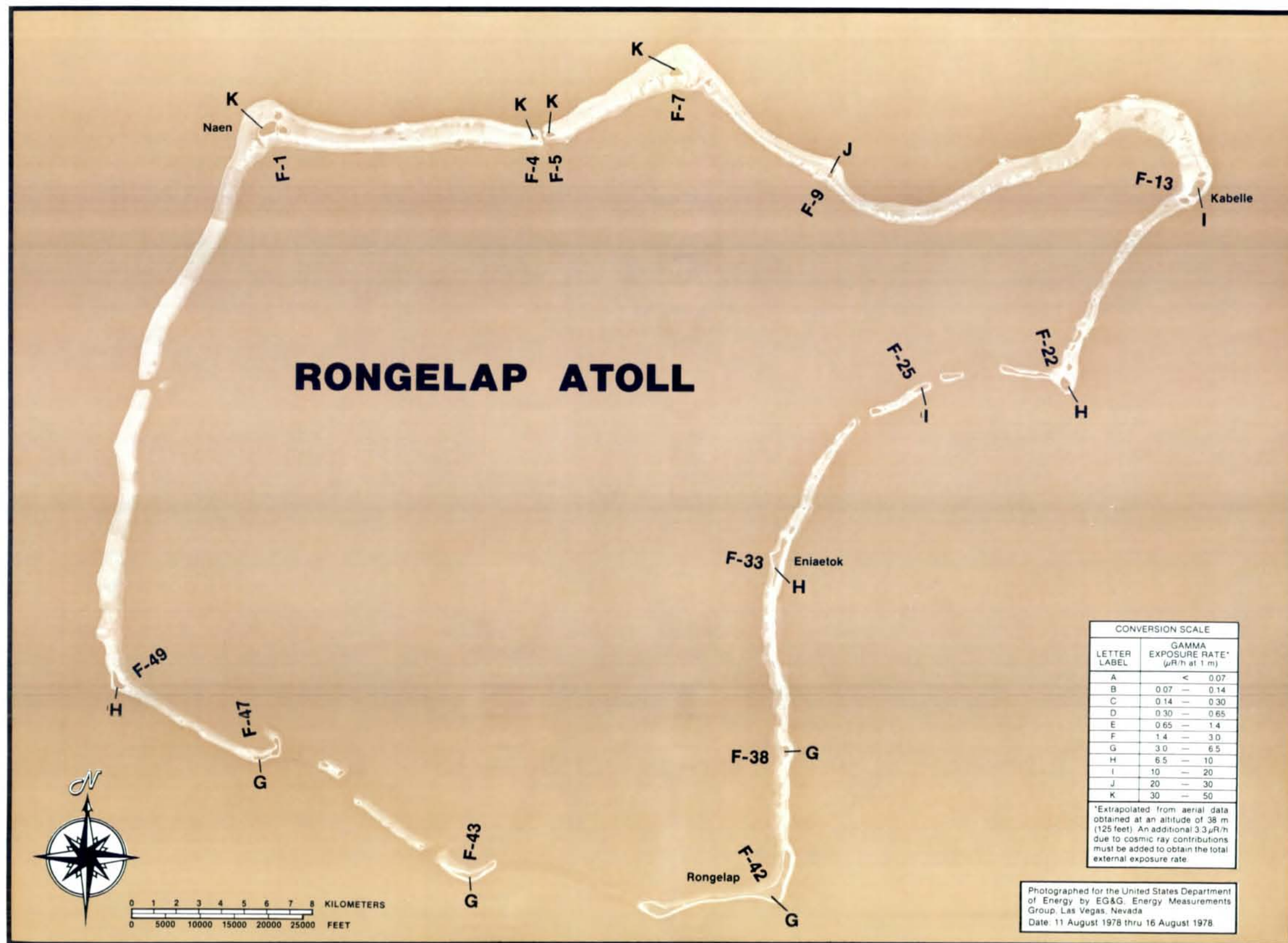


Figure 15. ISLAND-AVERAGED TERRESTRIAL EXPOSURE RATE LEVELS FOR RONGELAP ATOLL



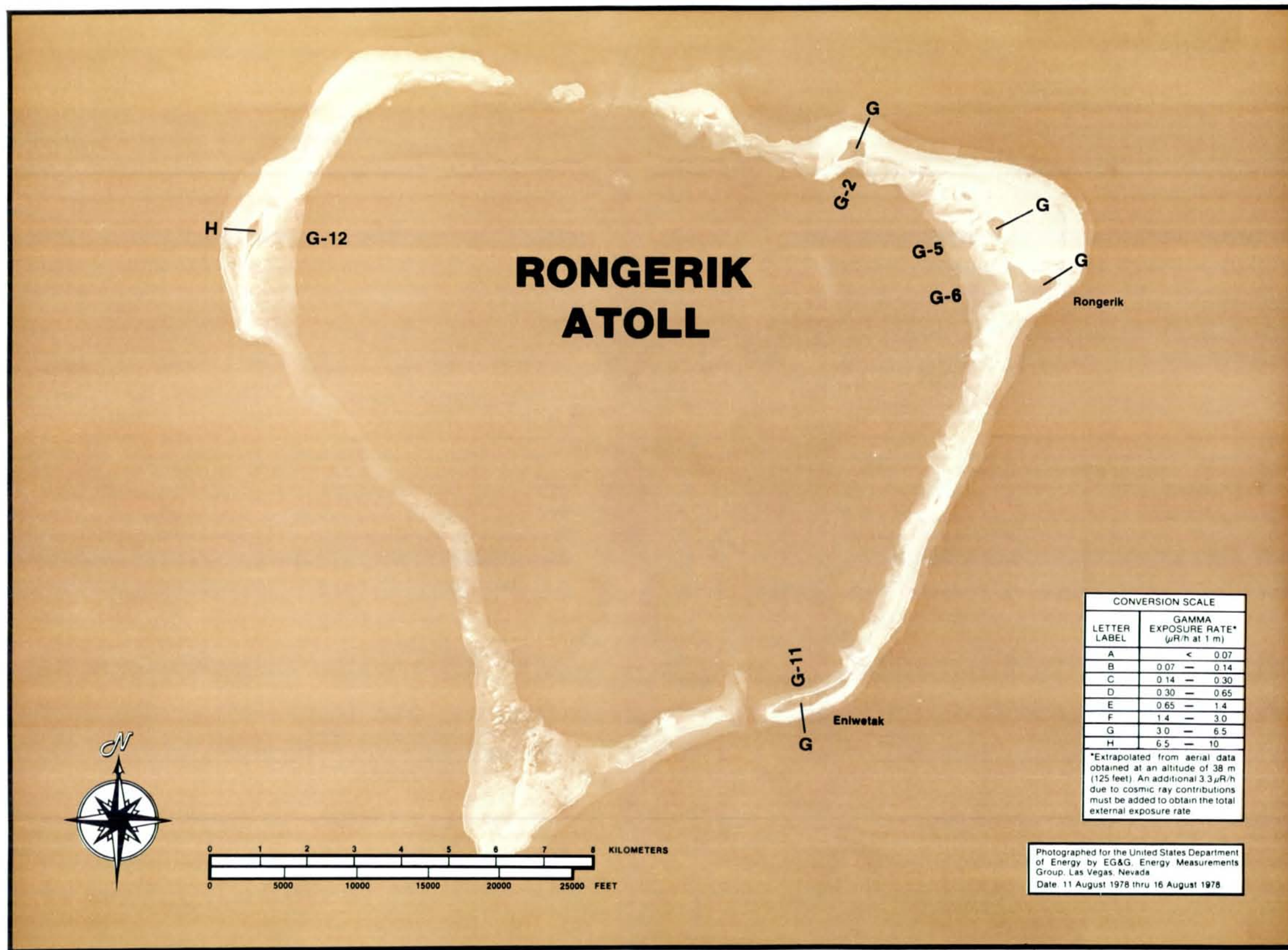


Figure 16. ISLAND-AVERAGED TERRESTRIAL EXPOSURE RATE LEVELS FOR RONGERIK ATOLL



northern part of Rongelap Atoll. Levels decreased quite rapidly, by essentially a factor of ten, going from the northern part to the southern part of Rongelap. Levels at Rongerik Atoll were similar to those observed over the southern part of Rongelap. Somewhat lower levels were observed at Ailinginae Atoll. Although the levels observed at Utirik, Taka, and Bikar Atolls were approximately a factor of ten lower than those in the southern part of Rongelap, and a factor of 50-100 times lower than those measured over northern Rongelap, they were still approximately two to three times higher than those observed over the remaining atolls. This is consistent with the estimated fallout pattern from the Bravo event. As shown in Figure 13, the remaining atolls and islands covered during the radiation survey have essentially the same terrestrial radiation levels. The numerical data in Table 4, however, does indicate slightly higher levels over Mejit Island and the northern part of Ailuk Atoll. These areas represent the limits at which direct fallout from the Bravo event can still be detected using the aerial radiation survey data. It is important to point out that although the levels observed at Mejit Island are slightly higher than those observed for southern Ailuk, Likiep, Wotho, and Ujelang Atolls, the actual values involved are extremely low. It would be difficult for most standard survey instruments to measure this difference, or, for that matter, to distinguish between levels measured over land and those measured over water at any of these locations.

In addition to the total terrestrial exposure rate values, Table 4 also gives the individual island-averaged contributions due to  $^{137}\text{Cs}$  and  $^{60}\text{Co}$  for Rongelap, Rongerik, and Bikini Atolls. Values for  $^{137}\text{Cs}$  are also presented for Ailinginae Atoll. These results were obtained from photopeak count rate data, as discussed in Section 3.3. Levels were too low at the other atolls for processing the second-by-second radiation data in this manner. Since the individual  $^{137}\text{Cs}$  and  $^{60}\text{Co}$  contributions were obtained from their respective photopeak count rate data, and the total terrestrial exposure rate was obtained independently from the total spectrum count rate data, the sum of the two components should not necessarily be expected to equal the total. On the average, however, the sum of the two individual components does agree well with that obtained from the total gross counts. This supports previous data which indicates that there is little or no naturally occurring terrestrial radioactivity within these coral atolls. Detailed spectral analysis also confirmed that  $^{137}\text{Cs}$  and  $^{60}\text{Co}$  were the only two gamma-emitting radionuclides existing with sufficient activity to allow positive identification from the aerial survey data. It was necessary to obtain a summed spectrum over a large area of a given island to perform this type of analysis for most of the atolls surveyed. The summed spectral data showed low levels of  $^{60}\text{Co}$  at

**Table 4. Island-Averaged Terrestrial Exposure Rate and Concentration Values Derived from the Aerial Survey Data**

| Location         | Island Number | Island Name   | Average Terrestrial Exposure Rate ( $\mu\text{R/h}$ at 1 meter) <sup>a</sup> |                             |                            | Average Concentration in Top 10 cm (pCi/g, wet Weight) |                  |
|------------------|---------------|---------------|------------------------------------------------------------------------------|-----------------------------|----------------------------|--------------------------------------------------------|------------------|
|                  |               |               | Total Gross Counts                                                           | $^{137}\text{Cs}$ Component | $^{60}\text{Co}$ Component | $^{137}\text{Cs}$                                      | $^{60}\text{Co}$ |
|                  |               |               |                                                                              |                             |                            |                                                        |                  |
| Bikini Atoll     | B-1           | Nam           | 32                                                                           | 21                          | 9.0                        | 37                                                     | 3.7              |
|                  | B-2           | Iroij*        | 12                                                                           | 6.8                         | 5.2                        | 12                                                     | 2.1              |
|                  | B-3           | Odrik*        | 4.4                                                                          | 1.6                         | 3.6                        | 2.8                                                    | 1.5              |
|                  | B-4           | Lomilik*      | 40                                                                           | 21                          | 20                         | 37                                                     | 8.1              |
|                  | B-5           | Aomen*        | 8.6                                                                          | 4.6                         | 3.6                        | 8.1                                                    | 1.5              |
|                  | B-6           | Bikini        | 35                                                                           | 31                          | 1.8                        | 55                                                     | 0.7              |
|                  | B-10          | Rojkere*      | 16                                                                           | 15                          | 1.4                        | 27                                                     | 0.6              |
|                  | B-12          | Eneu          | 2.7                                                                          | 2.3                         | 0.2                        | 4.1                                                    | 0.1              |
|                  | B-13          | Aerokojlol*   | 0.5                                                                          | — <sup>b</sup>              | —                          | —                                                      | —                |
|                  | B-15,16       | Lele, Eneman* | 6.4                                                                          | 1.3                         | 2.8                        | 2.3                                                    | 1.1              |
|                  | B-17          | Enidrik       | 7.9                                                                          | 4.2                         | 2.1                        | 7.4                                                    | 0.9              |
|                  | B-18          | Lukoj*        | 46                                                                           | 37                          | 9.0                        | 66                                                     | 3.7              |
|                  | B-19          | Jelete*       | 50                                                                           | 44                          | 9.0                        | 78                                                     | 3.7              |
|                  | B-21          | Oroken*       | 16                                                                           | 11                          | 5.0                        | 20                                                     | 2.0              |
| Rongelap Atoll   | F-1           | Naen          | 43                                                                           | 42                          | 3.0                        | 74                                                     | 1.2              |
|                  | F-5           | Yugui*        | 39                                                                           | 38                          | 2.8                        | 67                                                     | 1.1              |
|                  | F-7           | Lomuial       | 33                                                                           | 32                          | 2.2                        | 57                                                     | 0.9              |
|                  | F-9           | Lukuen*       | 29                                                                           | 28                          | 1.7                        | 50                                                     | 0.7              |
|                  | F-13          | Kabelle       | 14                                                                           | 14                          | 0.9                        | 25                                                     | 0.4              |
|                  | F-22          | Gabelle       | 9.0                                                                          | 8.8                         | 0.5                        | 16                                                     | 0.2              |
|                  | F-25          | Gogan*        | 14                                                                           | 13                          | 0.6                        | 23                                                     | 0.2              |
|                  | F-33          | Eniaetok      | 10                                                                           | 10                          | 0.5                        | 18                                                     | 0.2              |
|                  | F-38          | Busch*        | 5.3                                                                          | 5.5                         | 0.2                        | 9.7                                                    | 0.1              |
|                  | F-42          | Rongelap      | 4.5                                                                          | 4.5                         | 0.2                        | 8.0                                                    | 0.1              |
|                  | F-43          | Arbar*        | 4.1                                                                          | 3.7                         | 0.3                        | 6.5                                                    | 0.1              |
|                  | F-47          | Tufa*         | 5.2                                                                          | 4.6                         | 0.3                        | 8.1                                                    | 0.1              |
|                  | F-49          | Borukka*      | 7.2                                                                          | 6.8                         | 0.4                        | 12                                                     | 0.2              |
| Rongerik Atoll   | G-2           | Latoback      | 5.8                                                                          | 6.0                         | 0.4                        | 11                                                     | 0.2              |
|                  | G-5           | Bigonattam    | 6.5                                                                          | 6.6                         | 0.4                        | 12                                                     | 0.2              |
|                  | G-6           | Rongerik      | 6.0                                                                          | 6.0                         | 0.4                        | 11                                                     | 0.2              |
|                  | G-11          | Eniwetak*     | 4.8                                                                          | 4.1                         | 0.3                        | 7.3                                                    | 0.1              |
|                  | G-12          | Bock*         | 7.5                                                                          | 7.6                         | 0.5                        | 13                                                     | 0.2              |
| Ailinginae Atoll | C-8           | Majokoryaan*  | 2.4                                                                          | 2.5                         | —                          | 4.4                                                    | —                |
|                  | C-10          | Knox          | 1.5                                                                          | 1.4                         | —                          | 2.5                                                    | —                |
|                  | C-15          | Ucchuwanen*   | 1.9                                                                          | 1.9                         | —                          | 3.4                                                    | —                |

<sup>a</sup> An additional 3.3  $\mu\text{R/h}$  due to cosmic ray contributions must be added to obtain the total external exposure rate.

<sup>b</sup> A dash indicates activity levels were too low to allow processing for the second-by-second photopeak count rate data.

\* Correction factor applied to account for small island size (see Section 3.6.1 and Figure 20).



**Table 4. Island-Averaged Terrestrial Exposure Rate and Concentration Values Derived from the Aerial Survey Data (continued)**

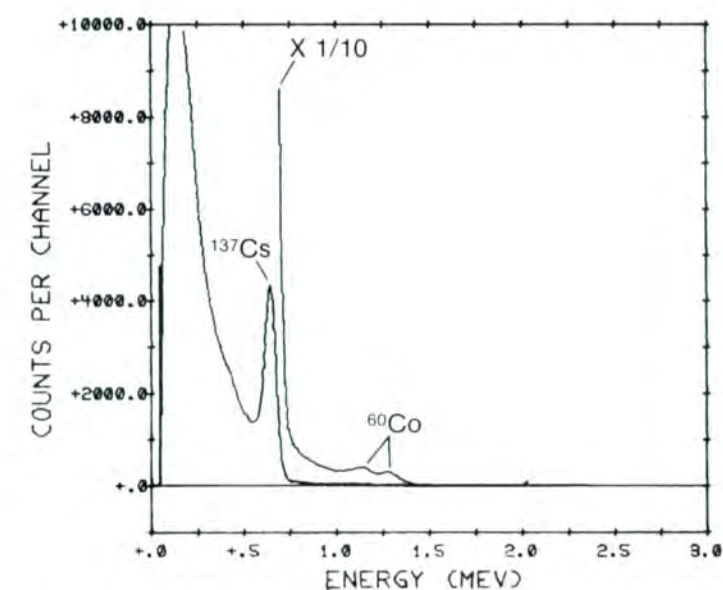
| Location                     | Island Number | Island Name | Average Terrestrial Exposure Rate ( $\mu\text{R/h}$ at 1 meter) <sup>a</sup> |                             |                            | Average Concentration in Top 10 cm (pCi/g, wet Weight) |                  |
|------------------------------|---------------|-------------|------------------------------------------------------------------------------|-----------------------------|----------------------------|--------------------------------------------------------|------------------|
|                              |               |             | Total Gross Counts                                                           | <sup>137</sup> Cs Component | <sup>60</sup> Co Component | <sup>137</sup> Cs                                      | <sup>60</sup> Co |
|                              |               |             |                                                                              |                             |                            |                                                        |                  |
| Ailinginae Atoll (continued) | C-19          | Ribinouri*  | 1.9                                                                          | 2.0                         | — <sup>b</sup>             | 3.5                                                    | —                |
|                              | C-23          | Enibuk*     | 1.8                                                                          | 1.7                         | —                          | 3.0                                                    | —                |
|                              | C-24          | Mogiri*     | 1.8                                                                          | 2.0                         | —                          | 3.5                                                    | —                |
|                              | C-27          | Sifo        | 1.5                                                                          | 1.4                         | —                          | 2.5                                                    | —                |
| Utirik Atoll                 | I-3           | Pigowak*    | 0.75                                                                         | —                           | —                          | (1.3) <sup>c</sup>                                     | —                |
|                              | I-6           | Utirik      | 0.73                                                                         | —                           | —                          | (1.3)                                                  | —                |
|                              | I-8           | Aon         | 0.69                                                                         | —                           | —                          | (1.2)                                                  | —                |
| Bikar Atoll                  | D-1           | Jaboerukku* | 0.50                                                                         | —                           | —                          | (0.88)                                                 | —                |
|                              | D-4           | Bikar*      | 0.52                                                                         | —                           | —                          | (0.92)                                                 | —                |
| Taka Atoll                   | H-4           | Taka        | 0.42                                                                         | —                           | —                          | (0.74)                                                 | —                |
| Mejit Island                 |               |             | 0.27                                                                         | —                           | —                          | (0.48)                                                 | —                |
| Ailuk Atoll                  | A-1           | Kapen       | 0.25                                                                         | —                           | —                          | (0.44)                                                 | —                |
|                              | A-4           | Enejelar    | 0.25                                                                         | —                           | —                          | (0.44)                                                 | —                |
|                              | A-7           | Bigen       | 0.24                                                                         | —                           | —                          | (0.42)                                                 | —                |
|                              | A-20          | Aliet       | 0.22                                                                         | —                           | —                          | (0.39)                                                 | —                |
|                              | A-33          | Bererjao    | 0.19                                                                         | —                           | —                          | (0.34)                                                 | —                |
|                              | A-51          | Ailuk       | 0.20                                                                         | —                           | —                          | (0.35)                                                 | —                |
|                              | A-53          | Agulue      | 0.21                                                                         | —                           | —                          | (0.37)                                                 | —                |
| Jemo Island                  |               |             | 0.22                                                                         | —                           | —                          | (0.38)                                                 | —                |
| Likiep Atoll                 | L-1           | Mato        | 0.21                                                                         | —                           | —                          | (0.37)                                                 | —                |
|                              | L-30          | Jiebaru     | 0.19                                                                         | —                           | —                          | (0.34)                                                 | —                |
|                              | L-37          | Likiep      | 0.19                                                                         | —                           | —                          | (0.34)                                                 | —                |
|                              | L-55          | Kapenor     | 0.22                                                                         | —                           | —                          | (0.39)                                                 | —                |
| Wotho Atoll                  | M-1           | Medyeron    | 0.20                                                                         | —                           | —                          | (0.35)                                                 | —                |
|                              | M-4           | Wotho       | 0.19                                                                         | —                           | —                          | (0.34)                                                 | —                |
|                              | M-17          | Kabben      | 0.22                                                                         | —                           | —                          | (0.39)                                                 | —                |
| Ujelang Atoll                | J-17          | Daisu*      | 0.21                                                                         | —                           | —                          | (0.37)                                                 | —                |
|                              | J-18          | Ujelang     | 0.20                                                                         | —                           | —                          | (0.35)                                                 | —                |
|                              | J-22          | Eimnlapp*   | 0.22                                                                         | —                           | —                          | (0.39)                                                 | —                |
|                              | J-25          | Kalo*       | 0.21                                                                         | —                           | —                          | (0.37)                                                 | —                |

<sup>a</sup> Values given in parentheses were inferred from the total gross count data.

\* Correction factor applied to account for small island size (see Section 3.6.1 and Figure 20).

Ailinginae as well as <sup>137</sup>Cs, which had been observed in the single-second spectral data. Positive identification of both <sup>137</sup>Cs and <sup>60</sup>Co was obtained at Utirik Atoll. Only <sup>137</sup>Cs could be identified for the remaining atolls and islands. Two typical summed spectra, obtained over Bikini and Ujelang Islands, are shown in Figures 17 and 18. These are net terrestrial spectra obtained by subtracting a normalized water background spectrum to remove cosmic and aircraft background components. Both <sup>137</sup>Cs and <sup>60</sup>Co can be identified in the Bikini spectrum, while only <sup>137</sup>Cs can be seen in the Ujelang spectrum. These two spectra have been normalized to the same system live time, so the vertical counts-per-channel scale serves as an indicator of the relative activity on the two islands.

In addition to the exposure rate data, it is also possible to obtain soil concentration values from the photopeak count rate data as discussed in Section 3.4 and Appendix C. These values are also given in Table 4 in terms of the average concentration, in pCi/g (wet weight), within the top 10 cm. Average concentration within other depth intervals can be obtained by multiplying by the appropriate ratio of the conversion factors given in Table 3. For example, the average <sup>137</sup>Cs concentration within the top 15 cm can be obtained by multiplying the values in Table 4 by 0.86. Multiplying by 0.67 gives the average concentration in the top 25 cm. Although soil concentration data could not be obtained directly for some of the atolls surveyed due to the low levels involved, it is possible to infer these values by assuming



**Figure 17. NET TERRESTRIAL GAMMA RAY SPECTRUM OBTAINED OVER BIKINI ISLAND**



$^{137}\text{Cs}$  is the only significant contributor to the total terrestrial exposure rate. For comparison, concentration values obtained in this manner are given in parentheses in Table 4.

### 3.6 DISCUSSION

#### 3.6.1 Comparison with Ground Data

The primary difference between data obtained with the airborne system and that obtained from ground measurements is the difference in area covered in a single measurement. Each one-second data point obtained with the airborne system covers an area several thousand times as large as a measurement made at 1 meter, such as a typical ionization chamber measurement, and several million times as large as a typical soil sample. For an ideal uniform distribution extending over a large area, each type of measurement should, in principle, lead to the same results. In practice, however, it is not unusual to find some local variation in radiation levels from point-to-point on the ground, even over relatively constant areas. The degree to which aerial data agrees or disagrees with ground data depends to a large extent on the magnitude and spatial extent of local variations which might exist, combined with the number of ground measurements made within a given area. In general, the more variable the radiation levels are within a given area, the larger the number of ground measurements required to obtain a large-area average comparable to that obtained with the airborne system.

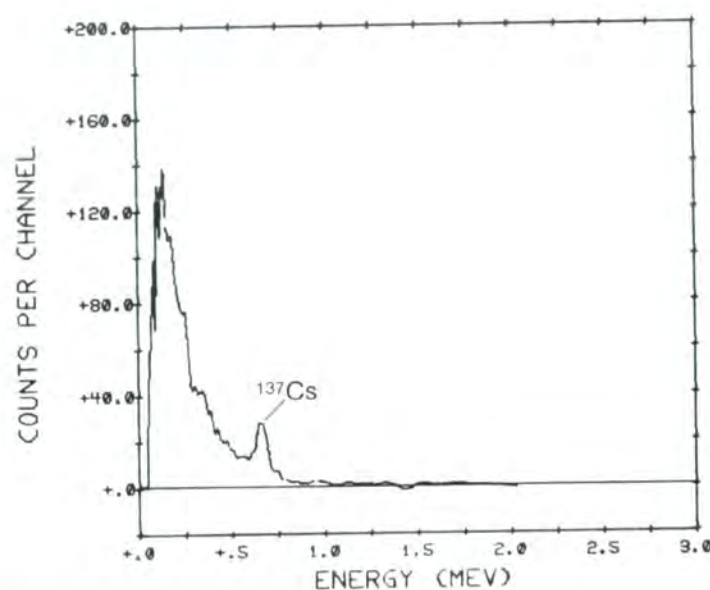


Figure 18. NET TERRESTRIAL GAMMA RAY SPECTRUM OBTAINED OVER UGELANG ISLAND

Local variations in radiation levels are a particular problem for Bikini Atoll, where nuclear testing took place. This is illustrated in Figure 19, where the maximum levels observed over the atoll are shown instead of the island-averaged values given in Table 4 and shown in Figure 14. Significant variations can be seen from one part of an island to another for several of the islands within the atoll.

The maximum levels shown in Figure 19 (and also in the detailed radiation contours given in Appendix D) may be lower, in some cases, than those actually measured on the ground. This is due to the large-area averaging property of the airborne system: high level activity confined to a small area will appear as a lower level of activity but spread out over a larger area. Although this is not a significant factor when computing area-averaged values over large areas, such as the island-averaged data given in Table 4, it can influence detailed point-by-point comparisons between ground data and aerial data.

The factors used to convert aerial data to ground level exposure rate or soil concentration values assume an infinite source distribution in the horizontal plane. In practice, this implies a source distribution which is large compared to the field-of-view of the airborne system. This criteria was satisfied in the present survey for islands having a width greater than approximately 400 meters. A "finite source" correction factor was required for smaller islands. Figure 20 gives a curve showing the appropriate correction factor as a function of nominal island width. This curve was developed empirically by comparing radiation levels inferred from the aerial data for small islands with those obtained over nearby large islands in areas where the average radiation levels appeared to be essentially constant. The empirical results agreed quite well with theoretical calculations of finite source correction factors.<sup>14</sup> Island-averaged data presented in Table 4 and in Figures 13-16 have had a finite source correction factor applied, whenever necessary. The data presented in Figure 19, showing maximum levels observed at Bikini Atoll, and the detailed radiation contour data presented in Appendix D have not been corrected for this effect. Figure 20 can be used to obtain an approximate correction factor, as required, for these data.

Vegetation attenuation could also account for some difference between ground data and data inferred from aerial measurements. Experiments conducted at Enewetak, however, indicated that this is not a significant factor for  $^{137}\text{Cs}$  and  $^{60}\text{Co}$  gamma ray energies. Even for the 60 keV gamma rays from  $^{241}\text{Am}$ , brush attenuation led to only a 15% reduction in the unscattered gamma ray flux.<sup>10</sup> Another indication that vegetation attenuation was not a significant factor is the good agreement between terrestrial exposure rate data obtained from the unscattered gamma ray photopeak data and that

obtained from the total count rate data, which includes scattered gamma rays (see Table 4).

Tables 5 and 6 show some direct comparisons between the aerial survey data and ground measurements: soil concentration data are compared in Table 5 and exposure rate data are compared in Table 6. Average  $^{137}\text{Cs}$  activity in the top 10 cm and the top 25 cm are compared in Table 5 for several islands at Rongelap Atoll. The soil sample results were based on preliminary analysis of profile samples obtained during the terrestrial portion of the present survey. The concentration values obtained from the aerial data are expressed in units of pCi/g, wet weight, in Table 4. These values were converted to pCi/g, dry weight, by assuming an average soil moisture content of 15%, in order to compare directly with the soil sample data. The 25 cm average values were obtained by multiplying by the ratio of the appropriate conversion factors given in Table 3 (see Section 3.4). Considering the rather high degree of variability observed in the soil sample data and the limited number of samples obtained, the results shown in Table 5 agree reasonably well. Because the aerial data are based on a weighted average of the depth distributions observed (see Table 2), one might expect the 25 cm soil sample data, which also tends to average out variations in depth distribution, to agree better than the 10 cm data. This was indeed found to be the case.

The exposure rate data given in Table 6 were obtained by Brookhaven National Laboratory (BNL) in 1976 and 1977 using an ionization chamber, which measures total external exposure rate. In order to compare these results with the aerial data, it was necessary to add the cosmic ray contribution (assumed to be  $3.3 \mu\text{R/h}$ ) to the terrestrial exposure rate data given in Table 4. Again, considering the limited number of ground measurements, the agreement is quite good.

Perhaps the most extensive series of ground measurements taken on a single island in the northern Marshalls were made in 1975 at Bikini Island by the Lawrence Livermore National Laboratory.<sup>5</sup> A total of 2500 exposure rate measurements were made on a 30 m rectangular grid over the entire surface of Bikini Island. The island-averaged terrestrial exposure rate obtained from these measurements was  $36 \mu\text{R/h}$ . This compares extremely well with the value of  $35 \mu\text{R/h}$  obtained from the aerial survey data. Soil samples taken during the same survey gave an average  $^{137}\text{Cs}$  activity in the top 15 cm of 41 pCi/g, and an average  $^{60}\text{Co}$  activity in the top 15 cm of 0.74 pCi/g. These values also compare extremely well with the 15 cm average values obtained from the aerial survey data (47 pCi/g for  $^{137}\text{Cs}$  and 0.6 pCi/g for  $^{60}\text{Co}$ ). The 15 cm average values were obtained from the 10 cm data given in Table 4 by multiplying by the appropriate ratio of the conversion factors given in Table 3.



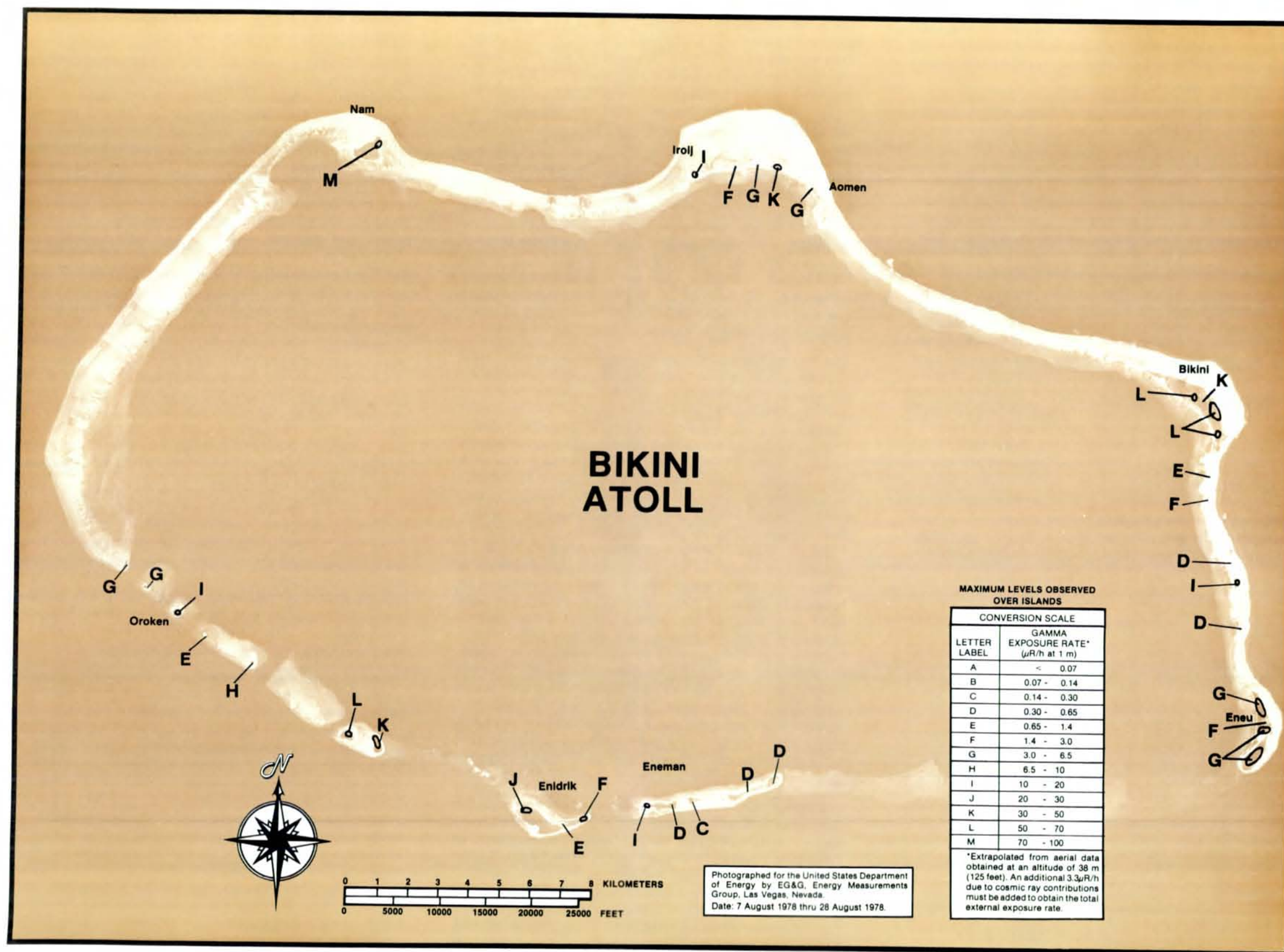


Figure 19. MAXIMUM RADIATION LEVELS OBSERVED OVER BIKINI ATOLL



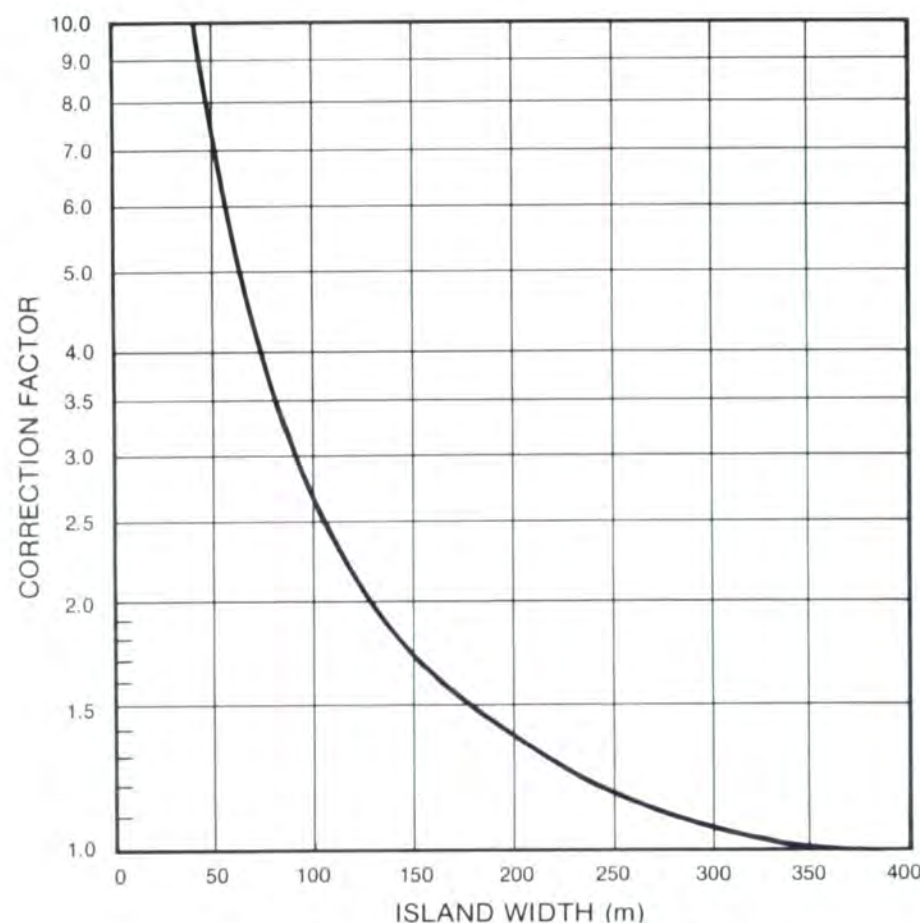


Figure 20. FINITE SOURCE CORRECTION FACTORS

| Table 5. Comparison Between Soil Sample Data and Aerial Data Obtained at Rongelap Atoll |                                                             |               |                    |               |
|-----------------------------------------------------------------------------------------|-------------------------------------------------------------|---------------|--------------------|---------------|
| Island                                                                                  | Average $^{137}\text{Cs}$ Concentration (pCi/g, dry weight) |               |                    |               |
|                                                                                         | Top 10 cm                                                   |               | Top 25 cm          |               |
|                                                                                         | Soil Sample Data*                                           | Aerial Data** | Soil Sample Data*  | Aerial Data** |
| Naen                                                                                    | 95 $\pm$ 65 (6)†                                            | 85            | 53 $\pm$ 29 (6)    | 57            |
| Yugui                                                                                   | 107 (1)                                                     | 77            | 46 (1)             | 52            |
| Lomuila                                                                                 | 47 $\pm$ 22 (4)                                             | 66            | 33 $\pm$ 14 (4)    | 44            |
| Kabelle                                                                                 | 27 $\pm$ 40 (5)                                             | 29            | 16 $\pm$ 16 (5)    | 19            |
| Eniaetok                                                                                | 13 $\pm$ 9 (5)                                              | 21            | 9.3 $\pm$ 6.0 (4)  | 14            |
| Rongelap                                                                                | 14 $\pm$ 8 (23)                                             | 9.2           | 7.7 $\pm$ 4.9 (21) | 6.2           |
| Arbar                                                                                   | 17 $\pm$ 15 (9)                                             | 7.5           | 9.1 $\pm$ 9.1 (9)  | 5.0           |
| Borukka                                                                                 | 27 $\pm$ 7 (3)                                              | 14            | 13 $\pm$ 3 (3)     | 9.4           |

\* Based on preliminary analysis of profile samples obtained during the terrestrial portion of the present survey.<sup>11</sup>

\*\*Corrected to dry weight by assuming an average soil moisture content of 15%.

† Values given in parentheses represent the number of measurement locations.

### 3.6.2 Negative $^{241}\text{Am}$ Results

Another radioisotope of particular importance for assessing the radiological condition of the atolls surveyed is  $^{241}\text{Am}$ . In addition to its own direct importance,  $^{241}\text{Am}$  is also used to infer  $^{239,240}\text{Pu}$  concentration based on ratio data obtained from soil sample analysis. These transuranic elements are of particular concern due to their long half-life (460 years for  $^{241}\text{Am}$  and 24,400 years for  $^{239}\text{Pu}$ , compared to 30 years for  $^{137}\text{Cs}$  and 5.3 years for  $^{60}\text{Co}$ ). This is the primary reason why the Enewetak radiological cleanup was specifically directed at reducing the concentration levels of these transuranic radionuclides.

Special photopeak stripping procedures were applied to the aerial data in an effort to detect the possible presence of the 60 keV gamma rays from  $^{241}\text{Am}$ . The results were negative for all of the atolls surveyed. Although the sensitivity of the airborne system is somewhat limited for detecting  $^{241}\text{Am}$  (varying as a function of the background due to other gamma ray emitters), the negative results can be used to establish an upper limit on the possible  $^{241}\text{Am}$  contamination. Figure 21 shows a curve giving the minimum detectable activity (MDA) of the aerial system for  $^{241}\text{Am}$  as a function of the terrestrial exposure rate. This curve can be used, together with the exposure rate data given in Table 4, to estimate an upper limit on  $^{241}\text{Am}$  activity for the atolls surveyed. The MDA values are given for the average activity in the top 3 cm to correspond with the depth established for the surface cleanup criteria at Enewetak.

### 3.6.3 Comparison With Other Locations

In order to help put the results of the present survey in proper perspective, it is useful to compare these results with typical radiation levels at other locations. Figure 22 shows typical terrestrial exposure rate values for the continental United States.<sup>15</sup> Exposure rate values are given using the same intervals used for the summary data presented in Figures 13-16 in order to allow for direct comparison. It can be seen that typical U.S. terrestrial exposure rates are comparable with those observed over southern Rongelap and Rongerik Atolls.

The total external exposure rate also includes cosmic ray contributions. This component varies from approximately 3.7  $\mu\text{R/h}$  at sea level in the United States to 7  $\mu\text{R/h}$  at an elevation of 7,000 feet, compared to 3.3  $\mu\text{R/h}$  (estimated) in the northern Marshalls.

For most of the atolls surveyed, the terrestrial exposure rate levels are lower than those found in the United States. The primary difference, however, is that the terrestrial levels in the United States are primarily due to naturally occurring uranium, thorium, and potassium;



**Table 6. Comparison Between Ion Chamber Data and Aerial Data for Several Atolls in the Northern Marshall Islands**

| Atoll    | Island   | Average Exposure Rate ( $\mu\text{R/h}$ at 1 m) |               |
|----------|----------|-------------------------------------------------|---------------|
|          |          | Ion Chamber Data*                               | Aerial Data** |
| Rongelap | Naen     | $43 \pm 19$ (11)†                               | 46            |
|          | Kabelle  | $22 \pm 7$ (11)                                 | 17            |
|          | Eniaetok | $9.9 \pm 2.7$ (11)                              | 13            |
|          | Rongelap | $7.3 \pm 1.5$ (57)                              | 7.8           |
| Rongerik | Eniwetak | $6.3 \pm 1.7$ (7)                               | 8.1           |
| Utirik   | Utirik   | $4.1 \pm 0.3$ (9)                               | 4.0           |
|          | Aon      | $4.0 \pm 0.3$ (3)                               | 4.0           |
| Ailuk    | Bigen    | $3.9 \pm 0.3$ (2)                               | 3.5           |
|          | Ailuk    | $3.7 \pm 0.1$ (5)                               | 3.5           |

\* Based on data given in Reference 8.

\*\* Includes an assumed  $3.3 \mu\text{R/h}$  cosmic ray contribution.

† Values given in parentheses represent the number of measurement locations.

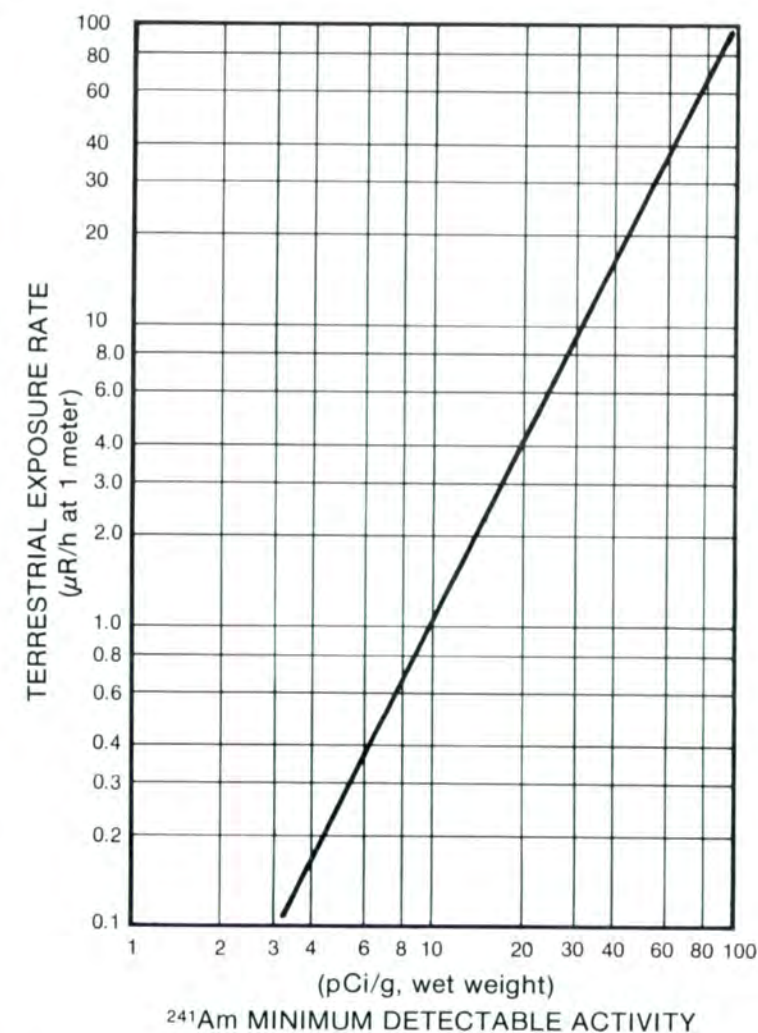
while the terrestrial activity found on the coral atolls of the northern Marshalls is primarily due to  $^{137}\text{Cs}$  from atmospheric fallout. This becomes important for internal dose assessments due to the possible uptake of  $^{137}\text{Cs}$  in the food chain, and its possible presence in the drinking water. For this reason, it is more useful to compare the  $^{137}\text{Cs}$  results with  $^{137}\text{Cs}$  activity at other locations.

Typical  $^{137}\text{Cs}$  activity in the continental United States, due to worldwide fallout, ranges from 0.1 to 1.0 pCi/g, depending, to a large extent, on the average rainfall within a given area. The average value is in the range of 0.2 to 0.4 pCi/g. Thus, the average  $^{137}\text{Cs}$  activity found at Mejit Island and at Ailuk, Likiep, Wotho and Ujelang Atolls is comparable with average  $^{137}\text{Cs}$  levels in the United States. Although the levels at Utirik are slightly higher than the average worldwide fallout levels, they are still within the range found in some areas of the United States.

Data are also available on  $^{137}\text{Cs}$  activity found in other areas of the central Pacific.<sup>16</sup> Levels due to worldwide fallout were found to vary from 0.1 to 0.4 pCi/g (averaged over the top 10 cm) at Majuro, Ponape, Truk, Palau, and

Guam. This again supports the statement that  $^{137}\text{Cs}$  activity at Mejit Island and Ailuk, Likiep, Wotho, and Ujelang Atolls are comparable to, and consistent with, worldwide fallout levels.

Detailed dose assessment studies, based on the results of the present survey, are documented elsewhere.<sup>11</sup>



**Figure 21.** MINIMUM DETECTABLE ACTIVITY OF THE AIRBORNE SYSTEM FOR  $^{241}\text{Am}$  AS A FUNCTION OF TERRESTRIAL EXPOSURE RATE. The MDA values are given for the average activity in the top 3 cm.



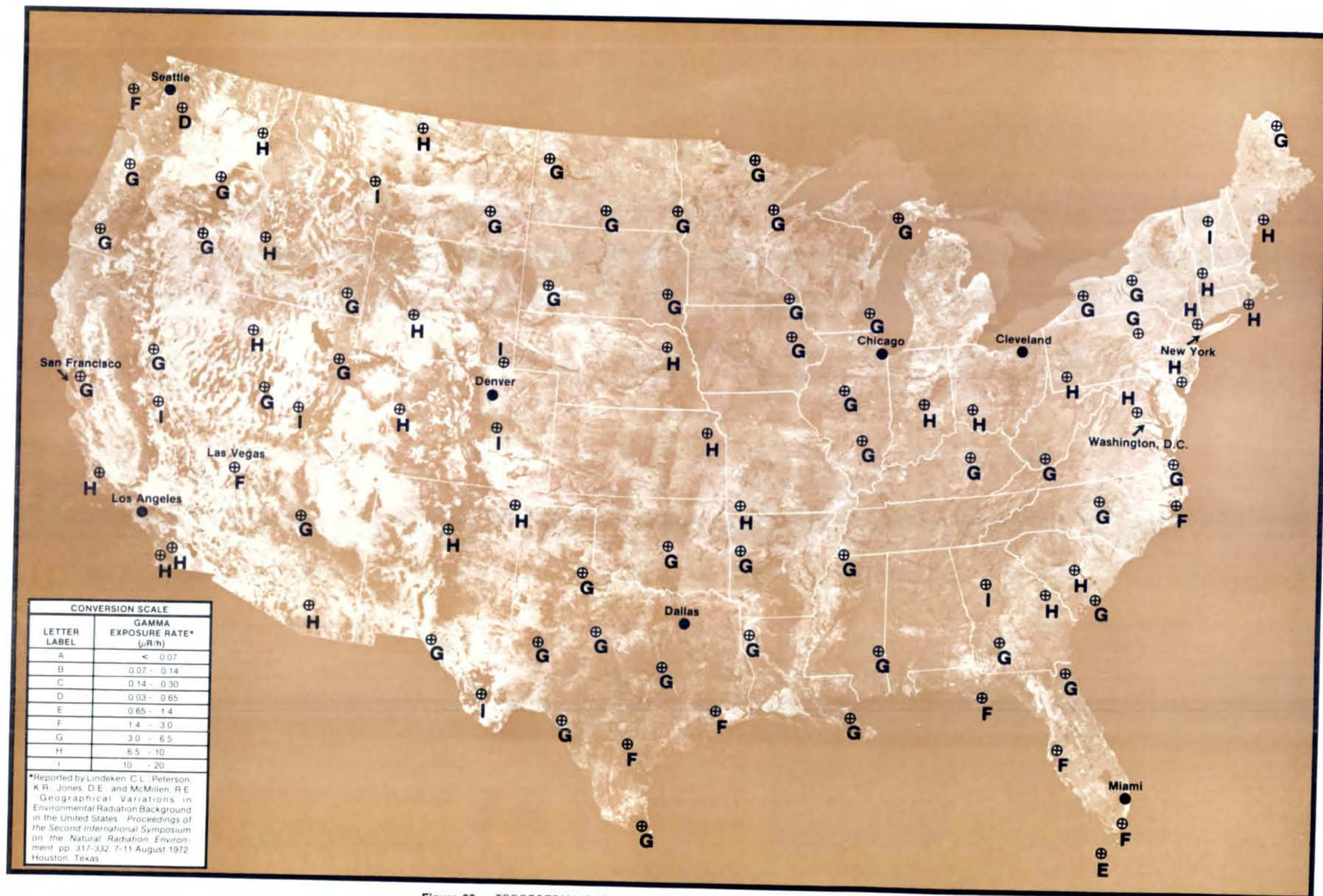


Figure 22. TERRESTRIAL RADIATION BACKGROUND IN THE UNITED STATES



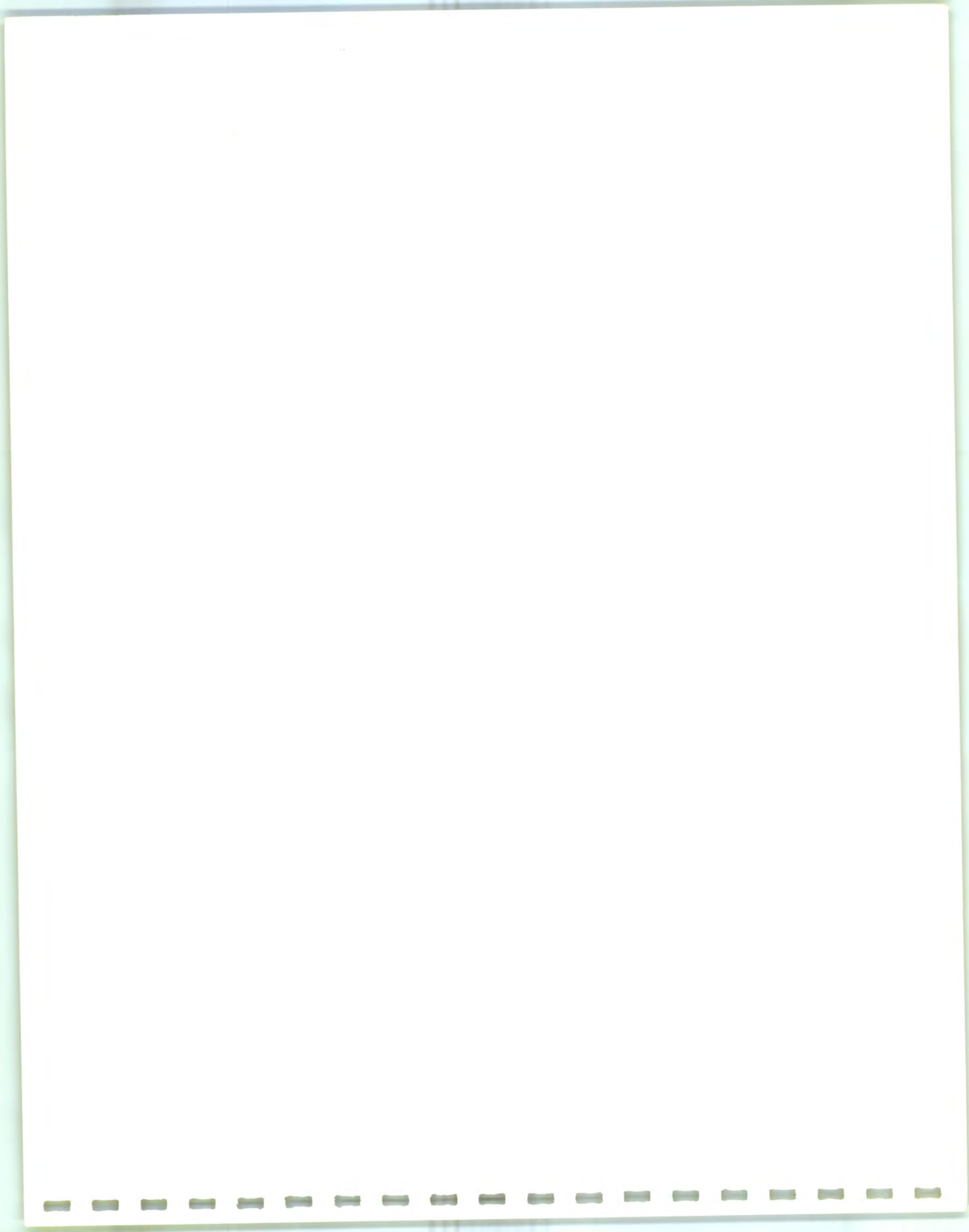




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## APPENDIX A. TECHNICAL INFORMATION: PHOTOGRAPHIC FILMS AND OPTICAL FILTERS

The information contained in this Appendix is from Eastman Kodak data and presents technical information on all film types used and transmittance data on all optical filters used. Additional information about the films can be obtained from the Eastman Kodak reference cited.

### KODAK AEROCOLOR NEGATIVE FILM 2445 (ESTAR BASE)

KODAK AEROCOLOR Negative Film 2445 (Estar Base) is a high-speed, very fine grain, **color-negative** aerial film. This film has a wide exposure latitude and is **specifically designed for processing to produce color negatives**. Since this film does not have integral color masking, direct interpretation can be made from the negative. Objects are recorded in colors complementary to their natural colors.

The 4-mil Estar Base is moisture resistant and provides good flexibility, extremely good dimensional stability, and very high resistance to tear. KODAK AEROCOLOR Negative Film 2445 has an abrasion-resistant emulsion, an antihalation undercoat, and a fast-drying backing.

The hardened emulsion provides sharpness and permits high-temperature, rapid processing in roller-transport processors such as the KODAK RT Color Processor, Model 1411C-M (modified), and the KODAK EKTACHROME RT Processor, Model 1811 (modified), using the KODAK AERO-NEG Color Process. This process consists of chemicals selected from Process EA-5 and Process C-22.

This film can be processed in rewind-processing equipment such as the Gordon/Morse M-10 Developing Outfit with Process E-4 chemicals (modified), although this is not a primary processing recommendation.

### APPLICATIONS

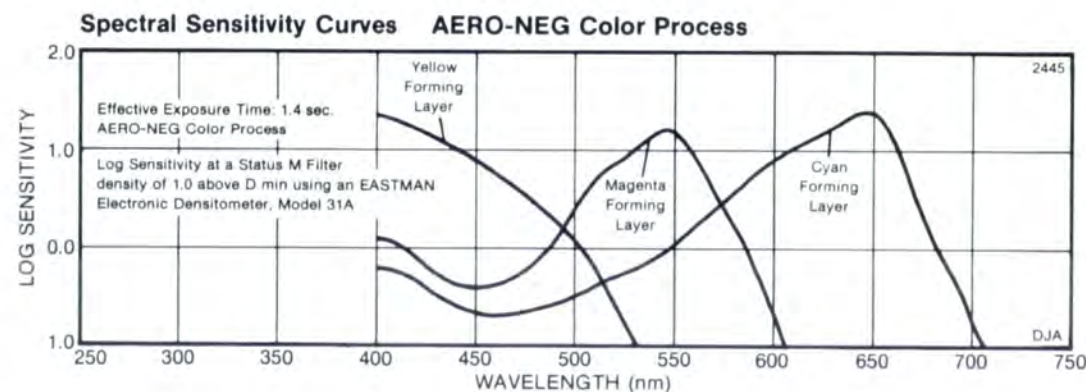
KODAK AEROCOLOR Negative Film 2445 (Estar Base) is for general use in low-to medium-altitude aerial-mapping and aerial-reconnaissance photography.

It is suited for geological, pollution, archaeological, crop, and forestry studies; traffic control; city planning; railway, highway, and hydraulic engineering; oceanography; and remote sensing, as well as other areas where photogrammetry is used.

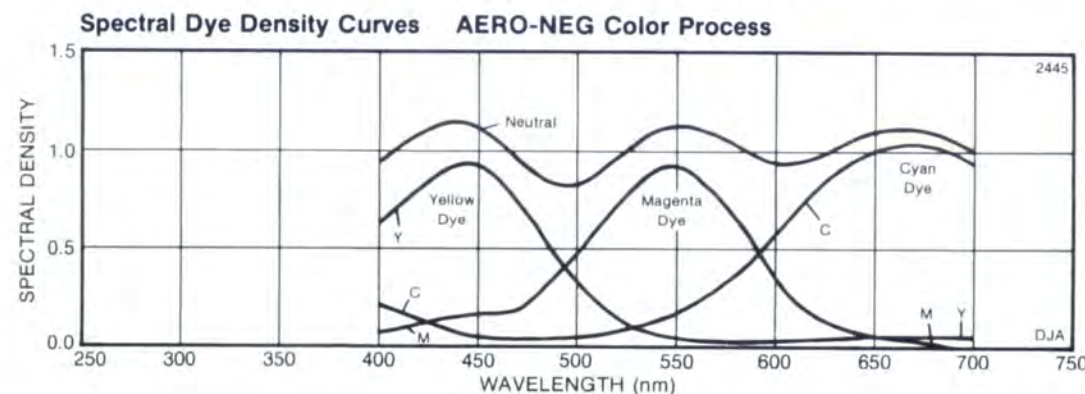
### SENSITIVITY

This is a multilayer color-negative film balanced for daylight exposure.

### KODAK AEROCOLOR Negative Film 2445 (ESTAR Base)

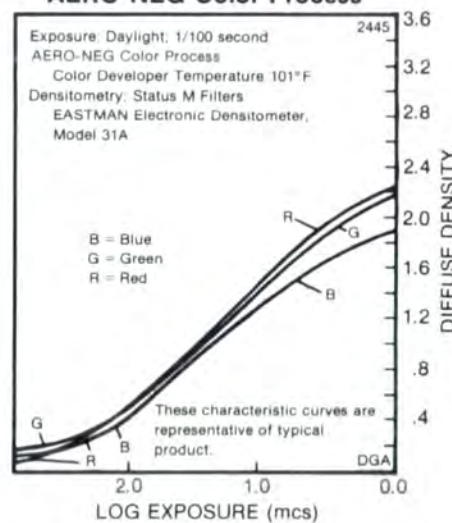


Sensitivity = Reciprocal of the exposure (ergs/cm<sup>2</sup>) required to produce a density of 1.0 above D min. Measurements were confined to the 400- to 700-nanometer region.

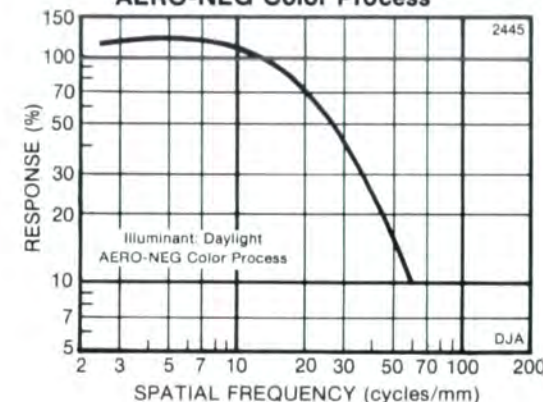


Spectral densities of dyes yielding an Equivalent Neutral Density (END) of 1.0 with D 5000 viewing illuminant. Measurements were confined to the 400- to 700-nanometer region.

### Characteristic Curves AERO-NEG Color Process



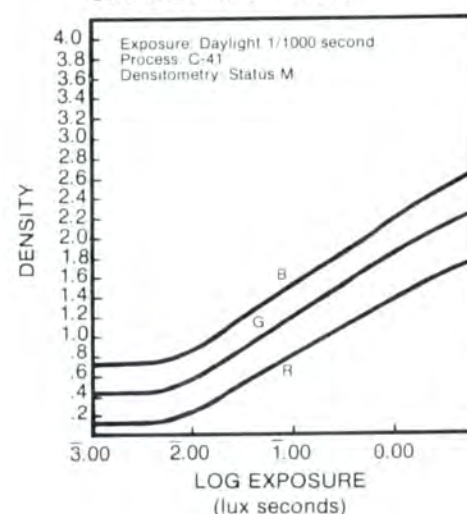
### Modulation-Transfer Curve AERO-NEG Color Process



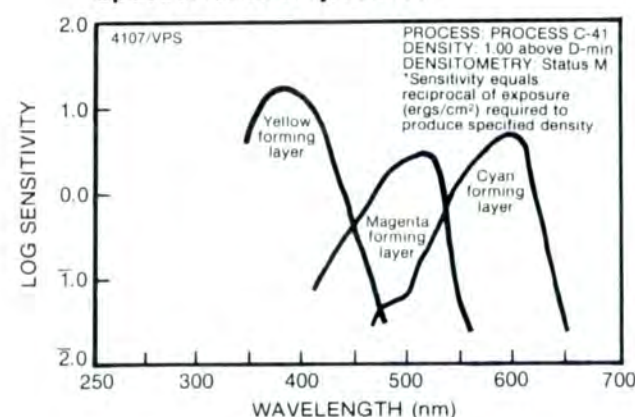


# KODAK VERICOLOR II Professional Film, 5025, Type S

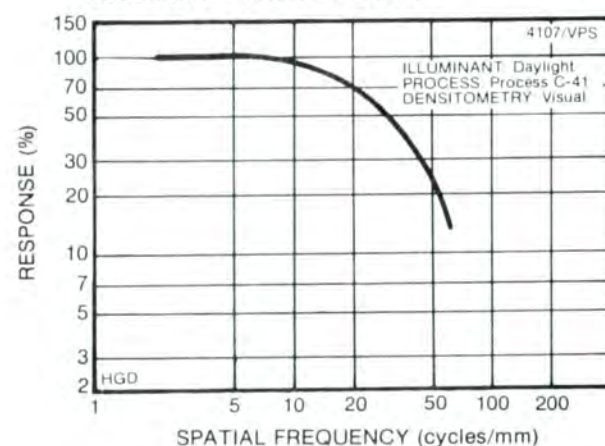
## Characteristic Curves



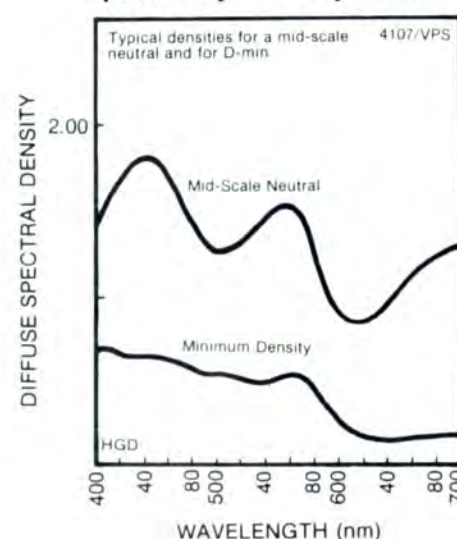
## Spectral Sensitivity Curves



## Modulation Transfer Curve



## Spectral Dye Density Curves



# KODAK AEROCHROME INFRARED FILM 2443 (ESTAR BASE)

KODAK AEROCHROME Infrared Films 2443 and 3443 (Estar Base and Estar Thin Base) have the same "false-color" reversal emulsion. The polyester base provides flexibility, dimensional stability, and high resistance to tear. The photographic properties of these two films are virtually identical; the physical properties differ due to the differences in base thicknesses and backings. These films are designed for aerial photography and are useful for camouflage detection, agricultural and forestry work, and remote-sensing applications where infrared discrimination is required.

False-color films differ from ordinary color films in that the three layers are sensitive to green, red, and infrared radiation instead of the usual blue, green, and red used for normal rendition of the visible spectrum. With these films, a yellow filter such as the KODAK WRATTEN Filter, No. 12, should be used over the camera lens to absorb the blue radiation to which all three layers are sensitive. When the film is processed as recommended, a yellow-positive image is formed in the green-sensitive layer, a magenta-positive image is formed in the red-sensitive layer, and a cyan-positive image is formed in the infrared-sensitive layer. The colors blue, green, and red appear in the final transparency, but with false rendition; the blue has resulted from green exposure; green, from red exposure and red, from infrared exposure.

These films can be processed in EA-5 chemicals in modern, continuous-processing machines, such as the following roller-transport processor: KODAK RT Color Processor, Model 1411C (modified); KODAK EKTACHROME RT Processor, Model 1411 (modified) and Model 1411A (modified); KODAK EKTACHROME RT Processor, Model 1811; or the KODAK EKTACHROME RT Processor; Model 1811 (modified).

## APPLICATIONS

Infrared-sensitive color films were originally designed for detecting camouflage by aerial photography. Objects that were painted green to simulate the color of foliage often had different infrared reflection characteristics and then could be detected with films of these types. A more recent and general use of these films is in agricultural and forest-survey work. In these applications, diseased foliage can often be identified and distinguished from healthy foliage by interpretation of the infrared reflectance of the foliage as recorded on the films. These films are also used to distinguish between deciduous and evergreen trees and, to some extent, to distinguish between different varieties of deciduous trees.



More and more use of infrared-sensitive films is being made in remote-sensing applications where infrared discrimination can be helpful.

**Note:** Thermal photography *cannot* be done with infrared sensitive films. These films are not thermal or heat detectors. They are sensitive *only* to the near-infrared spectral region, up to about 900 nanometers. Thermal recording usually involves obtaining a visible display of longer wavelength radiation, such as on a cathode-ray tube, and then photographing these thermographic displays by conventional means using standard black-and-white and color films.

## INTERPRETATION OF RESULTS

**Forest Survey:** A knowledge of the infrared reflectivity of the various subjects photographed is helpful in interpreting results. Although there is a similarity in visual color between deciduous and evergreen trees, healthy deciduous trees have a much higher infrared reflectivity than healthy evergreens. As a result, there are distinct differences between the colors of these trees as recorded by these films. Generally in spring and summer, healthy deciduous trees photograph magenta or red, and healthy evergreens photograph bluish purple. Dead or dying deciduous leaves or evergreen needles usually photograph as bright green because such leaves or needles have lost their infrared reflectivity. The leaves of deciduous trees, which turn red or yellow in autumn, still retain some of their infrared reflectivity. Consequently, red leaves photograph yellow, and yellow leaves photograph white.

**Camouflage Detection:** These films are effective when used to photograph objects painted to imitate foliage. Such paints have infrared reflectance characteristics quite different than those of true foliage. In the resulting color transparency, the areas of natural deciduous foliage will be magenta or red, and the painted objects will be purple or blue. Camouflaged areas are most easily detected by comparing a picture made on one of these films with a normal color picture of the same objects made on KODAK AEROCHROME MS Film 2448 (Estar Base).

For further information on the interpretation of infrared-color photographs, see *Applied Infrared Photography*, Kodak Publication No. M-28.

## SENSITIVITY

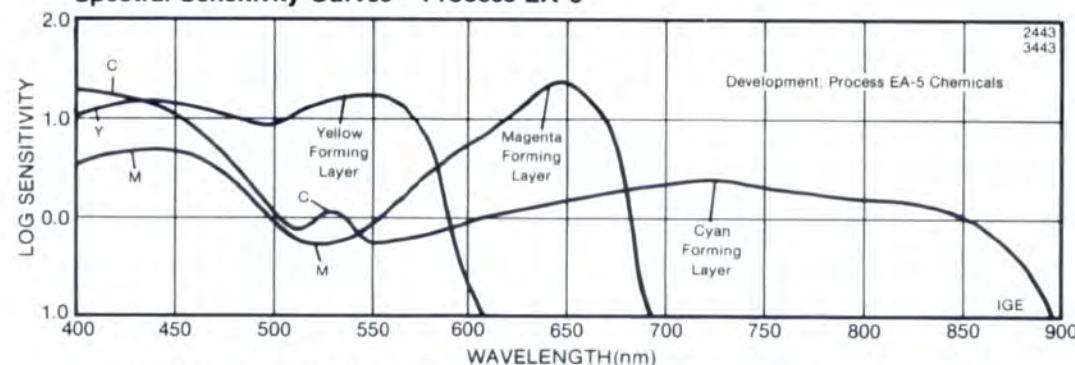
Sensitive to ultraviolet radiation, the visible region of the spectrum, and in the infrared to approximately 900 nm.

### KODAK AEROCHROME Infrared Film 2443 (ESTAR Base)

### KODAK AEROCHROME Infrared Film 3443 (ESTAR Thin Base)

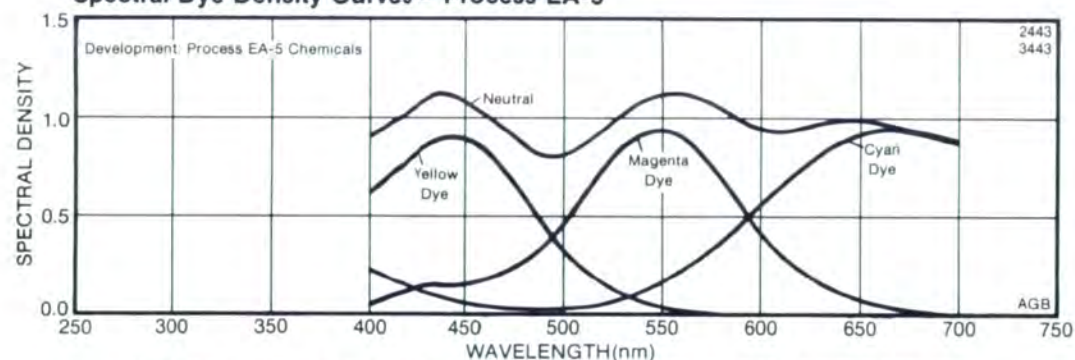
**Note:** Critical users of these two films should determine the actual sensitometric characteristics of their particular batch of film by using their own specialized techniques. The keeping conditions for these films have an effect on their sensitometric response.

**Spectral Sensitivity Curves - Process EA-5**



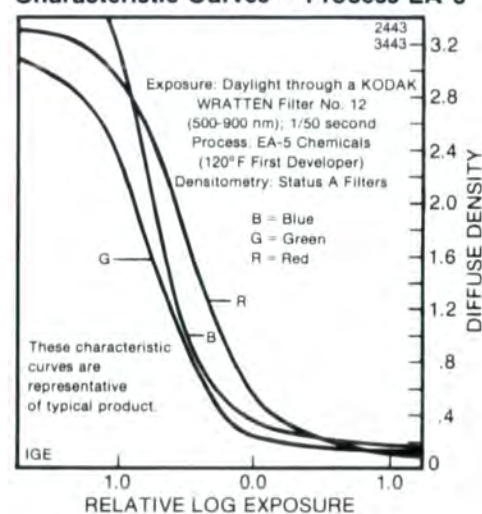
Sensitivity = Reciprocal of the exposure (ergs/cm<sup>2</sup>) required to produce a density of 1.0 above D min. Measurements were confined to the 400- to 900-nanometer region.

**Spectral Dye Density Curves - Process EA-5**

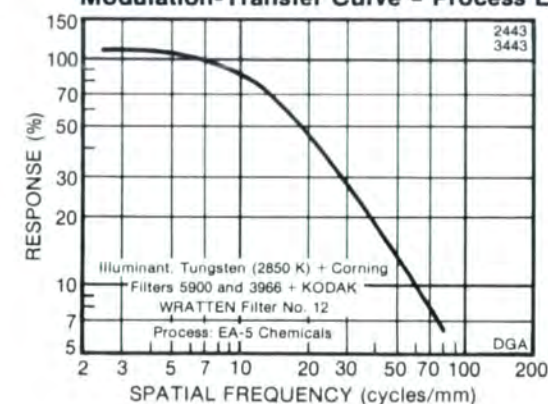


Spectral densities of dyes yielding an Equivalent Neutral Density (END) of 1.0 with D 5000 viewing illuminant. Measurements were confined to the 400- to 700-nanometer region.

**Characteristic Curves - Process EA-5**



**Modulation-Transfer Curve - Process EA-5**



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### KODAK PLUS-X AEROGRAPHIC FILM 2402 (ESTAR BASE)

KODAK PLUS-X AEROGRAPHIC Film 2402 (Estar Base) is a medium-grain, panchromatic, negative camera film that has medium speed, medium-high contrast, and extended red sensitivity for the reduction of haze effects. The thin emulsion, coated on 4-mil Estar Base (for flexibility, tear resistance, and dimensional stability), is highly hardened for high-temperature, rapid processing in modern continuous-processing machines.

This film can be processed in automatic processors such as the KODAK VERSAMAT Film Processor, Model 11C-M, with KODAK VERSAMAT Chemicals, Type A, KODAK VERSAMAT 641 Chemicals, or KODAK VERSAMAT 885 Chemicals. It can also be processed at normal temperatures using KODAK Developer D-19 or KODAK Developer DK-50 in rewind-processing machines, such as the Gordon/Morse M-10 Developing Outfit (Military Designator: B-5).

### APPLICATIONS

KODAK PLUS-X AEROGRAPHIC Film 2402 is for general use in reconnaissance aerial photography at medium-to-high altitudes. Because of the dimensional stability of the Estar Base it can also be used for mapping purposes. This film is capable of providing sharp negatives that are particularly suitable for first-order plotting.

### SENSITIVITY

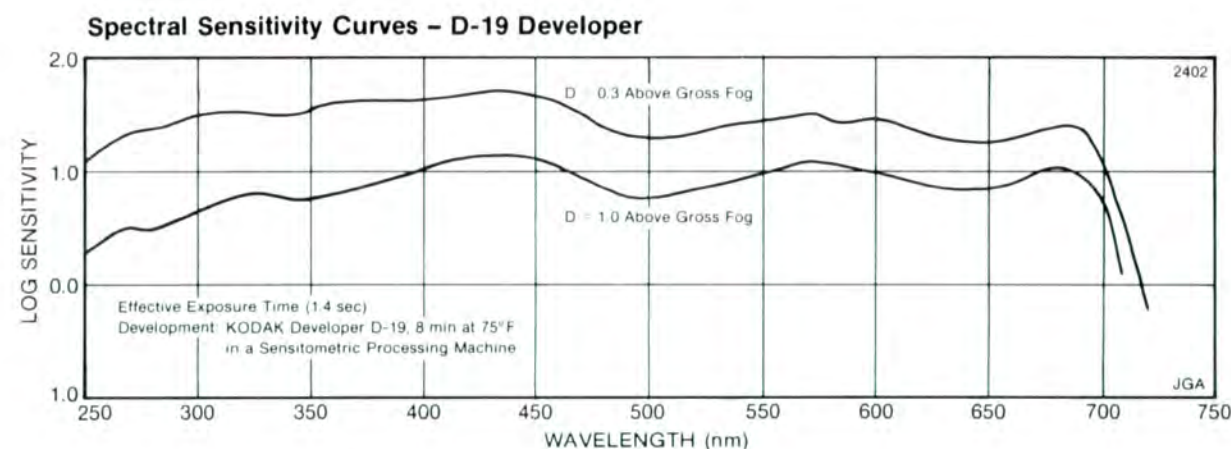
Panchromatic, with extended red sensitivity.

### KODAK INFRARED AEROGRAPHIC FILM 2424 (ESTAR BASE)

KODAK Infrared AEROGRAPHIC Film 2424 (Estar Base) is a negative aerial camera film that is sensitive to infrared radiation as well as to ultraviolet and visible radiation. With a KODAK WRATTEN Filter, No. 25, this film requires about the same exposure as KODAK PLUS-X AEROGRAPHIC Film 2402 (Estar Base) without a filter. Compared with extended red panchromatic-sensitized films, infrared-sensitive films usually provide increased contrast between water and land. They may also show more differentiation in vegetation.

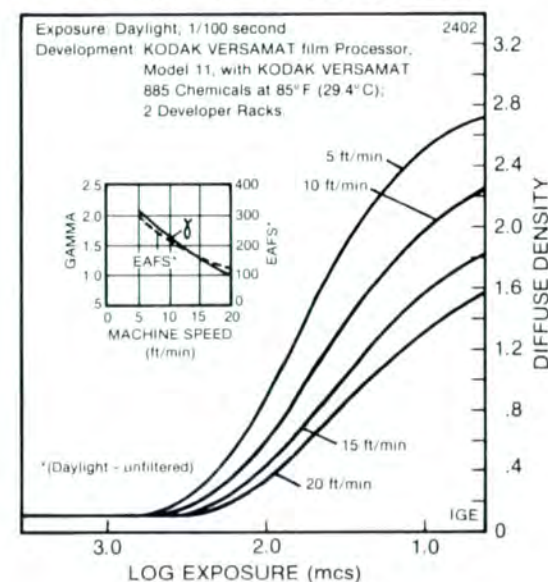
The thin emulsion, coated on 4-mil Estar Base (for flexibility, tear resistance, and dimensional stability), is hardened for high-temperature, rapid processing in a continuous processor. This film can be processed in the KODAK VERSAMAT Film Processor, Model 11C-M, with

### KODAK PLUS-X AEROGRAPHIC Film 2402 (ESTAR Base)

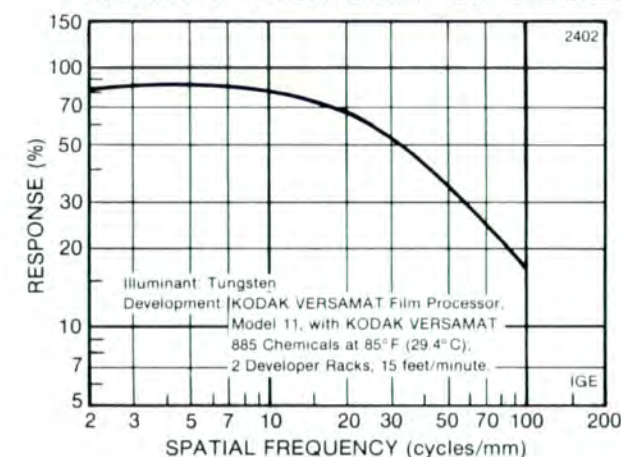


Sensitivity = Reciprocal of the exposure in ergs/cm<sup>2</sup> required to produce the indicated density (D) above gross fog

### Characteristic Curves – 885 Chemicals



### Modulation-Transfer Curve – 885 Chemicals



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KODAK VERSAMAT Chemicals, Type A, KODAK VERSAMAT 641 Chemicals, or KODAK VERSAMAT 885 Chemicals.

It can also be processed at normal temperatures in KODAK Developer D-19 or KODAK Developer DK-50 in rewind-processing machines, such as the Gordon/Morse M-10 Developing Outfit.

**Caution:** KODAK Infrared AEROGRAPHIC Film 2424 (Estar Base) is susceptible to static markings at low relative humidities. The film is packaged at the optimum relative humidity (45 to 50 percent) and is maintained at this level by the sealed package. In conditions of low relative humidity, the film should be loaded and used immediately after the package is opened, before the film becomes too dry. The camera should be checked to see that all parts are grounded adequately. Also, the film should be handled carefully during all loading, unloading, and preprocessing operations.

## APPLICATIONS

Infrared AEROGRAPHIC Film 2424 is especially suited for the reduction of haze effects, and for oblique long-distance photography, geological and archaeological studies, agricultural surveys, crop studies, forestry studies, oceanography, multiband aerial photography, hydrology, and other scientific applications where an infrared-sensitive film is needed. It may also be used for camouflage detection.

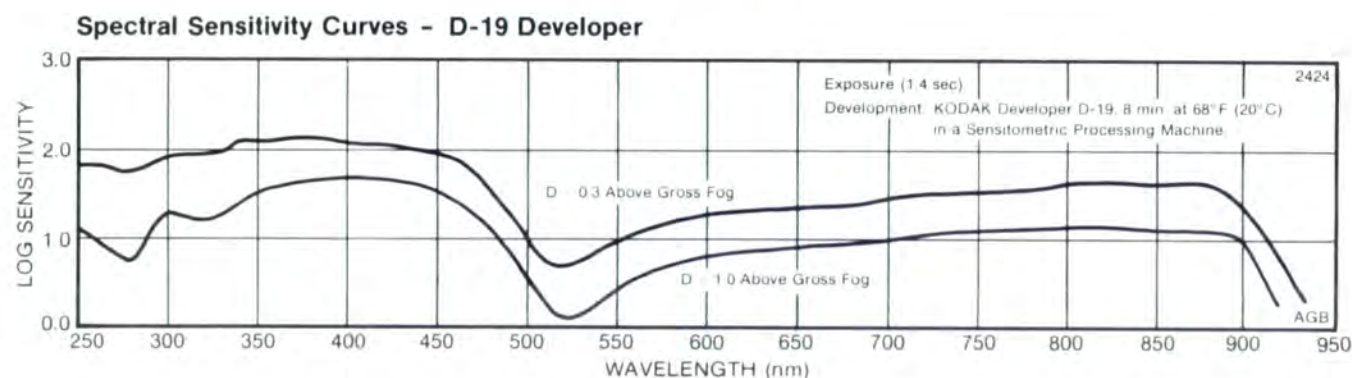
**Note:** Thermal photography **cannot** be done with infrared-sensitive films. These films are not thermal or heat detectors. They are sensitive **only** to the near-infrared spectral region, up to about 900 nanometers. Thermal recording usually involves obtaining a visible display of longer wavelength radiation, such as on a cathode-ray tube, and then photographing this display.

## INTERPRETATIONS OF RESULTS

Direct infrared photography with infrared-sensitive films is useful in many fields. The value of using near-infrared radiation with infrared-sensitive films lies in the ability of infrared-sensitive films to record tonal gradations not visible to the eye or recordable with normal photographic films. A knowledge of the infrared reflectivity of the various subjects photographed is helpful in interpreting results.

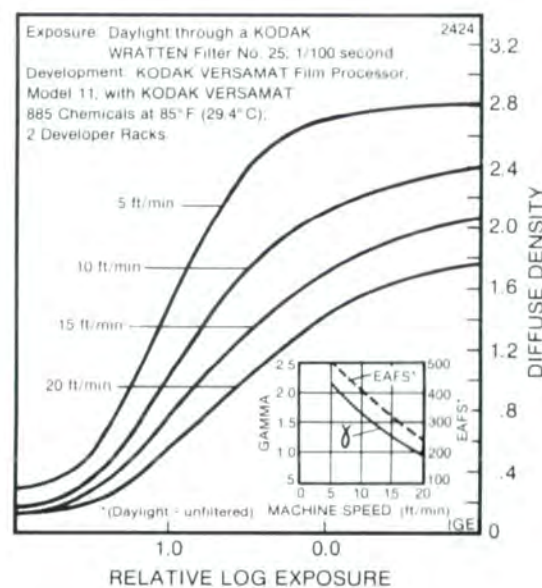
An infrared-sensitive film has some distinct advantages over a panchromatic film. For example, in prints made from black-and-white IR negatives, bodies of water are usually rendered very dark in sharp contrast to land. Vegetated fields and wooded areas are rendered very

## KODAK Infrared AEROGRAPHIC Film 2424 (ESTAR Base)

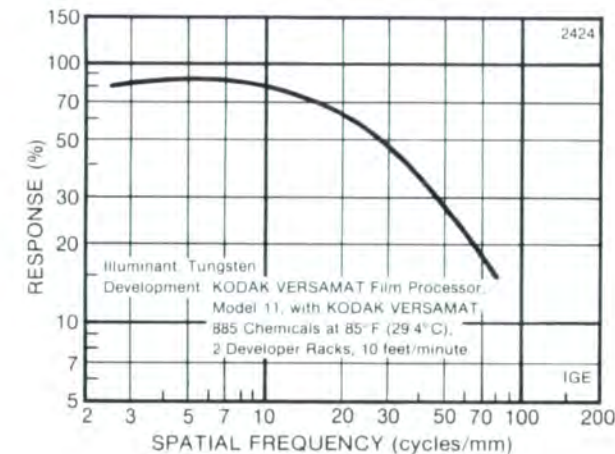


Sensitivity = Reciprocal of the exposure in ergs/cm<sup>2</sup> required to produce the indicated density (D) above gross fog.

## Characteristic Curves - 885 Chemicals



## Modulation-Transfer Curve - 885 Chemicals



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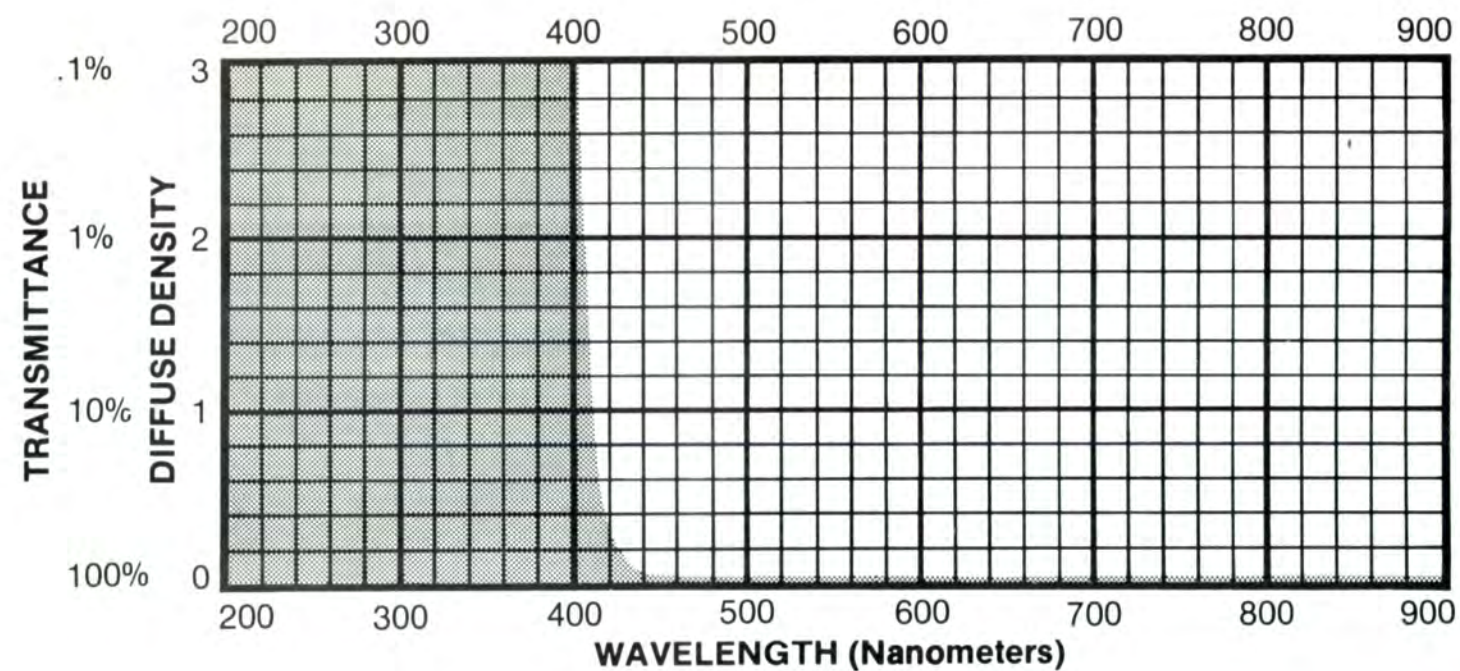
light. Coniferous and deciduous growth is differentiated, the former appearing darker than the latter. In infrared photographs taken at very high altitudes, urban areas appear as dark patches surrounded by lighter countryside.

## SENSITIVITY

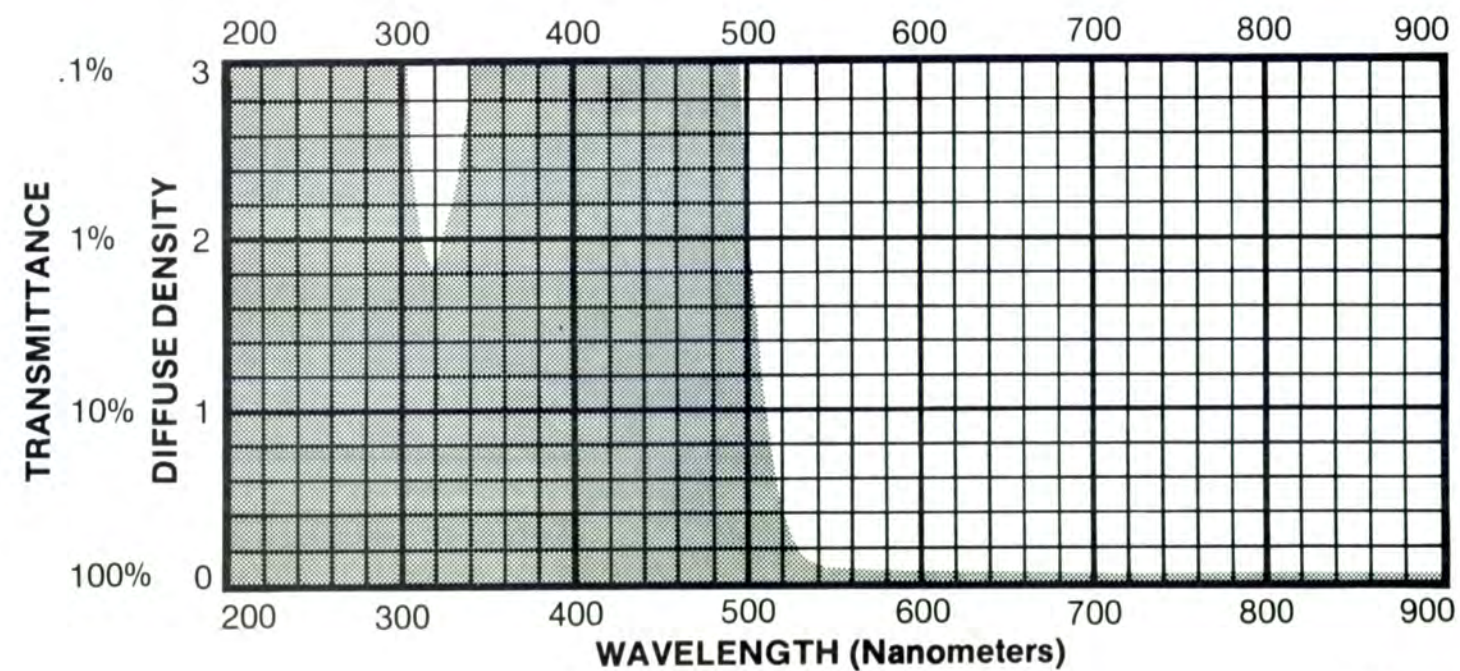
Sensitive to ultraviolet, the visible region of the spectrum and in the infrared to approximately 900 nm with maximum sensitivity from about 760 nm to 880 nm.



## WRATTEN 2A FILTER

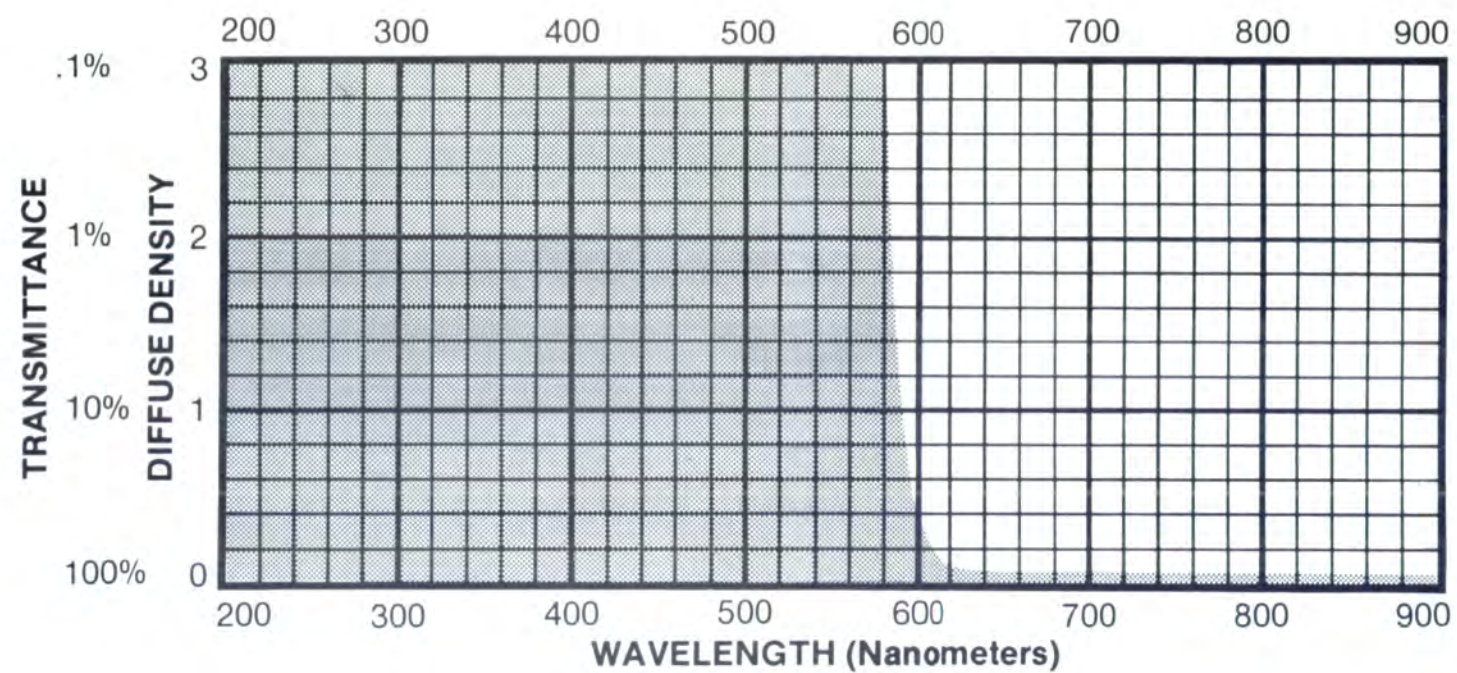


## WRATTEN 12 FILTER

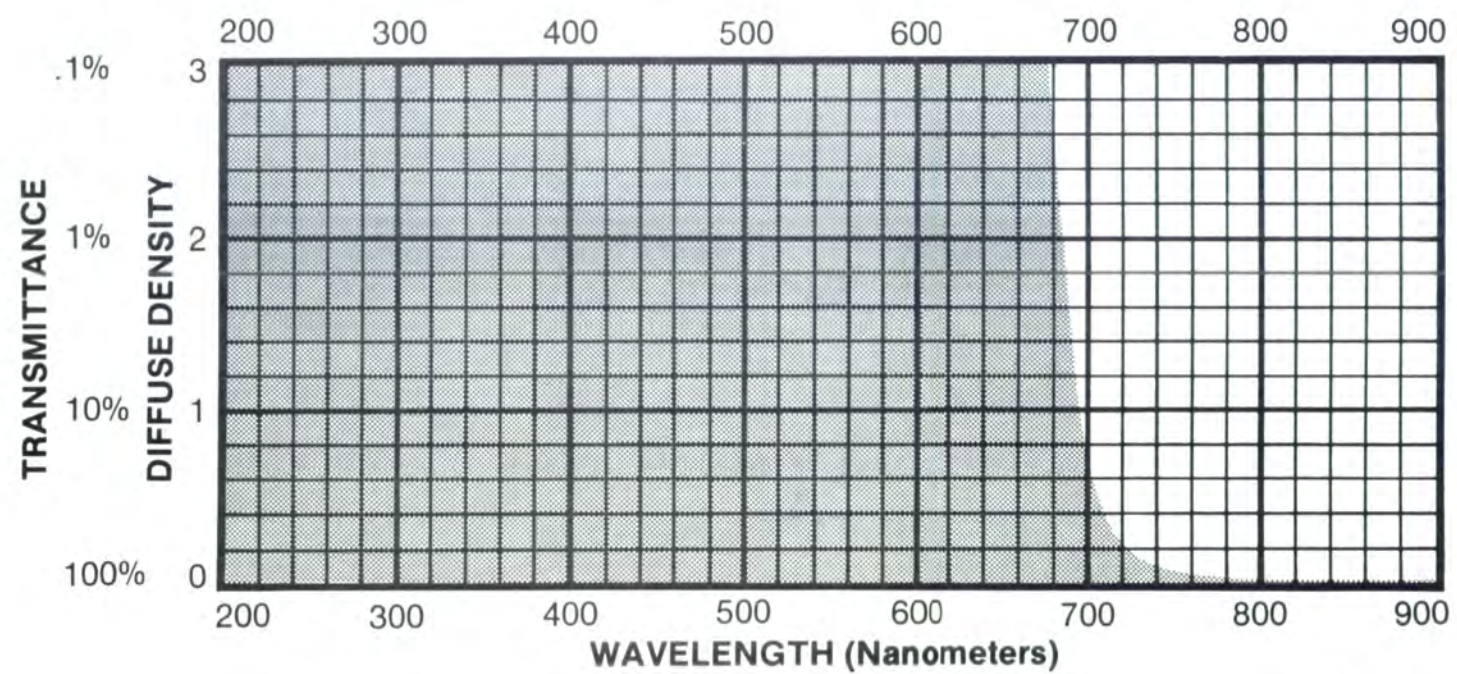




## WRATTEN 25 FILTER

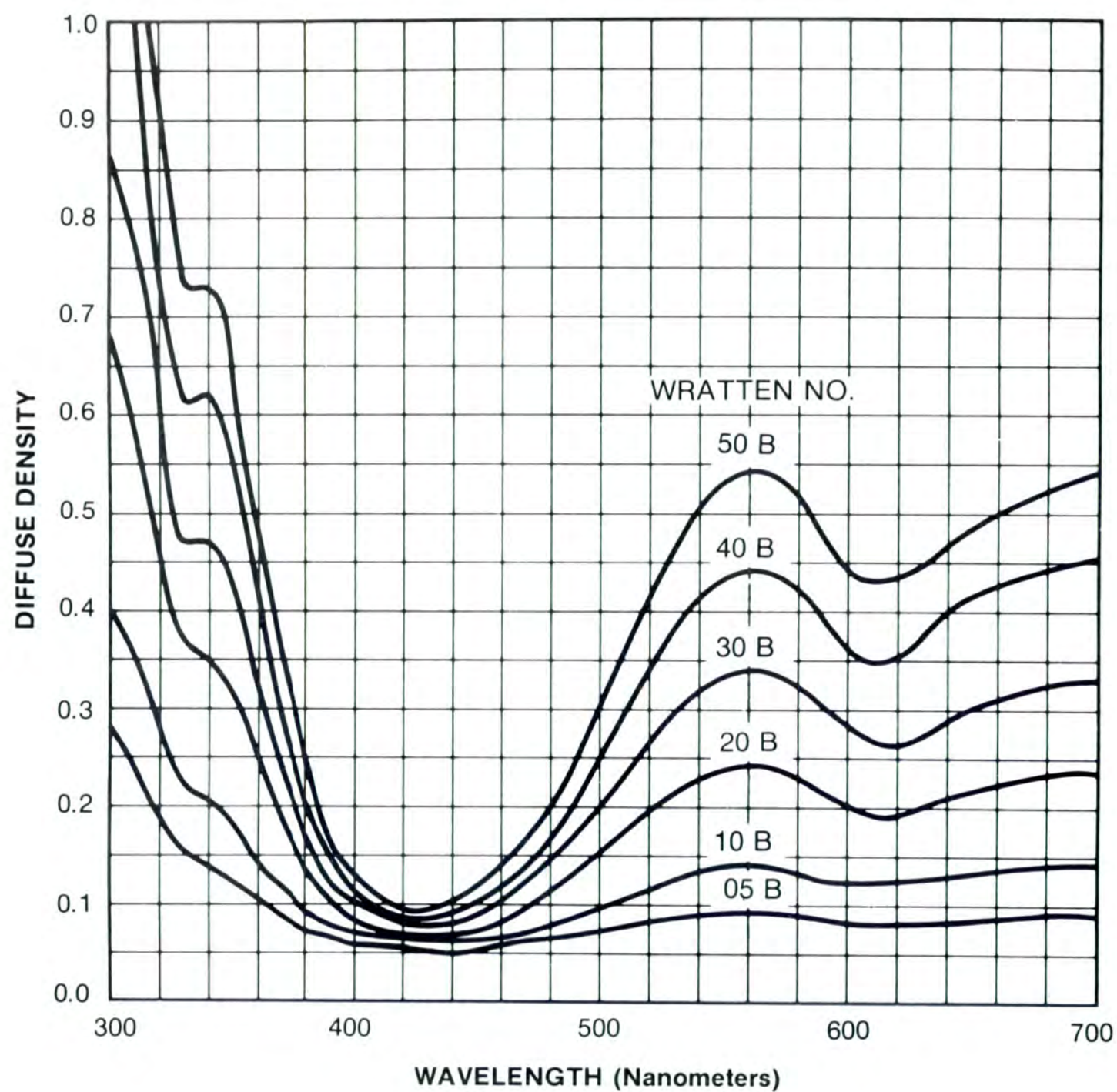


## WRATTEN 89 B FILTER





## BLUE COLOR CORRECTING FILTERS





# **APPENDIX B** **TABLE OF SELECTED VERTICAL AND OBLIQUE PHOTOGRAPHY**

This Appendix lists the date of coverage and photo scale factors for selected vertical photographic imagery of each island in the fourteen atolls and the two individual islands covered in the photographic survey. It also lists the date of selected oblique imagery of the major populated islands. The type of coverage (large format or multispectral) is also shown. In almost all instances, there were numerous other vertical and oblique images taken of each island, since several aircraft runs were made over each atoll.

The selected images shown in this table were chosen on the basis of centering in the frame, proper film density, minimum surface reflections off water, lowest tide, absence of cloud shadows, and proper sun angle.

Photographic imagery, both vertical and oblique, was also acquired for the major portion of Wotje Atoll at the request of another agency. The coverage was not complete and is not included in this Appendix.

All imagery are available to interested persons or agencies. Specific frame numbers or other information about the coverage may be obtained by contacting the authors.

| ISLAND<br>OR<br>LAND AREA | ATOLL<br>ID<br># | RC-10 PHOTOS   |          | MULTISPECTRAL PHOTOS               |          | OBLIQUE PHOTOS |
|---------------------------|------------------|----------------|----------|------------------------------------|----------|----------------|
|                           |                  | AEROCOLOR FILM |          | FOUR DIFFERENT<br>SPECTRAL REGIONS |          | VERICOLOR FILM |
|                           |                  | Date           | Scale    | Date                               | Scale    | Date           |
| AILUK ATOLL               |                  |                |          |                                    |          |                |
| Kapen                     | A-1              | 8-5-78         | 1:20,000 | 8-5-78                             | 1:38,100 | 8-10-78        |
| Enijabro                  | A-2              | 8-5-78         | 1:20,000 | 8-5-78                             | 1:38,100 |                |
|                           | A-3              | 8-10-78        | 1:6,000  | 8-10-78                            | 1:11,430 |                |
| Enejelar                  | A-4              | 8-5-78         | 1:20,000 | 8-5-78                             | 1:38,100 |                |
|                           | A-5              | 8-10-78        | 1:6,000  | 8-10-78                            | 1:11,430 |                |
|                           | A-6              | 8-10-78        | 1:6,000  | 8-10-78                            | 1:11,430 |                |
| Bigen                     | A-7              | 8-5-78         | 1:20,000 | 8-5-78                             | 1:38,100 |                |
|                           | A-8              | 8-10-78        | 1:6,000  | 8-10-78                            | 1:11,430 | 8-10-78        |
| Eneneman                  | A-9              | 8-10-78        | 1:6,000  | 8-10-78                            | 1:11,430 |                |
| Achaatakk                 | A-10             | 8-10-78        | 1:6,000  | 8-10-78                            | 1:11,430 |                |
| Ajeleb                    | A-11             | 8-10-78        | 1:6,000  | 8-10-78                            | 1:22,860 |                |
| Ajirikku                  | A-12             | 8-10-78        | 1:6,000  | 8-10-78                            | 1:22,860 |                |
| Enearumichi               | A-13             | 8-10-78        | 1:6,000  | 8-10-78                            | 1:22,860 |                |
| Enenekugi                 | A-14             | 8-10-78        | 1:6,000  | 8-10-78                            | 1:11,430 |                |
|                           | A-15             | 8-10-78        | 1:6,000  | 8-10-78                            | 1:11,430 |                |
|                           | A-16             | 8-10-78        | 1:6,000  | 8-10-78                            | 1:11,430 |                |
| Kabbo                     | A-17             | 8-10-78        | 1:6,000  | 8-10-78                            | 1:11,430 |                |
| Kabbo                     | A-18             | 8-10-78        | 1:6,000  | 8-10-78                            | 1:22,860 |                |
| Marokku                   | A-19             | 8-10-78        | 1:6,000  | 8-10-78                            | 1:11,430 |                |
| Aliet                     | A-20             | 8-10-78        | 1:12,000 | 8-10-78                            | 1:22,860 |                |
|                           | A-21             | 8-10-78        | 1:6,000  | 8-10-78                            | 1:11,430 |                |
|                           | A-22             | 8-10-78        | 1:6,000  | 8-10-78                            | 1:11,430 |                |
|                           | A-23             | 8-10-78        | 1:6,000  | 8-10-78                            | 1:22,860 |                |

| ISLAND<br>OR<br>LAND AREA | ATOLL<br>ID<br># | RC-10 PHOTOS   |          | MULTISPECTRAL PHOTOS               |          | OBLIQUE PHOTOS |
|---------------------------|------------------|----------------|----------|------------------------------------|----------|----------------|
|                           |                  | AEROCOLOR FILM |          | FOUR DIFFERENT<br>SPECTRAL REGIONS |          | VERICOLOR FILM |
|                           |                  | Date           | Scale    | Date                               | Scale    | Date           |
| Shurongan                 | A-24             | 8-10-78        | 1:6,000  | 8-10-78                            | 1:11,430 |                |
|                           | A-25             | 8-10-78        | 1:6,000  | 8-10-78                            | 1:11,430 |                |
|                           | A-26             | 8-10-78        | 1:6,000  | 8-10-78                            | 1:11,430 |                |
| Bauejin                   | A-27             | 8-10-78        | 1:6,000  | 8-10-78                            | 1:22,860 |                |
| Rujerukku                 | A-28             | 8-10-78        | 1:6,000  | 8-10-78                            | 1:22,860 |                |
| Bekerappu                 | A-29             | 8-10-78        | 1:6,000  | 8-10-78                            | 1:11,430 |                |
|                           | A-30             | 8-10-78        | 1:6,000  | 8-10-78                            | 1:11,430 |                |
| Bio                       | A-31             | 8-10-78        | 1:6,000  | 8-10-78                            | 1:11,430 |                |
|                           | A-32             | 8-10-78        | 1:6,000  | 8-10-78                            | 1:11,430 |                |
| Bererjao                  | A-33             | 8-10-78        | 1:6,000  | 8-10-78                            | 1:22,860 |                |
|                           | A-34             | 8-10-78        | 1:6,000  | 8-10-78                            | 1:11,430 |                |
| Tabu                      | A-35             | 8-10-78        | 1:6,000  | 8-10-78                            | 1:11,430 |                |
|                           | A-36             | 8-10-78        | 1:6,000  | 8-10-78                            | 1:11,430 |                |
| Kanon                     | A-37             | 8-10-78        | 1:6,000  | 8-10-78                            | 1:11,430 |                |
| Chiebeiku                 | A-38             | 8-10-78        | 1:6,000  | 8-10-78                            | 1:11,430 |                |
|                           | A-39             | 8-10-78        | 1:6,000  | 8-10-78                            | 1:11,430 |                |
|                           | A-40             | 8-10-78        | 1:6,000  | 8-10-78                            | 1:11,430 |                |
| Uriga                     | A-41             | 8-10-78        | 1:6,000  | 8-10-78                            | 1:11,430 |                |
| Maruppu                   | A-42             | 8-10-78        | 1:6,000  | 8-10-78                            | 1:22,860 |                |
|                           | A-43             | 8-10-78        | 1:6,000  | 8-10-78                            | 1:11,430 |                |
| Eninikugi                 | A-44             | 8-10-78        | 1:6,000  | 8-10-78                            | 1:11,430 |                |
|                           | A-45             | 8-10-78        | 1:6,000  | 8-10-78                            | 1:11,430 |                |
| Enoa                      | A-46             | 8-10-78        | 1:6,000  | 8-10-78                            | 1:11,430 |                |
| Eneao                     | A-47             | 8-10-78        | 1:6,000  | 8-10-78                            | 1:11,430 |                |
| Enemaneman                | A-48             | 8-10-78        | 1:6,000  | 8-10-78                            | 1:11,430 |                |
| Yappui                    | A-49             | 8-10-78        | 1:6,000  | 8-10-78                            | 1:11,430 |                |
|                           | A-50             | 8-10-78        | 1:6,000  | 8-10-78                            | 1:11,430 |                |
| Ailuk                     | A-51             | 8-5-78         | 1:20,000 | 8-5-78                             | 1:38,100 | 8-10-78        |
| Enije                     | A-52             | 8-10-78        | 1:6,000  | 8-10-78                            | 1:11,430 |                |
| Agulue                    | A-53             | 8-10-78        | 1:6,000  | 8-10-78                            | 1:22,860 |                |
| Atoll Chain<br>of Ailuk   |                  |                |          | (Gen)                              |          | 8-5-78         |
| Sand Spit<br>between 4-5  |                  | 8-10-78        | 1:6,000  |                                    |          |                |
| <b>BIKINI ATOLL</b>       |                  |                |          |                                    |          |                |
| Nam                       | B-1              | 8-7-78         | 1:20,000 | 8-7-78                             | 1:38,100 |                |
| Iroij                     | B-2              | 8-28-78        | 1:6,000  | 8-29-78                            | 1:19,050 |                |
| Odrik                     | B-3              | 8-7-78         | 1:12,000 | 8-7-78                             | 1:22,860 |                |
| Lomilik                   | B-4              | 8-7-78         | 1:12,000 | 8-17-78                            | 1:57,150 |                |
| Aomen                     | B-5              | 8-7-78         | 1:12,000 | 8-7-78                             | 1:22,860 |                |
| Bikini                    | B-6              | 8-7-78         | 1:20,000 | 8-28-78                            | 1:57,150 |                |



| ISLAND<br>OR<br>LAND AREA   | ATOLL<br>ID<br># | RC-10 PHOTOS   |          | MULTISPECTRAL PHOTOS               |          | OBLIQUE PHOTOS |
|-----------------------------|------------------|----------------|----------|------------------------------------|----------|----------------|
|                             |                  | AEROCOLOR FILM |          | FOUR DIFFERENT<br>SPECTRAL REGIONS |          | VERICOLOR FILM |
|                             |                  | Date           | Scale    | Date                               | Scale    | Date           |
| Bokantauk                   | B-7              | 8-17-78        | 1:6,000  | 8-17-78                            | 1:11,430 |                |
| Iomeler                     | B-8              | 8-8-78         | 1:6,000  | 8-8-78                             | 1:11,430 |                |
| Enealo                      | B-9              | 8-8-78         | 1:6,000  | 8-8-78                             | 1:11,430 |                |
| Rojkere                     | B-10             | 8-8-78         | 1:6,000  | 8-8-78                             | 1:11,430 |                |
| Eonjebi                     | B-11             | 8-8-78         | 1:6,000  | 8-8-78                             | 1:11,430 |                |
| Eneu                        | B-12             | 8-7-78         | 1:20,000 | 8-17-78                            | 1:57,150 |                |
| Aerokojlol                  | B-13             | 8-7-78         | 1:12,000 | 8-28-78                            | 1:57,150 |                |
| Bikdrin                     | B-14             | 8-7-78         | 1:12,000 | 8-28-78                            | 1:57,150 |                |
| Lele                        | B-15             | 8-7-78         | 1:12,000 | 8-7-78                             | 1:22,860 |                |
| Eneman                      | B-16             | 8-7-78         | 1:12,000 | 8-7-78                             | 1:22,860 |                |
| Enidrik                     | B-17             | 8-7-78         | 1:20,000 | 8-17-78                            | 1:57,150 |                |
| Lukoj                       | B-18             | 8-7-78         | 1:12,000 | 8-7-78                             | 1:22,860 |                |
| Jelete                      | B-19             | 8-8-78         | 1:6,000  | 8-7-78                             | 1:22,860 |                |
| Adrikan                     | B-20             | 8-17-78        | 1:6,000  | 8-17-78                            | 1:11,430 |                |
| Oroken                      | B-21             | 8-28-78        | 1:6,000  | 8-28-78                            | 1:11,430 |                |
| Bokaetoktok                 | B-22             | 8-28-78        | 1:6,000  | 8-17-78                            | 1:11,430 |                |
| Borkdrlul                   | B-23             | 8-17-78        | 1:6,000  | 8-17-78                            | 1:11,430 |                |
| Sand Spit<br>w/Construction |                  | 8-17-78        | 1:6,000  |                                    |          |                |
| <b>AILINGINAE ATOLL</b>     |                  |                |          |                                    |          |                |
| Najibuen                    | C-1              | 8-22-78        | 1:6,000  | 8-22-78                            | 1:11,430 |                |
| Bokoikaiaaru                | C-2              | 8-22-78        | 1:6,000  | 8-22-78                            | 1:11,430 |                |
|                             | C-3              | 8-22-78        | 1:6,000  | 8-22-78                            | 1:11,430 |                |
| Charaien                    | C-4              | 8-22-78        | 1:6,000  | 8-22-78                            | 1:11,430 |                |
| Bokoryuren                  | C-5              | 8-22-78        | 1:6,000  | 8-22-78                            | 1:11,430 |                |
|                             | C-6              | 8-22-78        | 1:6,000  | 8-22-78                            | 1:11,430 |                |
|                             | C-7              | 8-22-78        | 1:6,000  | 8-22-78                            | 1:11,430 |                |
| Majokoryaan                 | C-8              | 8-15-78        | 1:12,000 | 8-15-78                            | 1:22,860 |                |
| Bokoan                      | C-9              | 8-22-78        | 1:12,000 | 8-15-78                            | 1:22,860 |                |
| Knox                        | C-10             | 8-22-78        | 1:12,000 | 8-22-78                            | 1:22,860 |                |
| Kungeekan                   | C-11             | 8-22-78        | 1:6,000  | 8-22-78                            | 1:11,430 |                |
|                             | C-12             | 8-22-78        | 1:6,000  | 8-22-78                            | 1:11,430 |                |
| Bokanchinre                 | C-13             | 8-22-78        | 1:6,000  | 8-22-78                            | 1:11,430 |                |
|                             | C-14             | 8-22-78        | 1:6,000  | 8-22-78                            | 1:11,430 |                |
| Ucchuwanen                  | C-15             | 8-2-78         | 1:20,000 | 8-28-78                            | 1:38,100 |                |
| Pigessharukku               | C-16             | 9-2-78         | 1:12,000 | 9-2-78                             | 1:22,860 |                |
|                             | C-17             | 8-22-78        | 1:6,000  | 8-22-78                            | 1:11,430 |                |
| Kuobuen                     | C-18             | 8-15-78        | 1:12,000 | 8-2-78                             | 1:38,100 |                |
| Ribinouri                   | C-19             | 8-15-78        | 1:12,000 | 8-28-78                            | 1:38,100 |                |
| Airuken                     | C-20             | 8-22-78        | 1:6,000  | 8-22-78                            | 1:11,430 |                |
|                             | C-21             | 8-22-78        | 1:6,000  | 8-22-78                            | 1:11,430 |                |

| ISLAND<br>OR<br>LAND AREA                    | ATOLL<br>ID<br># | RC-10 PHOTOS   |          | MULTISPECTRAL PHOTOS               |          | OBLIQUE PHOTOS |
|----------------------------------------------|------------------|----------------|----------|------------------------------------|----------|----------------|
|                                              |                  | AEROCOLOR FILM |          | FOUR DIFFERENT<br>SPECTRAL REGIONS |          | VERICOLOR FILM |
|                                              |                  | Date           | Scale    | Date                               | Scale    | Date           |
| Eniuetakku                                   | C-22             | 8-22-78        | 1:12,000 | 8-22-78                            | 1:22,860 |                |
| Enibuk                                       | C-23             | 8-22-78        | 1:12,000 | 8-22-78                            | 1:22,860 |                |
| Mogiri                                       | C-24             | 8-2-78         | 1:20,000 | 8-28-78                            | 1:38,100 |                |
| Manchinikson                                 | C-25             | 8-22-78        | 1:12,000 | 8-22-78                            | 1:22,860 |                |
|                                              | C-26             | 8-22-78        | 1:6,000  | 8-22-78                            | 1:11,430 |                |
| Sifo                                         | C-27             | 8-22-78        | 1:12,000 | 8-22-78                            | 1:22,860 |                |
| <b>BIKAR ATOLL</b>                           |                  |                |          |                                    |          |                |
| Jaboerukku                                   | D-1              | 8-6-78         | 1:12,000 | 8-6-78                             | 1:22,860 | 8-6-78         |
| Arumenii                                     | D-2              | 8-6-78         | 1:12,000 | 8-6-78                             | 1:22,860 | 8-6-78         |
| Jaboero                                      | D-3              | 8-6-78         | 1:12,000 | 8-6-78                             | 1:22,860 | 8-6-78         |
| Bikar                                        | D-4              | 8-6-78         | 1:12,000 | 8-6-78                             | 1:22,860 | 8-6-78         |
|                                              | D-5              | 8-6-78         | 1:12,000 | 8-6-78                             | 1:22,860 | 8-6-78         |
|                                              |                  |                |          | (Gen)                              |          | 8-26-78        |
| <b>ENEWETAK ATOLL</b>                        |                  |                |          |                                    |          |                |
| Bokoluo                                      | E-1              | 8-29-78        | 1:20,000 | 8-29-78                            | 1:76,200 |                |
| Bokombako                                    | E-2              | 8-29-78        | 1:20,000 | 8-29-78                            | 1:76,200 |                |
| Kirunu                                       | E-3              | 8-29-78        | 1:20,000 | 8-29-78                            | 1:76,200 |                |
| Louj                                         | E-4              | 8-29-78        | 1:20,000 | 8-29-78                            | 1:76,200 |                |
|                                              |                  | 8-17-78        |          |                                    |          |                |
| Bocinwotme                                   | E-5              | 8-29-78        | 1:20,000 | 8-29-78                            | 1:76,200 |                |
| New Island NE<br>of Bocinwotme               | E-6              | 8-29-78        | 1:20,000 | 8-29-78                            | 1:76,200 |                |
| Bokaidrik (crater)                           |                  | 8-29-78        | 1:20,000 | 8-29-78                            | 1:76,200 | 8-31-78        |
| Boken                                        | E-7              | 8-29-78        | 1:20,000 | 8-17-78                            | 1:38,100 | 8-17-78        |
| Enjebi                                       | E-8              | 8-29-78        | 1:20,000 | 8-29-78                            | 1:76,200 | 8-17-78        |
| Mijikadrek                                   | E-9              | 8-29-78        | 1:20,000 | 8-17-78                            | 1:38,100 |                |
| Kidrinen                                     | E-10             | 8-29-78        | 1:20,000 | 8-17-78                            | 1:38,100 |                |
| Taiwel                                       | E-11             | 8-29-78        | 1:20,000 | 8-29-78                            | 1:76,200 |                |
| Bokenelab                                    | E-12             | 8-29-78        | 1:20,000 | 8-17-78                            | 1:38,100 |                |
| New Island<br>between<br>Bokenelab<br>& Elle | E-13             | 8-29-78        | 1:20,000 | 8-8-78                             | 1:38,100 |                |
| Elle                                         | E-14             | 8-29-78        | 1:20,000 | 8-17-78                            | 1:38,100 |                |
| Aej                                          | E-15             | 8-8-78         | 1:20,000 | 8-17-78                            | 1:38,100 |                |
| Lujor                                        | E-16             | 8-29-78        | 1:20,000 | 8-8-78                             | 1:38,100 |                |
| New Island                                   | E-17             | 8-29-78        | 1:20,000 | 8-8-78                             | 1:38,100 |                |
| Eleleron                                     | E-18             | 8-29-78        | 1:20,000 | 8-17-78                            | 1:38,100 |                |
| Aomon                                        | E-19             | 8-29-78        | 1:20,000 | 8-8-78                             | 1:38,100 | 8-17-78        |
| Existing Island<br>between<br>Aomon & Bijile | E-20             | 8-7-78         | 1:12,000 | 8-17-78                            | 1:31,100 |                |



| ISLAND<br>OR<br>LAND AREA | ATOLL<br>ID<br># | RC-10 PHOTOS            |          | MULTISPECTRAL PHOTOS               |          | OBLIQUE PHOTOS |
|---------------------------|------------------|-------------------------|----------|------------------------------------|----------|----------------|
|                           |                  | AEROCOLOR FILM          |          | FOUR DIFFERENT<br>SPECTRAL REGIONS |          | VERICOLOR FILM |
|                           |                  | Date                    | Scale    | Date                               | Scale    | Date           |
| Bijile                    | E-21             | 8-7-78                  | 1:12,000 | 8-17-78                            | 1:38,100 | 8-17-78        |
| Lojwa                     | E-22             | 8-7-78                  | 1:12,000 | 8-7-78                             | 1:22,860 |                |
| Alembel                   | E-23             | 8-29-78                 | 1:20,000 | 8-8-78                             | 1:38,100 |                |
| Billae                    | E-24             | 8-8-78                  | 1:20,000 | 8-17-78                            | 1:38,100 |                |
| New Island                | E-25             | 8-8-78                  | 1:20,000 | 8-17-78                            | 1:38,100 |                |
| Runit                     | E-26             | 8-17-78                 | 1:20,000 | 8-29-78                            | 1:76,200 | 8-17-78        |
| Boko                      | E-27             | 8-7-78                  | 1:12,000 | 8-7-78                             | 1:22,860 |                |
| Munjor                    | E-28             | 8-7-78                  | 1:12,000 | 8-7-78                             | 1:22,860 |                |
| Inedral                   | E-29             | 8-7-78                  | 1:12,000 | 8-7-78                             | 1:22,860 |                |
|                           | E-30             | 8-7-78                  | 1:12,000 | 8-7-78                             | 1:22,860 |                |
| Jinedrol                  | E-31             | 8-7-78                  | 1:12,000 | 8-17-78                            | 1:38,100 |                |
| Ananij                    | E-32             | 8-7-78                  | 1:12,000 | 8-7-78                             | 1:22,860 |                |
| Part of Ananij            | E-33             | 8-7-78                  | 1:12,000 | 8-7-78                             | 1:22,860 |                |
| Jinimi                    | E-34             | 8-29-78                 | 1:20,000 | 8-17-78                            | 1:38,100 |                |
| Japtan                    | E-35             | 8-7-78                  | 1:12,000 | 8-7-78                             | 1:22,860 | 8-17-78        |
| Jedrol                    | E-36             | 8-7-78                  | 1:12,000 | 8-17-78                            | 1:38,100 | 8-7-78         |
| Medren                    | E-37             | 8-29-78                 | 1:20,000 | 8-29-78                            | 1:76,200 | 8-17-78        |
| Bokandretok               | E-38             | 8-7-78                  | 1:12,000 | 8-7-78                             | 1:22,860 |                |
| Enewetak                  | E-39             | 8-29-78                 | 1:20,000 | 8-29-78                            | 1:76,200 | 8-17-78        |
| Ikuren                    | E-40             | 8-17-78                 | 1:20,000 | 8-17-78                            | 1:38,100 |                |
| *Part of Ikuren           | E-41             | 8-17-78                 | 1:20,000 | 8-17-78                            | 1:38,100 |                |
| *Part of Ikuren           | E-42             | 8-17-78                 | 1:20,000 | 8-17-78                            | 1:38,100 |                |
| Mut                       | E-43             | 8-17-78                 | 1:20,000 | 8-17-78                            | 1:38,100 |                |
| Boken                     | E-44             | 8-17-78                 | 1:20,000 | 8-17-78                            | 1:38,100 |                |
| Ribewon                   | E-45             | 8-17-78                 | 1:20,000 | 8-29-78                            | 1:76,200 |                |
| Kidrenen                  | E-46             | 8-29-78                 | 1:20,000 | 8-17-78                            | 1:38,100 |                |
| Biken                     | E-47             | 8-29-78                 | 1:20,000 | 8-17-78                            | 1:38,100 |                |
| Drekatimon                | Oscar            | Coral Heads - No Photos |          |                                    |          |                |
| Unibor                    | Mack             | Coral Heads - No Photos |          |                                    |          |                |
| RONGELAP ATOLL            |                  |                         |          |                                    |          |                |
| Naen                      | F-1              | 8-21-78                 | 1:12,000 | 9-5-78                             | 1:22,860 |                |
| Piganiyaroyaro            | F-2              | 8-16-78                 | 1:6,000  | 9-2-78                             | 1:11,430 |                |
| Yugui                     | F-3              | 8-16-78                 | 1:6,000  | 9-2-78                             | 1:11,430 |                |
| Aerik                     | F-4              | 9-2-78                  | 1:6,000  | 9-2-78                             | 1:11,430 |                |
| Yugui                     | F-5              | 9-2-78                  | 1:6,000  | 9-2-78                             | 1:11,430 |                |
|                           | F-6              | 8-16-78                 | 1:6,000  | 8-16-78                            | 1:11,430 |                |
| Lomuilal                  | F-7              | 8-21-78                 | 1:12,000 | 8-21-78                            | 1:22,860 |                |
| Gejen                     | F-8              | 8-16-78                 | 1:6,000  | 8-16-78                            | 1:11,430 |                |
| Lukuen                    | F-9              | 8-16-78                 | 1:6,000  | 8-16-78                            | 1:11,430 |                |
| Eriirippu                 | F-10             | 8-16-78                 | 1:6,000  | 8-16-78                            | 1:11,430 |                |

| ISLAND<br>OR<br>LAND AREA | ATOLL<br>ID<br># | RC-10 PHOTOS   |          | MULTISPECTRAL PHOTOS               |          | OBLIQUE PHOTOS |
|---------------------------|------------------|----------------|----------|------------------------------------|----------|----------------|
|                           |                  | AEROCOLOR FILM |          | FOUR DIFFERENT<br>SPECTRAL REGIONS |          | VERICOLOR FILM |
|                           |                  | Date           | Scale    | Date                               | Scale    | Date           |
| Anielap                   | F-11             | 8-21-78        | 1:12,000 | 8-21-78                            | 1:22,860 |                |
|                           | F-12             | 9-2-78         | 1:6,000  | 9-2-78                             | 1:11,430 |                |
| Kabelle                   | F-13             | 8-21-78        | 1:12,000 | 8-21-78                            | 1:22,860 |                |
|                           | F-14             | 8-16-78        | 1:6,000  | 8-16-78                            | 1:11,430 |                |
| Mejatto                   | F-15             | 9-2-78         | 1:6,000  | 9-2-78                             | 1:11,430 |                |
|                           | F-16             | 9-2-78         | 1:6,000  | 9-2-78                             | 1:11,430 |                |
| Yuzugan                   | F-17             | 9-2-78         | 1:6,000  | 9-2-78                             | 1:11,430 |                |
| Ribiyurigan               | F-18             | 8-16-78        | 1:6,000  | 8-16-78                            | 1:11,430 |                |
| Laberedj                  | F-19             | 8-21-78        | 1:12,000 | 8-21-78                            | 1:22,860 |                |
|                           | F-20             | 8-16-78        | 1:6,000  | 9-2-78                             | 1:11,430 |                |
| Boken                     | F-21             | 8-21-78        | 1:12,000 | 9-2-78                             | 1:11,430 |                |
| Gabelle                   | F-22             | 8-21-78        | 1:12,000 | 8-21-78                            | 1:22,860 |                |
| Mellu                     | F-23             | 8-21-78        | 1:20,000 | 8-21-78                            | 1:38,100 |                |
| Aniejat                   | F-24             | 8-21-78        | 1:12,000 | 8-21-78                            | 1:22,860 |                |
| Gogan                     | F-25             | 8-21-78        | 1:12,000 | 8-21-78                            | 1:22,860 |                |
|                           | F-26             | 9-2-78         | 1:6,000  | 9-2-78                             | 1:11,430 |                |
|                           | F-27             | 9-2-78         | 1:6,000  | 9-2-78                             | 1:11,430 |                |
| Kieshiechi                | F-28             | 9-2-78         | 1:6,000  | 9-2-78                             | 1:11,430 |                |
| Enybarbar                 | F-29             | 9-2-78         | 1:6,000  | 9-2-78                             | 1:11,430 |                |
| Bigannuo                  | F-30             | 8-16-78        | 1:6,000  | 8-16-78                            | 1:11,430 |                |
|                           | F-31             | 8-21-78        | 1:20,000 | 8-16-78                            | 1:11,430 |                |
| Erapuotsu                 | F-32             | 8-16-78        | 1:6,000  | 9-2-78                             | 1:11,430 |                |
| Eniaetok                  | F-33             | 8-21-78        | 1:20,000 | 8-21-78                            | 1:57,150 |                |
|                           | F-34             | 8-16-78        | 1:6,000  | 8-16-78                            | 1:11,430 |                |
|                           | F-35             | 8-21-78        | 1:12,000 | 8-21-78                            | 1:22,860 |                |
|                           | F-36             | 8-16-78        | 1:6,000  | 8-16-78                            | 1:11,430 |                |
|                           | F-37             | 9-2-78         | 1:6,000  | 9-2-78                             | 1:11,430 |                |
| Busch                     | F-38             | 8-16-78        | 1:6,000  | 9-5-78                             | 1:22,860 |                |
|                           | F-39             | 8-16-78        | 1:6,000  | 8-16-78                            | 1:11,430 |                |
|                           | F-40             | 8-16-78        | 1:6,000  | 8-16-78                            | 1:11,430 |                |
| Bokujarito                | F-41             | 8-16-78        | 1:6,000  | 9-2-78                             | 1:11,430 |                |
| Rongelap                  | F-42             | 8-21-78        | 1:30,000 | 9-2-78                             | 1:38,100 | 8-21-78        |
| Arbar                     | F-43             | 8-21-78        | 1:20,000 | 8-21-78                            | 1:57,150 |                |
| Bikien                    | F-44             | 8-16-78        | 1:6,000  | 8-16-78                            | 1:11,430 |                |
| Eniroruuri                | F-45             | 8-16-78        | 1:6,000  | 8-16-78                            | 1:11,430 |                |
| Eniran                    | F-46             | 8-21-78        | 1:12,000 | 8-21-78                            | 1:22,860 |                |
| Tufa                      | F-47             | 8-21-78        | 1:20,000 | 8-21-78                            | 1:38,100 |                |
| Arugaren                  | F-48             | 8-16-78        | 1:6,000  | 8-16-78                            | 1:11,430 |                |
| Borukka                   | F-49             | 8-21-78        | 1:20,000 | 8-21-78                            | 1:38,100 |                |
| Pokoreppu                 | F-50             | 8-16-78        | 1:6,000  | 9-2-78                             | 1:11,430 |                |
|                           | F-51             | 9-2-78         | 1:6,000  | 9-2-78                             | 1:11,430 |                |
| (Gen)                     |                  |                |          |                                    |          | 8-16-78        |



| ISLAND<br>OR<br>LAND AREA | ATOLL<br>ID<br># | RC-10 PHOTOS   |          | MULTISPECTRAL PHOTOS               |          | OBLIQUE PHOTOS |
|---------------------------|------------------|----------------|----------|------------------------------------|----------|----------------|
|                           |                  | AEROCOLOR FILM |          | FOUR DIFFERENT<br>SPECTRAL REGIONS |          | VERICOLOR FILM |
|                           |                  | Date           | Scale    | Date                               | Scale    | Date           |
| RONGERIK ATOLL            |                  |                |          |                                    |          |                |
| Jedibberdib               | G-1              | 8-16-78        | 1:6,000  | 8-16-78                            | 1:11,430 |                |
| Latoback                  | G-2              | 8-16-78        | 1:12,000 | 8-16-78                            | 1:22,860 |                |
| Moterikku                 | G-3              | 8-16-78        | 1:6,000  | 8-16-78                            | 1:11,430 |                |
| Mortlock                  | G-4              | 8-16-78        | 1:6,000  | 8-16-78                            | 1:11,430 |                |
| Bigonattam                | G-5              | 8-16-78        | 1:12,000 | 8-16-78                            | 1:22,860 | 8-16-78        |
| Rongerik                  | G-6              | 8-16-78        | 1:20,000 | 8-16-78                            | 1:38,100 | 8-16-78        |
|                           | G-7              | 8-16-78        | 1:6,000  | 8-16-78                            | 1:11,430 |                |
|                           | G-8              | 8-16-78        | 1:6,000  | 8-16-78                            | 1:11,430 |                |
| Tarrowatt                 | G-9              | 8-16-78        | 1:12,000 | 8-16-78                            | 1:22,860 |                |
| Bokeredj                  | G-10             | 8-16-78        | 1:6,000  | 8-16-78                            | 1:11,430 |                |
| Eniwetak                  | G-11             | 8-16-78        | 1:24,000 | 8-16-78                            | 1:45,720 | 8-16-78        |
| Bock                      | G-12             | 8-11-78        | 1:24,000 | 8-16-78                            | 1:45,720 |                |
| TAKA ATOLL                |                  |                |          |                                    |          |                |
| Waatowerikku              | H-1              | 8-24-78        | 1:6,000  | 8-24-78                            | 1:11,430 | 8-24-78        |
|                           | H-2              | 8-24-78        | 1:6,000  | 8-24-78                            | 1:11,430 |                |
| Raajerun                  | H-3              | 8-24-78        | 1:6,000  | 8-24-78                            | 1:11,430 | 8-6-78         |
| Taka                      | H-4              | 8-24-78        | 1:12,000 | 8-24-78                            | 1:22,860 | 8-6-78         |
| Eluk                      | H-5              | 8-24-78        | 1:12,000 | 8-24-78                            | 1:22,860 | 8-6-78         |
|                           | H-6              | 8-24-78        | 1:12,000 | 8-24-78                            | 1:22,860 |                |
|                           |                  |                |          | (Gen)                              |          | 8-24-78        |
| UTIRIK ATOLL              |                  |                |          |                                    |          |                |
| Piji                      | I-1              | 8-11-78        | 1:6,000  | 8-24-78                            | 1:11,430 |                |
| Eerukku                   | I-2              | 8-11-78        | 1:6,000  | 8-24-78                            | 1:11,430 |                |
| Pigowak                   | I-3              | 8-11-78        | 1:6,000  | 8-24-78                            | 1:22,860 | 8-11-78        |
| Maaje                     | I-4              | 8-11-78        | 1:6,000  | 8-24-78                            | 1:11,430 | 8-11-78        |
|                           | I-5              | 8-11-78        | 1:6,000  | 8-24-78                            | 1:11,430 | 8-11-78        |
| Utirik                    | I-6              | 9-5-78         | 1:20,000 | 9-5-78                             | 1:38,100 | 8-6-78         |
|                           | I-7              | 8-24-78        | 1:6,000  | 8-24-78                            | 1:11,430 | 8-24-78        |
| Aon                       | I-8              | 8-24-78        | 1:12,000 | 8-27-78                            | 1:38,100 | 8-11-78        |
|                           |                  |                |          | (Gen)                              |          | 8-24-78        |
| UJELANG ATOLL             |                  |                |          |                                    |          |                |
| Pyokon                    | J-1              | 8-7-78         | 1:6,000  | 8-7-78                             | 1:11,430 |                |
| Boggelininlapp            | J-2              | 8-7-78         | 1:6,000  | 8-7-78                             | 1:11,430 |                |
|                           | J-3              | 8-7-78         | 1:6,000  | 8-7-78                             | 1:11,430 |                |
| Seroko                    | J-4              | 8-7-78         | 1:6,000  | 8-7-78                             | 1:11,430 |                |
| Pokon                     | J-5              | 8-7-78         | 1:6,000  | 8-7-78                             | 1:11,430 |                |
|                           | J-6              | 8-7-78         | 1:6,000  | 8-7-78                             | 1:11,430 |                |

| ISLAND<br>OR<br>LAND AREA | ATOLL<br>ID<br># | RC-10 PHOTOS   |          | MULTISPECTRAL PHOTOS               |          | OBLIQUE PHOTOS |
|---------------------------|------------------|----------------|----------|------------------------------------|----------|----------------|
|                           |                  | AEROCOLOR FILM |          | FOUR DIFFERENT<br>SPECTRAL REGIONS |          | VERICOLOR FILM |
|                           |                  | Date           | Scale    | Date                               | Scale    | Date           |
|                           | J-7              | 8-7-78         | 1:6,000  | 8-7-78                             | 1:11,430 |                |
| Kilagen                   | J-8              | 8-7-78         | 1:6,000  | 8-7-78                             | 1:11,430 |                |
|                           | J-9              | 8-7-78         | 1:6,000  | 8-7-78                             | 1:11,430 |                |
|                           | J-10             | 8-7-78         | 1:6,000  | 8-7-78                             | 1:11,430 |                |
|                           | J-11             | 8-7-78         | 1:6,000  | 8-7-78                             | 1:11,430 |                |
|                           | J-12             | 8-7-78         | 1:6,000  | 8-7-78                             | 1:11,430 |                |
|                           | J-13             | 8-7-78         | 1:6,000  | 8-7-78                             | 1:11,430 |                |
|                           | J-14             | 8-7-78         | 1:6,000  | 8-7-78                             | 1:11,430 |                |
| Maron                     | J-15             | 8-7-78         | 1:6,000  | 8-7-78                             | 1:11,430 |                |
|                           | J-16             | 8-7-78         | 1:6,000  | 8-7-78                             | 1:11,430 |                |
| Daisu                     | J-17             | 8-7-78         | 1:6,000  | 8-7-78                             | 1:11,430 | 8-7-78         |
| Ujelang                   | J-18             | 8-7-78         | 1:20,000 | 8-7-78                             | 1:22,860 | 8-7-78         |
|                           | J-19             | 8-7-78         | 1:6,000  | 8-7-78                             | 1:11,430 |                |
| Burle                     | J-20             | 8-7-78         | 1:6,000  | 8-7-78                             | 1:11,430 |                |
| Ronu                      | J-21             | 8-7-78         | 1:6,000  | 8-7-78                             | 1:11,430 |                |
| Eimnlapp                  | J-22             | 8-7-78         | 1:20,000 | 8-7-78                             | 1:22,860 |                |
| Ennimenetto               | J-23             | 8-7-78         | 1:6,000  | 8-7-78                             | 1:22,860 |                |
| Kiriniyan                 | J-24             | 8-7-78         | 1:6,000  | 8-7-78                             | 1:11,430 |                |
| Kalo                      | J-25             | 8-7-78         | 1:6,000  | 8-7-78                             | 1:11,430 |                |
|                           |                  |                |          | (Gen)                              |          | 8-7-78         |
| <b>LIKIEP ATOLL</b>       |                  |                |          |                                    |          |                |
| Mato                      | L-1              | 8-27-78        | 1:20,000 | 8-27-78                            | 1:38,100 |                |
| Rikuraru                  | L-2              | 8-27-78        | 1:20,000 | 8-27-78                            | 1:38,100 |                |
| Mere                      | L-3              | 8-23-78        | 1:12,000 | 8-23-78                            | 1:22,860 |                |
| Pokonchieichi             | L-4              | 8-23-78        | 1:12,000 | 8-23-78                            | 1:22,860 |                |
| Kerenegan                 | L-5              | 8-27-78        | 1:6,000  | 8-27-78                            | 1:11,430 |                |
| Eninon                    | L-6              | 8-27-78        | 1:6,000  | 8-27-78                            | 1:11,430 |                |
| Aapuran                   | L-7              | 8-23-78        | 1:12,000 | 8-23-78                            | 1:22,860 |                |
| Enechieraru               | L-8              | 8-27-78        | 1:6,000  | 8-27-78                            | 1:11,430 |                |
|                           | L-9              | 8-27-78        | 1:6,000  | 8-27-78                            | 1:11,430 |                |
| Kaben                     | L-10             | 8-27-78        | 1:6,000  | 8-23-78                            | 1:22,860 |                |
| Eneneman                  | L-11             | 8-27-78        | 1:6,000  | 8-27-78                            | 1:11,430 |                |
| Enrukku                   | L-12             | 8-26-78        | 1:6,000  | 8-27-78                            | 1:11,430 |                |
| Jeltonet                  | L-13             | 8-26-78        | 1:20,000 | 8-26-78                            | 1:38,100 |                |
| Pikenmen-<br>menchalen    | L-14             | 8-26-78        | 1:6,000  | 8-26-78                            | 1:11,430 |                |
| Bikkenimen-<br>shaiarekko | L-15             | 8-26-78        | 1:6,000  | 8-26-78                            | 1:11,430 |                |
| Boguraburabu              | L-16             | 8-26-78        | 1:6,000  | 8-26-78                            | 1:11,430 |                |
|                           | L-17             | 8-26-78        | 1:6,000  | 8-26-78                            | 1:11,430 |                |
| Kejien                    | L-18             | 8-26-78        | 1:6,000  | 8-26-78                            | 1:11,430 |                |



| ISLAND<br>OR<br>LAND AREA | ATOLL<br>ID<br># | RC-10 PHOTOS   |          | MULTISPECTRAL PHOTOS               |          | OBLIQUE PHOTOS |
|---------------------------|------------------|----------------|----------|------------------------------------|----------|----------------|
|                           |                  | AEROCOLOR FILM |          | FOUR DIFFERENT<br>SPECTRAL REGIONS |          | VERICOLOR FILM |
|                           |                  | Date           | Scale    | Date                               | Scale    | Date           |
|                           | L-19             | 8-26-78        | 1:6,000  | 8-26-78                            | 1:11,430 | 8-11-78        |
| Tamori                    | L-20             | 8-26-78        | 1:6,000  | 8-26-78                            | 1:11,430 | 8-11-78        |
| Kaberuberukan             | L-21             | 8-26-78        | 1:6,000  | 8-23-78                            | 1:22,860 | 8-11-78        |
|                           | L-22             | 8-11-78        | 1:6,000  | 8-26-78                            | 1:11,430 |                |
|                           | L-23             | 8-11-78        | 1:6,000  | 8-26-78                            | 1:11,430 |                |
|                           | L-24             | 8-11-78        | 1:6,000  | 8-26-78                            | 1:11,430 |                |
| Nachibaru                 | L-25             | 8-23-78        | 1:12,000 | 8-23-78                            | 1:22,860 |                |
| Eniiecchi                 | L-26             | 8-26-78        | 1:20,000 | 8-26-78                            | 1:38,100 |                |
| Kirenmaru                 | L-27             | 8-23-78        | 1:12,000 | 8-23-78                            | 1:22,860 |                |
| Meron                     | L-28             | 8-26-78        | 1:6,000  | 8-26-78                            | 1:22,860 | 8-23-24-78     |
|                           | L-29             | 8-26-78        | 1:6,000  | 8-26-78                            | 1:22,860 |                |
| Jiebaru                   | L-30             | 8-27-78        | 1:12,000 | 8-27-78                            | 1:22,860 | 8-23-24-78     |
| Kere                      | L-31             | 8-23-78        | 1:12,000 | 8-23-78                            | 1:22,860 |                |
| Kire                      | L-32             | 8-11-78        | 1:6,000  | 8-26-78                            | 1:11,430 | 8-11-78        |
|                           | L-33             | 8-11-78        | 1:6,000  | 8-23-78                            | 1:11,430 |                |
| Biebi                     | L-34             | 8-23-78        | 1:12,000 | 8-23-78                            | 1:22,860 |                |
| Mukkuri                   | L-35             | 8-23-78        | 1:12,000 | 8-23-78                            | 1:22,860 | 8-11-78        |
| Lado                      | L-36             | 9-1-78         | 1:20,000 | 9-1-78                             | 1:38,100 |                |
| Likiep                    | L-37             | 9-1-78         | 1:20,000 | 9-1-78                             | 1:38,100 | 8-11-78        |
|                           | L-38             | 8-23-78        | 1:6,000  | 8-23-78                            | 1:11,430 |                |
|                           | L-39             | 8-23-78        | 1:6,000  | 8-23-78                            | 1:11,430 |                |
| Enenuuwan                 | L-40             | 8-23-78        | 1:6,000  | 8-23-78                            | 1:11,430 |                |
|                           | L-41             | 8-23-78        | 1:6,000  | 8-23-78                            | 1:11,430 |                |
|                           | L-42             | 8-23-78        | 1:6,000  | 8-23-78                            | 1:11,430 |                |
|                           | L-43             | 8-23-78        | 1:6,000  | 8-23-78                            | 1:11,430 |                |
|                           | L-44             | 8-23-78        | 1:6,000  | 8-23-78                            | 1:11,430 |                |
| Agony                     | L-45             | 8-26-78        | 1:12,000 | 9-1-78                             | 1:38,100 | 8-11-78        |
| Entrance                  | L-46             | 8-23-78        | 1:6,000  | 8-23-78                            | 1:11,430 | 8-11-78        |
| Etoile                    | L-47             | 8-26-78        | 1:12,000 | 9-1-78                             | 1:38,100 | 8-11-78        |
|                           | L-48             | 9-1-78         | 1:20,000 | 9-1-78                             | 1:38,100 |                |
|                           | L-49             | 8-23-78        | 1:6,000  | 8-23-78                            | 1:11,430 |                |
| Lukunor                   | L-50             | 9-1-78         | 1:20,000 | 9-1-78                             | 1:38,100 |                |
|                           | L-51             | 9-1-78         | 1:20,000 | 9-1-78                             | 1:38,100 |                |
| Aaneru                    | L-52             | 8-23-78        | 1:12,000 | 8-23-78                            | 1:22,860 |                |
| Tokaen                    | L-53             | 8-23-78        | 1:12,000 | 8-23-78                            | 1:22,860 |                |
| Matten                    | L-54             | 8-23-78        | 1:12,000 | 8-23-78                            | 1:22,860 |                |
| Kapenor                   | L-55             | 8-26-78        | 1:20,000 | 8-27-78                            | 1:38,100 |                |
| Bokelan                   | L-56             | 8-23-78        | 1:6,000  | 8-23-78                            | 1:11,430 |                |
| Rongelab                  | L-57             | 8-23-78        | 1:12,000 | 8-23-78                            | 1:22,860 |                |
| Rongerik                  | L-58             | 8-27-78        | 1:6,000  | 8-27-78                            | 1:11,430 |                |
| Atoll Chain<br>of Likiep  |                  |                |          | (Gen)                              |          | 8-3-78         |

| ISLAND<br>OR<br>LAND AREA | ATOLL<br>ID<br># | RC-10 PHOTOS   |          | MULTISPECTRAL PHOTOS               |          | OBLIQUE PHOTOS |
|---------------------------|------------------|----------------|----------|------------------------------------|----------|----------------|
|                           |                  | AEROCOLOR FILM |          | FOUR DIFFERENT<br>SPECTRAL REGIONS |          | VERICOLOR FILM |
|                           |                  | Date           | Scale    | Date                               | Scale    | Date           |
| WOTHO ATOLL               |                  |                |          |                                    |          |                |
| Medyeron                  | M-1              | 8-19-78        | 1:20,000 | 8-19-78                            | 1:38,100 |                |
| Worrbar                   | M-2              | 8-19-78        | 1:6,000  | 8-19-78                            | 1:38,100 |                |
| Mokeromok                 | M-3              | 8-18-78        | 1:30,000 | 8-19-78                            | 1:38,100 |                |
| Wotho                     | M-4              | 8-18-78        | 1:30,000 | 8-18-78                            | 1:57,150 | 8-18-78        |
|                           | M-5              | 8-19-78        | 1:6,000  | 8-19-78                            | 1:22,860 |                |
|                           | M-6              | 8-22-78        | 1:6,000  | 8-22-78                            | 1:11,430 |                |
|                           | M-7              | 8-22-78        | 1:6,000  | 8-22-78                            | 1:11,430 |                |
|                           | M-8              | 8-19-78        | 1:12,000 | 8-19-78                            | 1:22,860 |                |
|                           | M-9              | 8-19-78        | 1:6,000  | 8-19-78                            | 1:38,100 |                |
|                           | M-10             | 8-19-78        | 1:6,000  | 8-19-78                            | 1:38,100 |                |
|                           | M-11             | 8-19-78        | 1:12,000 | 8-19-78                            | 1:22,860 |                |
| Ruisuwaa                  | M-12             | 8-22-78        | 1:6,000  | 8-22-78                            | 1:11,430 |                |
| Jebenau                   | M-13             | 8-19-78        | 1:6,000  | 8-19-78                            | 1:38,100 |                |
| Uditi                     | M-14             | 8-19-78        | 1:6,000  | 8-19-78                            | 1:38,100 |                |
| Erotjeman                 | M-15             | 8-22-78        | 1:6,000  | 8-22-78                            | 1:11,430 |                |
| Yeldo                     | M-16             | 8-22-78        | 1:12,000 | 8-22-78                            | 1:22,860 |                |
| Kabben                    | M-17             | 8-19-78        | 1:20,000 | 8-19-78                            | 1:38,100 |                |
| Eirek                     | M-18             | 8-19-78        | 1:12,000 | 8-19-78                            | 1:22,860 |                |
| Ombelim                   | M-19             | 8-22-78        | 1:6,000  | 8-22-78                            | 1:11,430 |                |
| Begin                     | M-20             | 8-19-78        | 1:6,000  | 8-19-78                            | 1:38,100 |                |
|                           |                  |                |          |                                    | (Gen)    | 8-18-78        |
| UJAE ATOLL                |                  |                |          |                                    |          |                |
| Enylamieg                 | N-1              | 8-31-78        | 1:12,000 | 8-31-78                            | 1:38,100 |                |
| Biginnigar                | N-2              | 8-31-78        | 1:6,000  | 8-31-78                            | 1:11,430 |                |
| Erlie                     | N-3              | 8-31-78        | 1:6,000  | 8-31-78                            | 1:11,430 |                |
| Bik                       | N-4              | 8-31-78        | 1:6,000  | 8-31-78                            | 1:11,430 |                |
| Ebbetyu                   | N-5              | 8-31-78        | 1:12,000 | 8-31-78                            | 1:38,100 |                |
| Rua                       | N-6              | 8-31-78        | 1:6,000  | 8-31-78                            | 1:11,430 |                |
| Wotya                     | N-7              | 8-31-78        | 1:12,000 | 8-31-78                            | 1:22,860 |                |
| Langeba                   | N-8              | 8-31-78        | 1:6,000  | 8-31-78                            | 1:11,430 |                |
| Ujae                      | N-9              | 8-31-78        | 1:20,000 | 8-31-78                            | 1:38,100 |                |
|                           | N-10             | 8-31-78        | 1:6,000  | 8-31-78                            | 1:11,430 |                |
| Bock                      | N-11             | 8-31-78        | 1:6,000  | 8-31-78                            | 1:11,430 |                |
|                           | N-12             | 8-31-78        | 1:6,000  | 8-31-78                            | 1:11,430 |                |
| Atoll Ujae                |                  |                |          |                                    | (Gen)    | 8-7-78         |
| LAE ATOLL                 |                  |                |          |                                    |          |                |
| Ribong                    | P-1              | 8-31-78        | 1:12,000 | 8-31-78                            | 1:22,860 |                |
| Bigilapij                 | P-2              | 8-31-78        | 1:6,000  | 8-31-78                            | 1:11,430 |                |



| ISLAND<br>OR<br>LAND AREA      | ATOLL<br>ID<br># | RC-10 PHOTOS   |          | MULTISPECTRAL PHOTOS               |           | OBLIQUE PHOTOS |
|--------------------------------|------------------|----------------|----------|------------------------------------|-----------|----------------|
|                                |                  | AEROCOLOR FILM |          | FOUR DIFFERENT<br>SPECTRAL REGIONS |           | VERICOLOR FILM |
|                                |                  | Date           | Scale    | Date                               | Scale     | Date           |
| Bui                            | P-3              | 8-31-78        | 1:6,000  | 8-31-78                            | 1:11,430  |                |
| Reipu                          | P-4              | 8-31-78        | 1:6,000  | 8-31-78                            | 1:11,430  |                |
| Bigenaj                        | P-5              | 8-31-78        | 1:6,000  | 8-31-78                            | 1:11,430  |                |
| Luisap                         | P-6              | 8-31-78        | 1:6,000  | 8-31-78                            | 1:22,860  |                |
| Enijaridoyu                    | P-7              | 8-31-78        | 1:6,000  | 8-31-78                            | 1:11,430  |                |
| Eninanetsu                     | P-8              | 8-31-78        | 1:6,000  | 8-31-78                            | 1:11,430  |                |
| Yonbiji                        | P-9              | 8-31-78        | 1:6,000  | 8-31-78                            | 1:11,430  |                |
|                                | P-10             | 8-31-78        | 1:6,000  | 8-31-78                            | 1:11,430  |                |
| Gibinrii                       | P-11             | 8-31-78        | 1:6,000  | 8-31-78                            | 1:11,430  |                |
| Lae                            | P-12             | 8-31-78        | 1:20,000 | 8-31-78                            | 1:76,200  |                |
| Rarime                         | P-13             | 8-31-78        | 1:6,000  | 8-31-78                            | 1:11,430  |                |
|                                | P-14             | 8-31-78        | 1:6,000  | 8-31-78                            | 1:11,430  |                |
|                                | P-15             | 8-31-78        | 1:6,000  | 8-31-78                            | 1:11,430  |                |
| Lotj                           | P-16             | 8-31-78        | 1:12,000 | 8-31-78                            | 1:22,860  |                |
| Sand Spit<br>(between P1 - P2) | *                | 8-31-78        | 1:6,000  | 8-31-78                            | 1:11,430  |                |
| <b>JEMO ISLAND</b>             |                  |                |          |                                    |           |                |
| Jemo Island                    |                  | 7-29-78        | 1:30,000 | 7-29-78                            | 1:114,300 |                |
|                                |                  | 8-5-78         | 1:8,000  | 8-5-78                             | 1:15,240  |                |
| <b>MEJIT ISLAND</b>            |                  |                |          |                                    |           |                |
| Mejit Island                   |                  | 8-5-78         | 1:30,000 | 8-5-78                             | 1:114,300 |                |
|                                |                  | 9-1-78         | 1:20,000 | 9-1-78                             | 1:38,100  |                |
|                                |                  |                |          | 8-5-78                             | 1:57,150  |                |



# Appendix C. PHOTOPEAK CONVERSION FACTOR DERIVATION

The unscattered flux of gamma rays of energy E at a height h above a smooth air-ground interface due to an emitter distributed in the soil is given by (see Figure C1):

$$\phi = \int_0^\infty \int_0^\infty \frac{S_v}{4\pi r^2} \exp \left[ -(\mu/\rho)_a \rho_a r_a \right] \exp \left[ -(\mu/\rho)_s \rho_s r_s \right] 2\pi x \, dx \, dz \quad (C1)$$

where

- $S_v$  = the activity per unit volume  $[(\gamma/\text{sec})/\text{cm}^3]$   
 $r = r_a + r_s$  (cm),  
 $(\mu/\rho)_a, (\mu/\rho)_s$  = the air and soil mass attenuation coefficients ( $\text{cm}^2/\text{g}$ ), and  
 $\rho_a, \rho_s$  = the air and soil density ( $\text{g}/\text{cm}^3$ ).

This expression assumes a source distribution which varies only with depth. A uniform distribution in the horizontal plane is assumed, which leads to results expressed in terms of an area average over the field-of-view of the detector. For fallout activity the distribution after a period of time can be reasonably approximated by an exponential distribution given by:

$$S_v = S_v^0 e^{-\alpha z} \quad (C2)$$

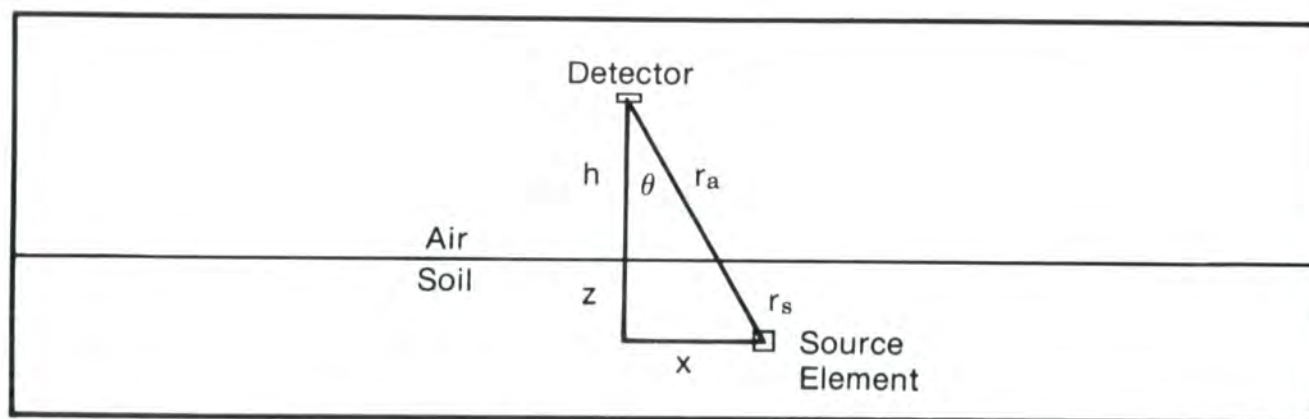


Figure C-1. GEOMETRY USED IN THE DERIVATION OF CONVERSION FACTORS RELATING PHOTOPEAK COUNT RATE DATA TO ISOTOPE CONCENTRATION IN THE GROUND



## C-2

where

$S_v^0$  = the activity per unit volume at the surface  $[(\gamma/\text{sec})/\text{cm}^3]$

$\alpha$  = the reciprocal of the relaxation length  $(\text{cm}^{-1})$ .

Rewriting equation (C1) in terms of  $\theta$  and  $z$ , combining with Equation (C2) and integrating over  $z$  leads to:

$$\phi = \frac{S_v^0}{2} \int_0^{\pi/2} \frac{\tan \theta \exp \left[ -(\mu/\rho)_a \rho_a h \sec \theta \right]}{\alpha + (\mu/\rho)_s \rho_s \sec \theta} d\theta \quad (\text{C3})$$

The detector response to a given flux,  $\phi$ , of gamma rays of energy  $E$  incident at an angle  $\theta$  can be given in terms of an effective detector area,  $A$ , defined by:

$$A = \frac{N_p}{\phi} \quad (\text{C4})$$

where  $N_p$  is the net photopeak count rate  $(\text{sec}^{-1})$ .

The effective area, in general, varies as a function of the gamma ray angle of incidence and is normally written as:

$$A = A_0 R(\theta) \quad (\text{C5})$$

where

$A_0$  = the detector photopeak count rate for a unit flux incident perpendicular to the detector face  $[(\text{cps})/(\gamma/\text{cm}^2)/\text{sec}]$  and

$R(\theta)$  = the ratio of the detector response at an angle  $\theta$  to that at  $\theta = 0^\circ$

Both  $A_0$  and  $R(\theta)$  can be determined experimentally.



Combining Equations (C4) and (C5) with Equation (C3) leads to an expression which relates the measured photopeak count rate to source activity in the soil.

This is given by:

$$\frac{N_p}{S_v^0} = \left[ \frac{A_0}{2} \int_0^{\pi/2} \frac{R(\theta) \tan \theta \exp \left[ -(\mu/\rho)_a \rho_a h \sec \theta \right]}{\alpha + (\mu/\rho)_s \rho_s \sec \theta} d\theta \right] \quad (C6)$$

The conversion factor  $N_p/S_v^0$  given by Equation (C6) is in units of cps per ( $\gamma/\text{cm}^3\text{sec}$ ). For a specific isotope the conversion factor is normally changed to units of cps per ( $\text{pCi}/\text{cm}^3$ ). Multiplying the expression in the brackets in Equation (C6) by the soil density (in  $\text{g}/\text{cm}^3$ ) leads to the conversion factor  $N_p/(S_v^0/\rho)$  normally given in units of cps per ( $\text{pCi}/\text{g}$ ).

In general, it is more useful to relate the photopeak count rate data to an average concentration within a given depth rather than a surface concentration as given in Equation (C6). The average concentration in the top  $z$  cm,  $S_v^z$ , for a source distributed exponentially with depth is given by:

$$S_v^z = \frac{1}{z} \int_0^z S_v^0 e^{-\alpha z} dz = \frac{S_v^0}{\alpha z} (1 - e^{-\alpha z}) \quad (C7)$$

Combining Equations (C6) and (C7) leads to the final expression for the conversion factor used for the northern Marshall Islands aerial survey:

$$\frac{(S_v^z/\rho)}{N_p} = \frac{(1 - e^{-\alpha z})}{\alpha z} B \left[ \frac{A_0 \rho_s}{2} \int_0^{\pi/2} \frac{R(\theta) \tan \theta \exp \left[ -(\mu/\rho)_a \rho_a h \sec \theta \right]}{\alpha + (\mu/\rho)_s \rho_s \sec \theta} d\theta \right]^{-1} \quad (C8)$$

in units of  $[(\text{pCi}/\text{g})/(\text{cps})]$ , where  $B$  converts  $\gamma/\text{sec}$  to  $\text{pCi}$  for a specific isotope.



Conversion factors given in Section 3.4 for  $^{137}\text{Cs}$  and  $^{60}\text{Co}$  were obtained by numerically integrating Equation (C8) with the appropriate input parameters. Values for the detector efficiency were obtained by hovering over  $^{137}\text{Cs}$  and  $^{60}\text{Co}$  calibration sources at a known distance. For  $^{137}\text{Cs}$ , a net photopeak count rate of 183 cps was obtained from a 1 mCi point source at a distance of 45 m. For  $^{60}\text{Co}$ , the photopeak count rate for a window set over both photopeaks was 285 cps for a 1 mCi point source at a distance of 45 m. Previous experiments have shown that a good approximation to the actual angular response of the large detector array for  $^{137}\text{Cs}$  and  $^{60}\text{Co}$  can be obtained by averaging the results obtained from the two limiting cases of an isotropic response,  $R(\theta)=1$ , and a cosine response,  $R(\theta) = \cos \theta$ . Soil mass attenuation coefficients were obtained by assuming a soil composition of 80%  $\text{CaCO}_3$  and 20% soil moisture plus organic material. This was based on studies done at Enewetak during the Enewetak cleanup project. The actual values used were  $0.08 \text{ cm}^2/\text{g}$  for  $^{137}\text{Cs}$  and  $0.057 \text{ cm}^2/\text{g}$  for  $^{60}\text{Co}$ . An average soil density of  $1.5 \text{ g/cm}^3$  was assumed, again based on data obtained at Enewetak. The air density was assumed to be  $1.15 (10^{-3}) \text{ g/cm}^3$ .



## Appendix D — TERRESTRIAL EXPOSURE RATE CONTOUR MAPS

Detailed results of the aerial radiological survey are presented in the form of terrestrial exposure rate contour maps superimposed on atoll photographs obtained during the photographic survey. Results are given for the total terrestrial exposure rate and, where possible, for the individual contributions due to  $^{137}\text{Cs}$  and  $^{60}\text{Co}$  (see Section 3.5). The atolls were surveyed in sections, with each section generally covering a distance of three to six kilometers. Each section was identified using the frame number of the photograph which served as the base map. Islands within each atoll were identified using the code numbers assigned during the photographic survey. Appendix B relates these code numbers to island names. Names given reflect the Marshallese spelling whenever available. Otherwise, names given are those obtained from existing navigation maps, prepared by the U.S. Army Map Service in the 1940s. These maps generally reflect the Japanese spelling.

Results are presented in the order in which the atolls were surveyed (see Table 1 in Section 3.1). A photomosaic of each atoll is included as a base map key for identifying the area covered within each section and the frame number of the photograph used as the base map. Table D-1 can be used to locate the page number for any given contour map.

Several points should be kept in mind when utilizing or interpreting the isoradiation contour maps. The first concerns the large-area averaging property of the airborne system. Each one second data point represents an average value for an area which is several thousand times as large as the area being measured with a detector at 1 meter, such as a typical ionization chamber measurement, and several million times the area typically measured with a soil sample. This becomes important when trying to make point-by-point comparisons between aerial data and ground data, especially for some islands at Bikini Atoll which show a high degree of variability in the terrestrial radiation levels. In general, elevated activity confined to a small area will appear as a lower level of activity but spread out over a larger area in the radiation contour data.

The factors used to convert aerial data to ground level exposure rate or soil concentration values assume a source distribution which is large compared to the field-of-view of the airborne system. This criteria was satisfied in the present survey for islands having a width greater than approximately 400 meters. For smaller islands, it is necessary to apply a "finite source" correction factor to infer valid ground data (see Figure 20).

The contour maps show radiation levels which extend out over the water. This is not due to radioactivity in the water, but simply results from the fact that the airborne system can detect gamma radiation from an island at some distance from the shoreline. The degree to which these contours extend out over the water simply serves as an indicator of the terrestrial activity on the island. In a similar manner, the contour data will indicate lower radiation levels around the edge of an island than those indicated for the interior due to the presence of water within the field-of-view of the detector system as the aircraft approaches the shoreline.

**Table D-1. Page Number Location Key for the Terrestrial Exposure Rate Contour Maps**

| Atoll<br>(Island)   | Base<br>Photograph<br>Frame<br>Number | Island(s)<br>Number(s) | Page Number For:          |                                       |                                      |
|---------------------|---------------------------------------|------------------------|---------------------------|---------------------------------------|--------------------------------------|
|                     |                                       |                        | Total<br>Exposure<br>Rate | $^{137}\text{Cs}$<br>Exposure<br>Rate | $^{60}\text{Co}$<br>Exposure<br>Rate |
| Rongelap<br>Atoll   | 167                                   | F-1 to F-3             | D-4                       | D-5                                   | D-6                                  |
|                     | 159                                   | F-4 to F-5             | D-7                       | D-8                                   | D-9                                  |
|                     | 189                                   | F-6 to F-8             | D-10                      | D-11                                  | D-12                                 |
|                     | 153                                   | F-9 to F-10            | D-13                      | D-13                                  | D-14                                 |
|                     | 139                                   | F-11 to F-14           | D-15                      | D-16                                  | D-17                                 |
|                     | 136                                   | F-15 to F-17           | D-18                      | D-19                                  | D-20                                 |
|                     | 179                                   | F-18 to F-22           | D-21                      | D-21                                  | D-22                                 |
|                     | 177                                   | F-23                   | D-23                      | D-24                                  | D-25                                 |
|                     | 175                                   | F-24 to F-28           | D-26                      | D-26                                  | D-27                                 |
|                     | 172                                   | F-29 to F-30           | D-28                      | D-29                                  | D-30                                 |
|                     | 80                                    | F-31 to F-33           | D-31                      | D-31                                  | D-32                                 |
|                     | 200                                   | F-34 to F-38           | D-32                      | D-33                                  | D-33                                 |
|                     | 196                                   | F-39 to F-41           | D-34                      | D-35                                  | D-36                                 |
|                     | 216                                   | F-42                   | D-37                      | D-37                                  | D-38                                 |
|                     | 72                                    | F-43 to F-44           | D-38                      | D-39                                  | D-39                                 |
|                     | 50                                    | F-45 to F-47           | D-40                      | D-40                                  | D-41                                 |
|                     | 56                                    | F-48 to F-49           | D-41                      | D-42                                  | D-42                                 |
|                     | 7                                     | F-50                   | D-43                      | D-44                                  | D-45                                 |
| Utirik<br>Atoll     | 204                                   | I-1 to I-2             | D-47                      | *                                     | *                                    |
|                     | 179                                   | I-3 to I-7             | D-48                      | *                                     | *                                    |
|                     | 182                                   | I-8                    | D-49                      | *                                     | *                                    |
| Taka<br>Atoll       | 25                                    | H-1 to H-4             | D-51                      | *                                     | *                                    |
|                     | 123                                   | H-5 to H-6             | D-52                      | *                                     | *                                    |
| Bikar<br>Atoll      | 145                                   | D-1 to D-2             | D-54                      | *                                     | *                                    |
|                     | 99                                    | D-3 to D-4             | D-55                      | *                                     | *                                    |
|                     | 115                                   | D-5                    | D-56                      | *                                     | *                                    |
| Rongerik<br>Atoll   | 74                                    | G-1 to G-2             | D-58                      | D-58                                  | D-59                                 |
|                     | 70                                    | G-3 to G-6             | D-60                      | D-61                                  | D-62                                 |
|                     | 85                                    | G-7 to G-9             | D-63                      | D-63                                  | D-64                                 |
|                     | 64                                    | G-10 to G-11           | D-65                      | D-66                                  | D-67                                 |
|                     | 102                                   | G-12                   | D-68                      | D-69                                  | D-70                                 |
| Ailinginae<br>Atoll | 24                                    | C-1 to C-2             | D-72                      | D-73                                  | *                                    |
|                     | 17                                    | C-3 to C-4             | D-74                      | D-75                                  | *                                    |
|                     | 14                                    | C-5 to C-9             | D-76                      | D-77                                  | *                                    |

\*Activity too low to allow processing for individual isotope.



| Table D-1. (continued)           |                                       |                        |                           |                                       |                                      |
|----------------------------------|---------------------------------------|------------------------|---------------------------|---------------------------------------|--------------------------------------|
| Atoll<br>(Island)                | Base<br>Photograph<br>Frame<br>Number | Island(s)<br>Number(s) | Page Number For:          |                                       |                                      |
|                                  |                                       |                        | Total<br>Exposure<br>Rate | <sup>137</sup> Cs<br>Exposure<br>Rate | <sup>60</sup> Co<br>Exposure<br>Rate |
| Ailinginae<br>Atoll<br>Continued | 26                                    | C-10 to C-13           | D-78                      | D-78                                  | *                                    |
|                                  | 27                                    | C-14 to C-15           | D-79                      | D-80                                  | *                                    |
|                                  | 29                                    | C-16 to C-18           | D-81                      | D-81                                  | *                                    |
|                                  | 30                                    | C-19 to C-20           | D-82                      | D-83                                  | *                                    |
|                                  | 31                                    | C-21 to C-23           | D-84                      | D-84                                  | *                                    |
|                                  | 32                                    | C-24                   | D-85                      | D-86                                  | *                                    |
|                                  | 33                                    | C-25 to C-27           | D-87                      | D-88                                  | *                                    |
|                                  |                                       |                        |                           |                                       |                                      |
| Likiep<br>Atoll                  | 136                                   | L-1 to L-2             | D-90                      | *                                     | *                                    |
|                                  | 131                                   | L-3 to L-7             | D-91                      | *                                     | *                                    |
|                                  | 126                                   | L-8 to L-12            | D-92                      | *                                     | *                                    |
|                                  | 114                                   | L-13 to L-15           | D-93                      | *                                     | *                                    |
|                                  | 109                                   | L-16 to L-20           | D-94                      | *                                     | *                                    |
|                                  | 68                                    | L-21 to L-26           | D-94                      | *                                     | *                                    |
|                                  | 65                                    | L-27 to L-32           | D-95                      | *                                     | *                                    |
|                                  | 62                                    | L-33 to L-36           | D-95                      | *                                     | *                                    |
|                                  | 50                                    | L-37                   | D-96                      | *                                     | *                                    |
|                                  | 53                                    | L-38 to L-44           | D-97                      | *                                     | *                                    |
|                                  | 93                                    | L-45 to L-48           | D-98                      | *                                     | *                                    |
|                                  | 86                                    | L-49 to L-51           | D-99                      | *                                     | *                                    |
|                                  | 162                                   | L-52 to L-53           | D-100                     | *                                     | *                                    |
|                                  | 157                                   | L-54                   | D-101                     | *                                     | *                                    |
|                                  | 147                                   | L-55 to L-56           | D-102                     | *                                     | *                                    |
|                                  | 143                                   | L-57 to L-58           | D-103                     | *                                     | *                                    |
|                                  |                                       |                        |                           |                                       |                                      |
|                                  |                                       |                        |                           |                                       |                                      |
|                                  |                                       |                        |                           |                                       |                                      |
| Ailuk<br>Atoll                   | 86                                    | A-1 to A-6             | D-105                     | *                                     | *                                    |
|                                  | 122                                   | A-7 to A-13            | D-106                     | *                                     | *                                    |
|                                  | 163                                   | A-14 to A-20           | D-107                     | *                                     | *                                    |
|                                  | 161                                   | A-21 to A-25           | D-108                     | *                                     | *                                    |
|                                  | 92                                    | A-26 to A-38           | D-109                     | *                                     | *                                    |
|                                  | 96                                    | A-39 to A-48           | D-109                     | *                                     | *                                    |
|                                  | 98                                    | A-49 to A-51           | D-110                     | *                                     | *                                    |
|                                  | 69                                    | A-52                   | D-111                     | *                                     | *                                    |
|                                  | 39                                    | A-53                   | D-112                     | *                                     | *                                    |
|                                  |                                       |                        |                           |                                       |                                      |
| Jemo<br>Island                   | —                                     | —                      | D-113                     | *                                     | *                                    |
| Mejit<br>Island                  | —                                     | —                      | D-114                     | *                                     | *                                    |

\*Activity to low to allow processing for individual isotope.

| Table D-1. (continued) |                                       |                        |                           |                                       |                                      |
|------------------------|---------------------------------------|------------------------|---------------------------|---------------------------------------|--------------------------------------|
| Atoll<br>(Island)      | Base<br>Photograph<br>Frame<br>Number | Island(s)<br>Number(s) | Page Number For:          |                                       |                                      |
|                        |                                       |                        | Total<br>Exposure<br>Rate | <sup>137</sup> Cs<br>Exposure<br>Rate | <sup>60</sup> Co<br>Exposure<br>Rate |
| Wotho<br>Atoll         | 10                                    | M-1 to M-2             | D-116                     | *                                     | *                                    |
|                        | 60                                    | M-3 to M-4             | D-117                     | *                                     | *                                    |
|                        | 56                                    | M-5 to M-11            | D-118                     | *                                     | *                                    |
|                        | 136                                   | M-12 to M-14           | D-118                     | *                                     | *                                    |
|                        | 117                                   | M-15 to M-17           | D-119                     | *                                     | *                                    |
|                        | 109                                   | M-18 to M-19           | D-120                     | *                                     | *                                    |
|                        | 153                                   | M-20                   | D-121                     | *                                     | *                                    |
|                        |                                       |                        |                           |                                       |                                      |
| Ujelang<br>Atoll       | 130                                   | J-1 to J-3             | D-123                     | *                                     | *                                    |
|                        | 138                                   | J-4 to J-5             | D-124                     | *                                     | *                                    |
|                        | 143                                   | J-6 to J-11            | D-125                     | *                                     | *                                    |
|                        | 145                                   | J-12 to J-17           | D-126                     | *                                     | *                                    |
|                        | 153                                   | J-18                   | D-127                     | *                                     | *                                    |
|                        | 157                                   | J-19 to J-20           | D-128                     | *                                     | *                                    |
|                        | 166                                   | J-21 to J-22           | D-129                     | *                                     | *                                    |
|                        | 168                                   | J-23 to J-24           | D-130                     | *                                     | *                                    |
|                        | 174                                   | J-25                   | D-131                     | *                                     | *                                    |
|                        |                                       |                        |                           |                                       |                                      |
| Bikini<br>Atoll        | 177                                   | B-1                    | D-133                     | D-134                                 | D-135                                |
|                        | 38                                    | B-2 to B-5             | D-136                     | D-137                                 | D-138                                |
|                        | 15                                    | B-6                    | D-139                     | D-140                                 | D-141                                |
|                        | 7                                     | B-7 to B-11            | D-142                     | D-143                                 | D-144                                |
|                        | 200                                   | B-12                   | D-145                     | D-146                                 | D-147                                |
|                        | 12                                    | B-13 to B-16           | D-148                     | D-148                                 | D-149                                |
|                        | 34                                    | B-17                   | D-150                     | D-151                                 | D-152                                |
|                        | 212                                   | B-18 to B-19           | D-153                     | D-154                                 | D-155                                |
|                        | 215                                   | B-20 to B-23           | D-156                     | D-156                                 | D-157                                |
|                        |                                       |                        |                           |                                       |                                      |

\*Activity to low to allow processing for individual isotope.



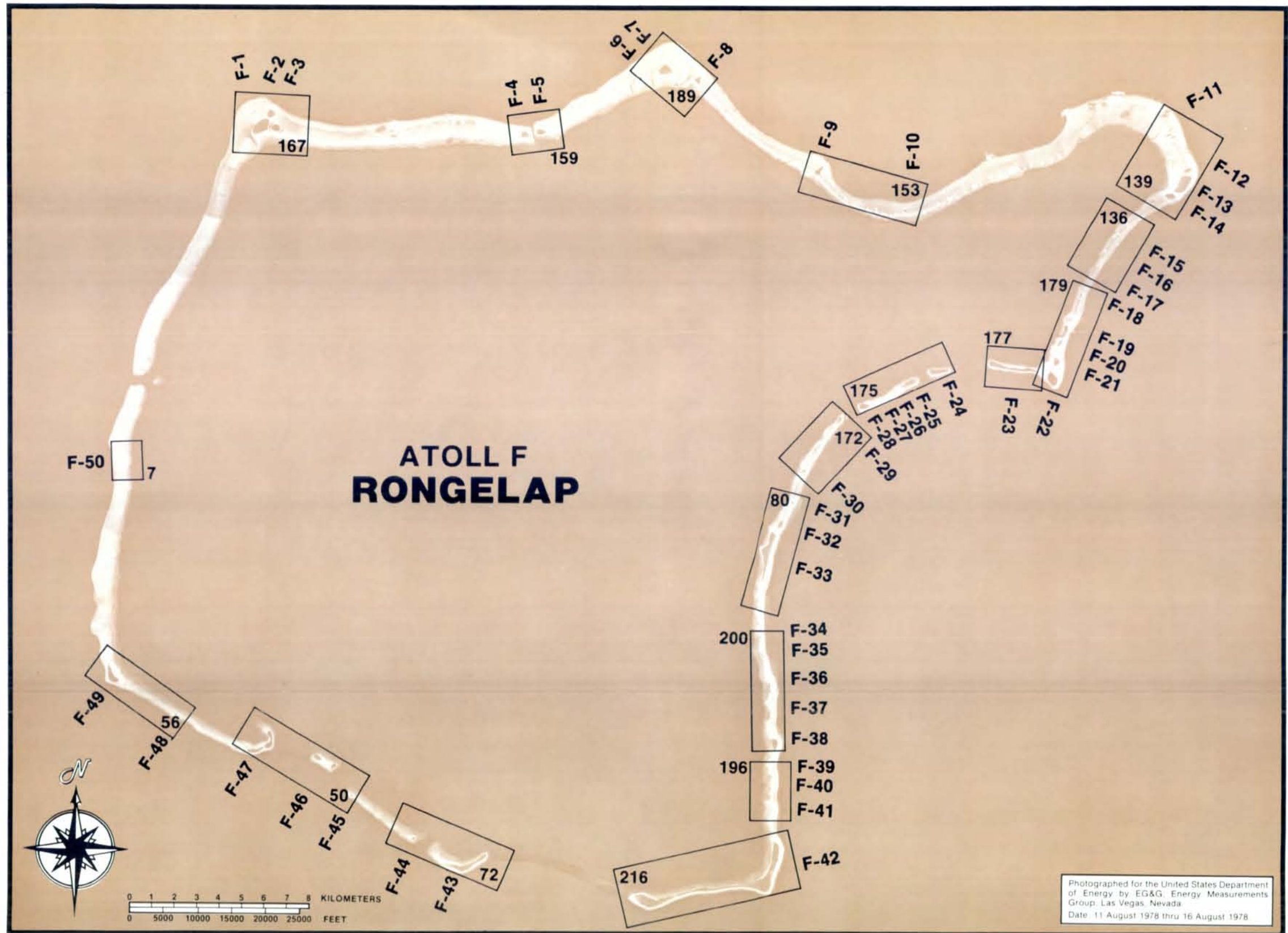


Figure D-1. BASE MAP KEY FOR RONGELAP ATOLL. The photomosaic shows the area covered by each base map photograph and the photograph frame number used to identify each survey area.



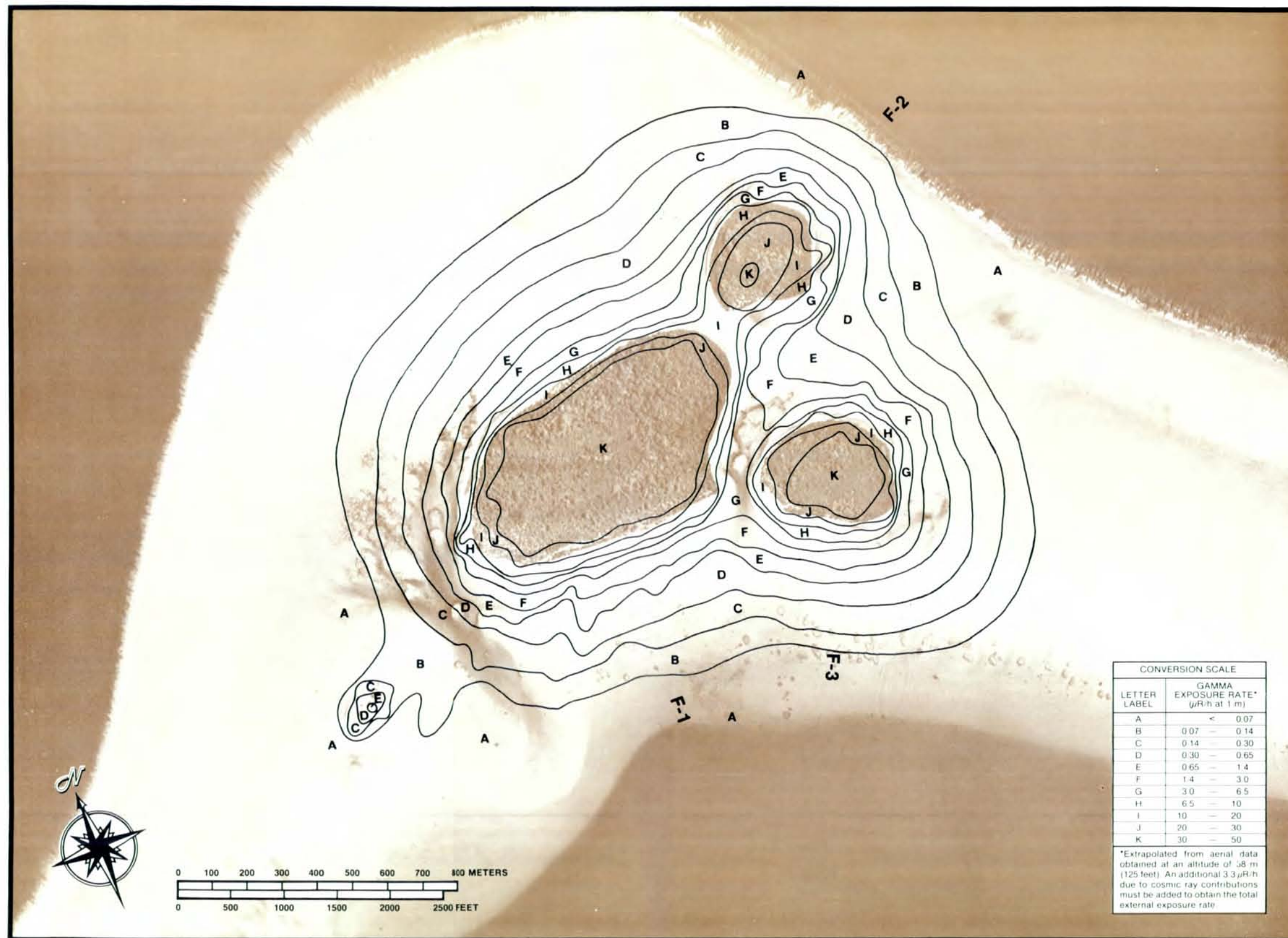


Figure D-2. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS F-1 TO F-3 AT RONGELAP ATOLL. (Photograph Frame Number 167)



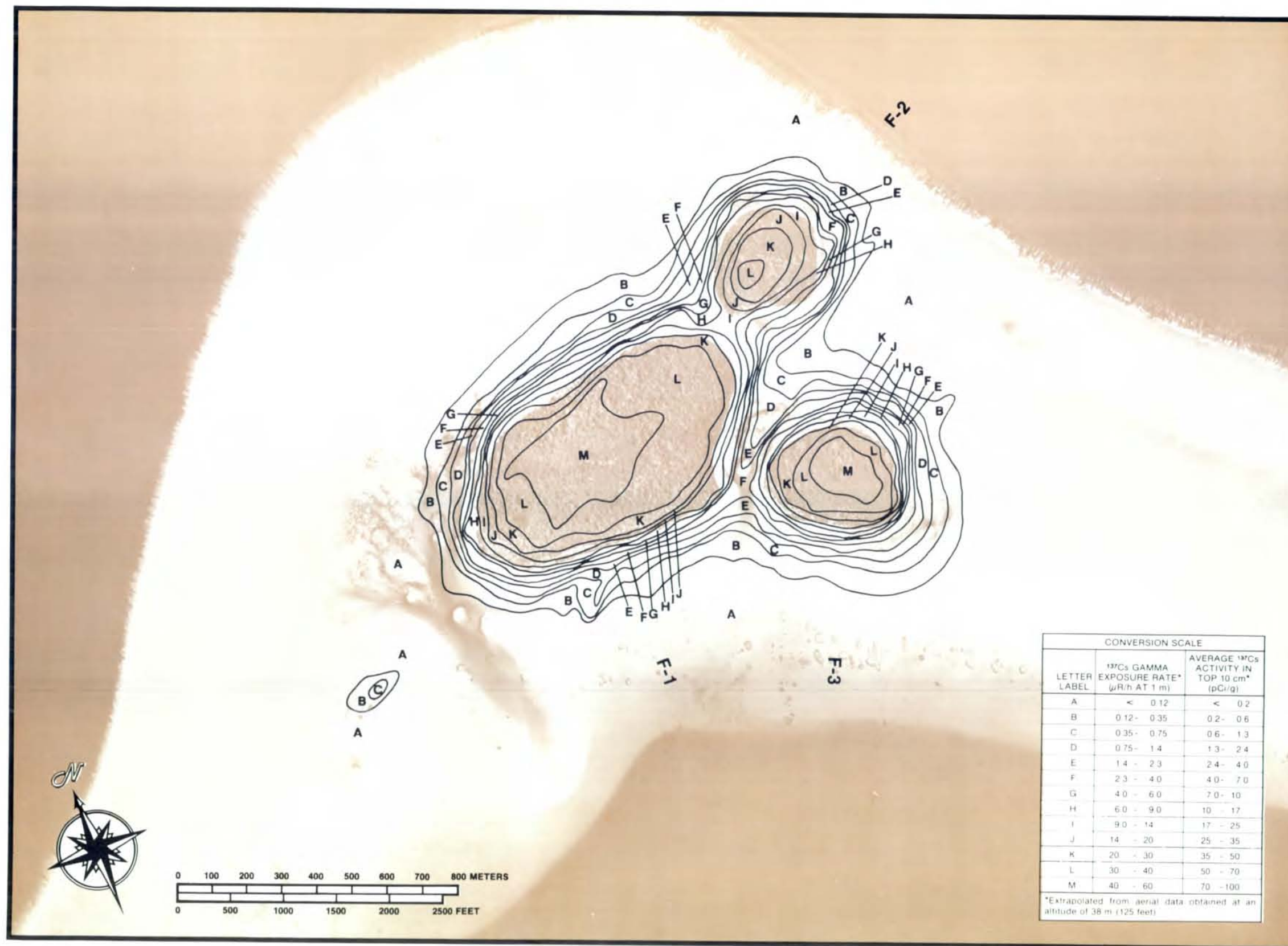


Figure D-3. CESIUM 137 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS F-1 TO F-3 AT RONGELAP ATOLL. (Photograph Frame Number 167)





Figure D-4. COBALT 60 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS F-1 TO F-3 AT RONGELAP ATOLL. (Photograph Frame Number 167)





Figure D-5. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS F-4 TO F-5 AT RONGELAP ATOLL. (Photograph Frame Number 159)



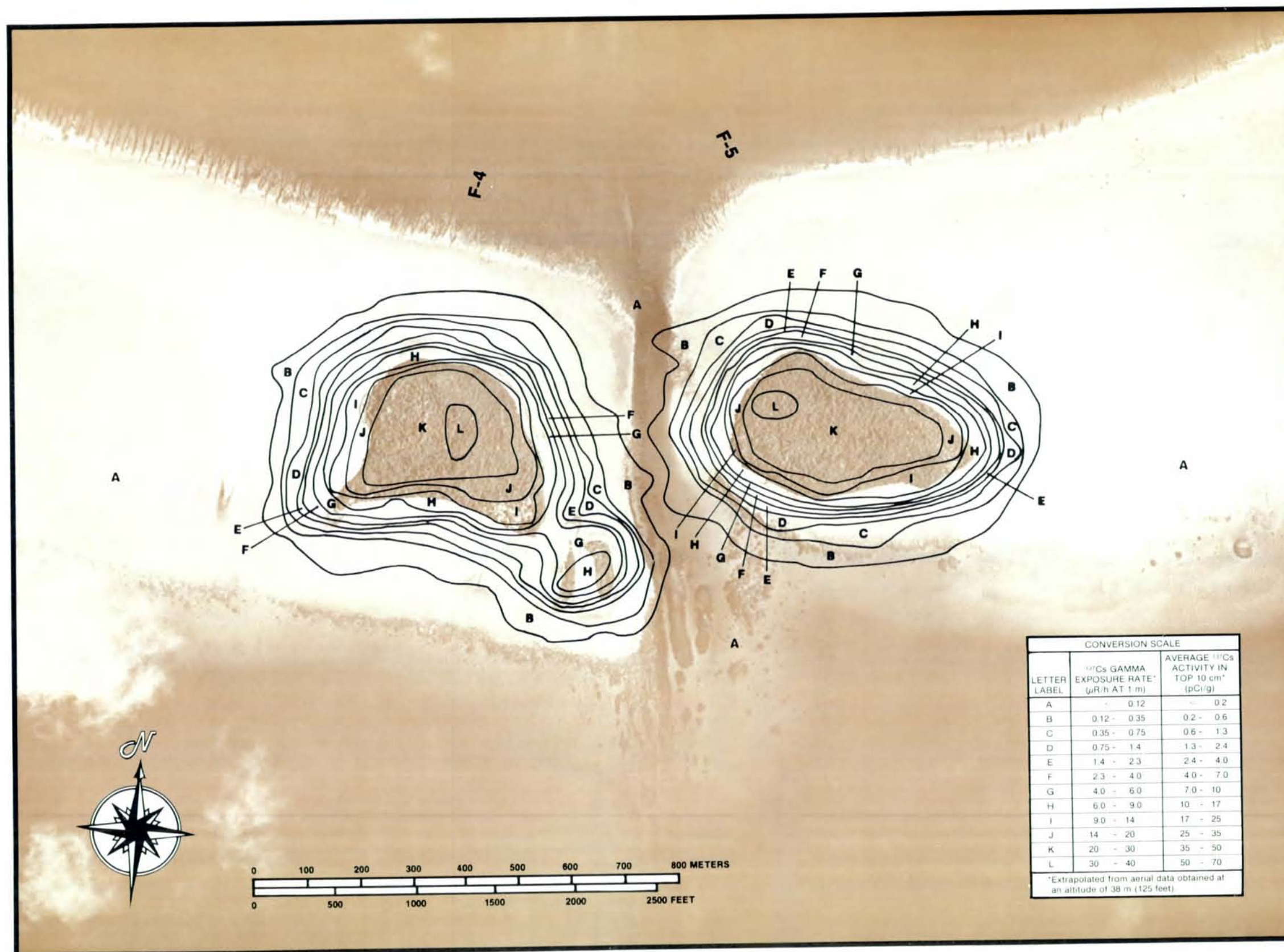


Figure D-6. CESIUM 137 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS F-4 TO F-5 AT RONGELAP ATOLL. (Photograph Frame Number 159)



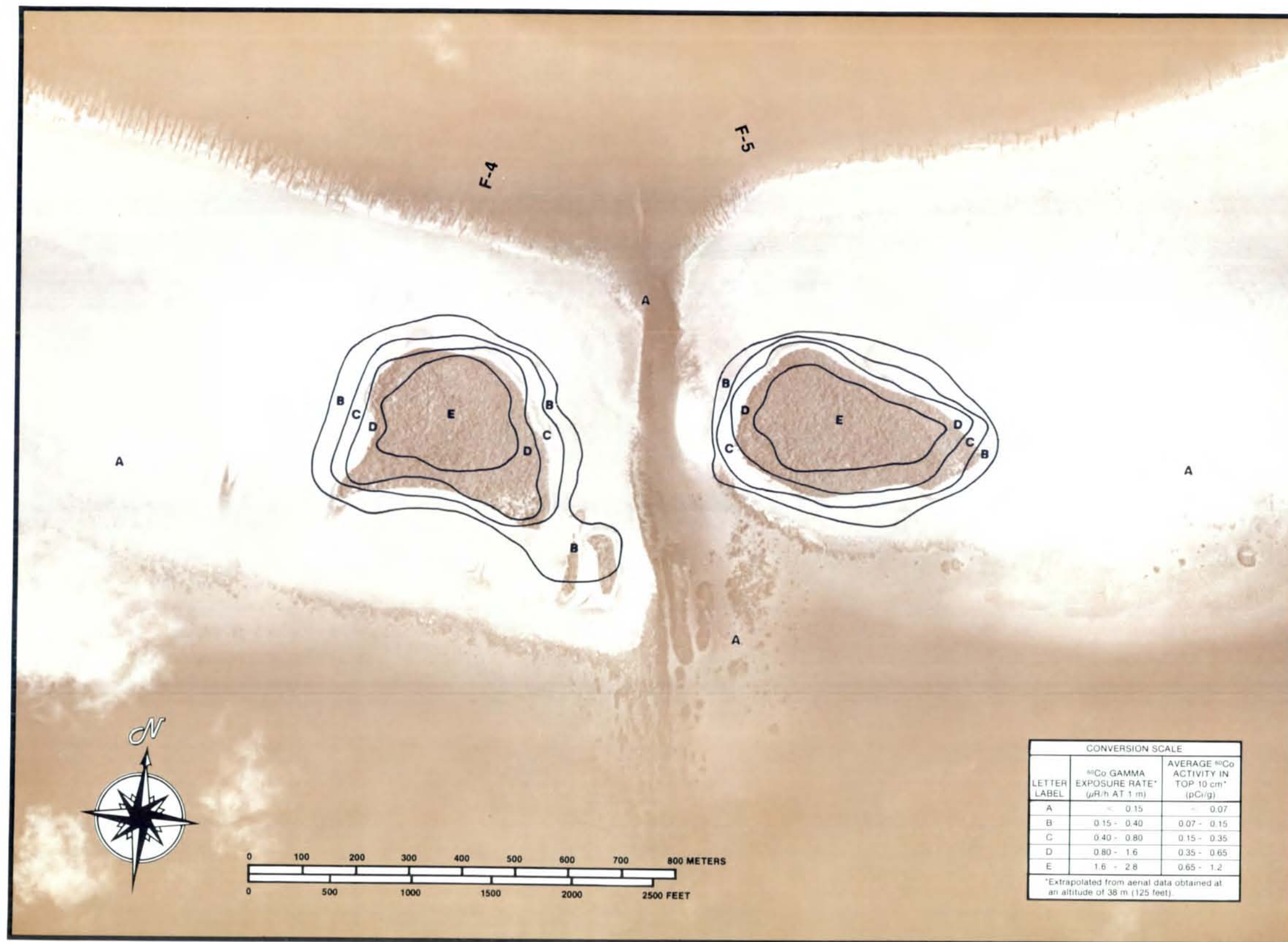


Figure D-7. COBALT 60 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS F-4 TO F-5 AT RONGELAP ATOLL. (Photograph Frame Number 159)



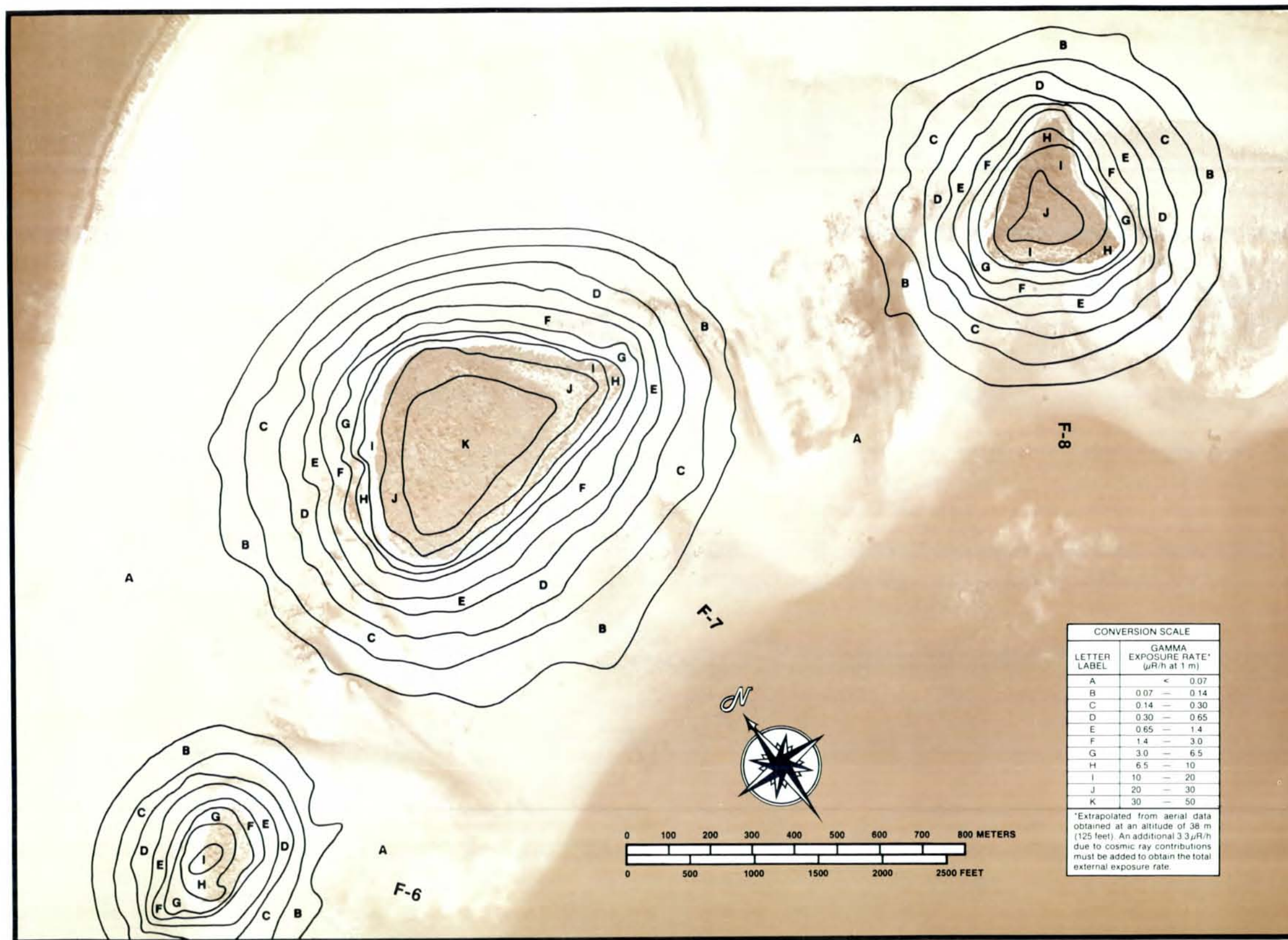


Figure D-8. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS F-6 TO F-8 AT RONGELAP ATOLL. (Photograph Frame Number 189)



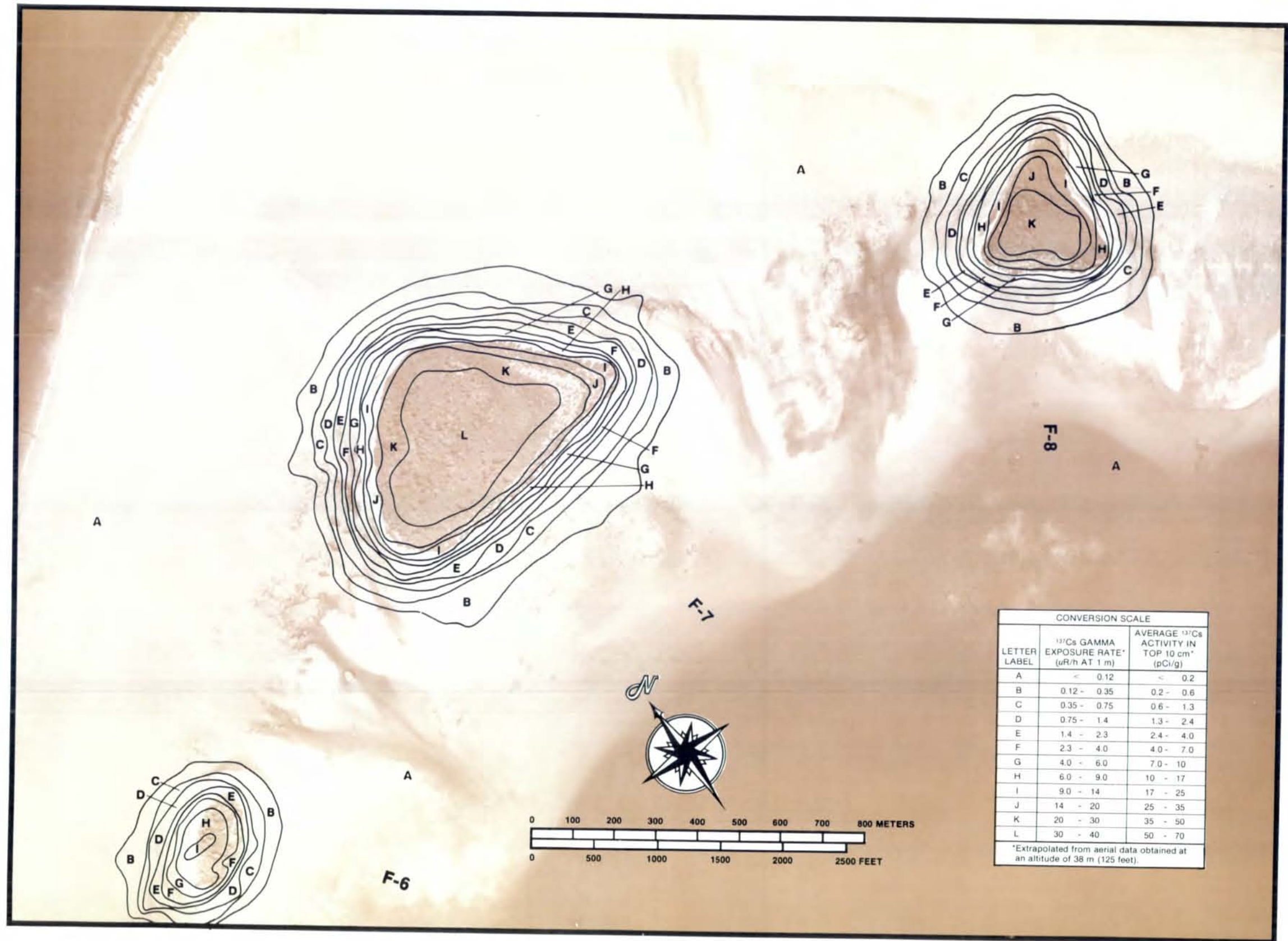


Figure D-9. CESIUM 137 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS F-6 TO F-8 AT RONGELAP ATOLL. (Photograph Frame Number 189)



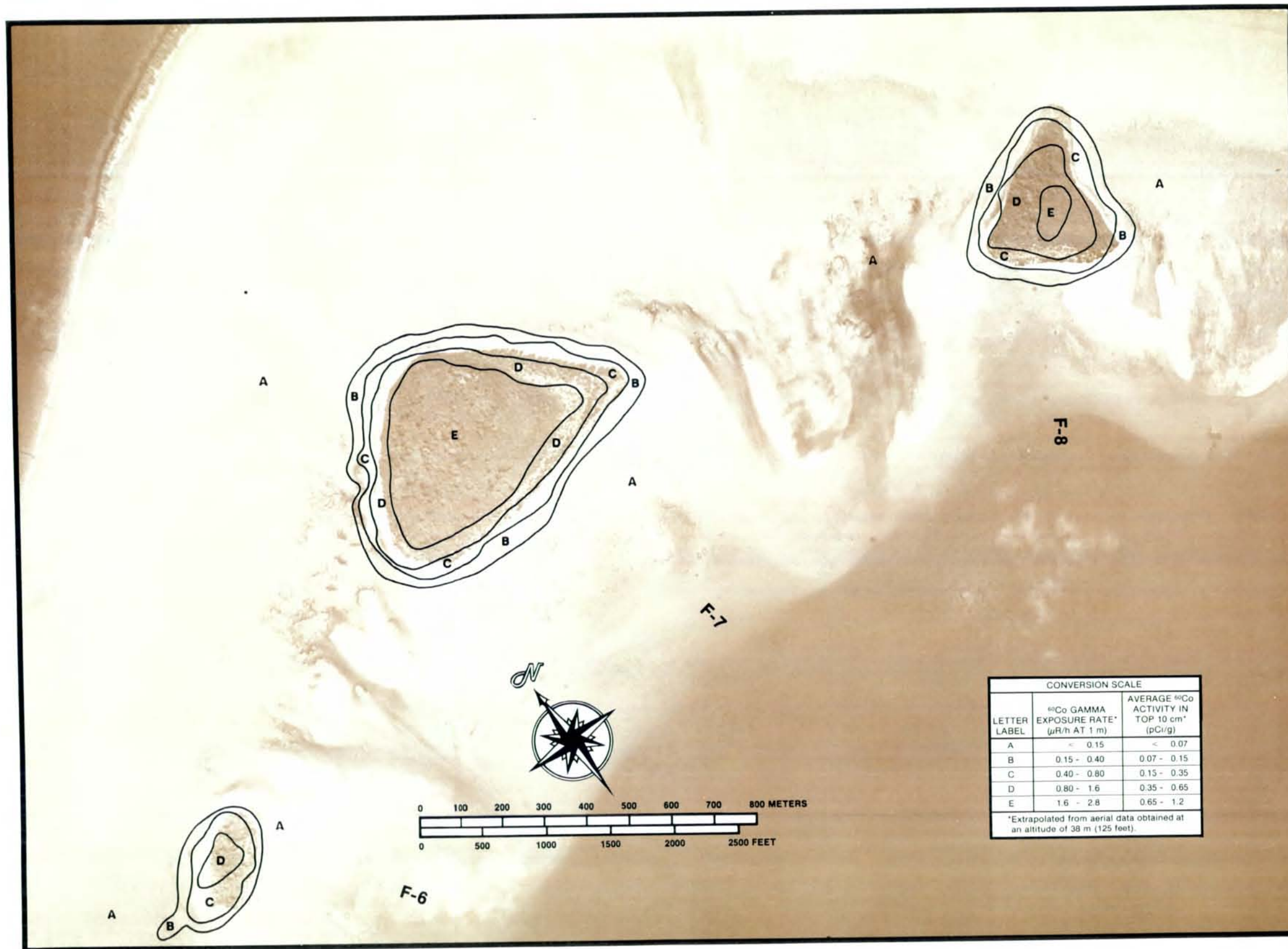


Figure D-10. COBALT 60 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS F-6 TO F-8 AT RONGELAP ATOLL. (Photograph Frame Number 189)



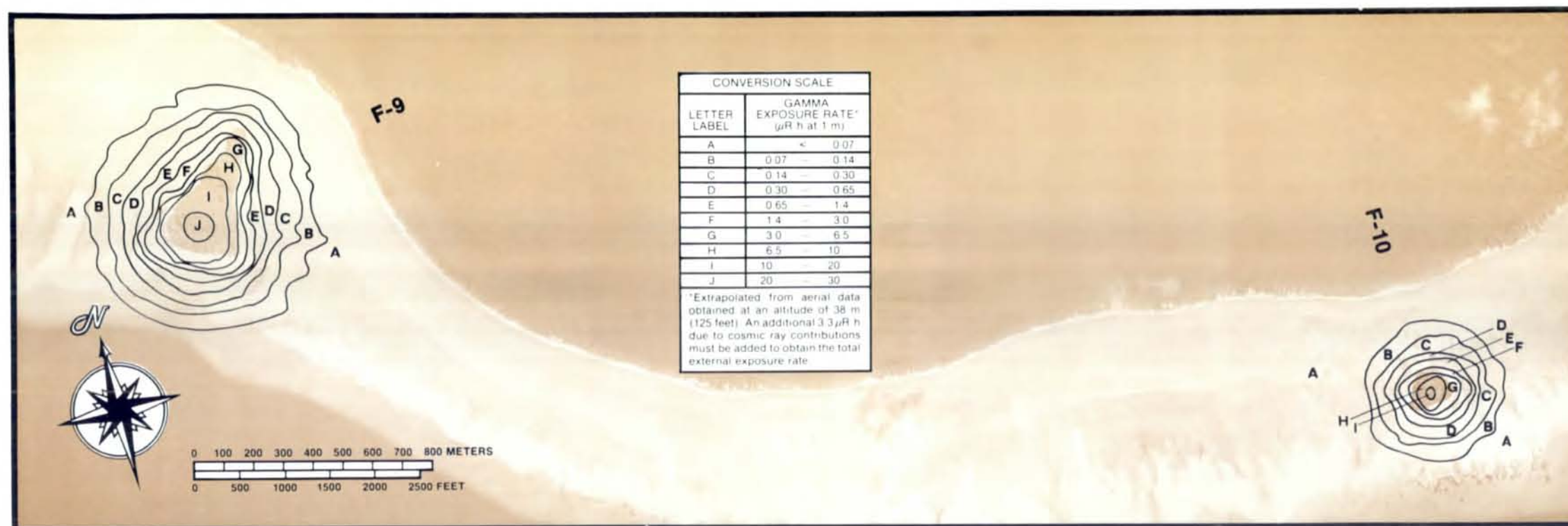


Figure D-11. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS F-9 TO F-10 AT RONGELAP ATOLL. (Photograph Frame Number 153)

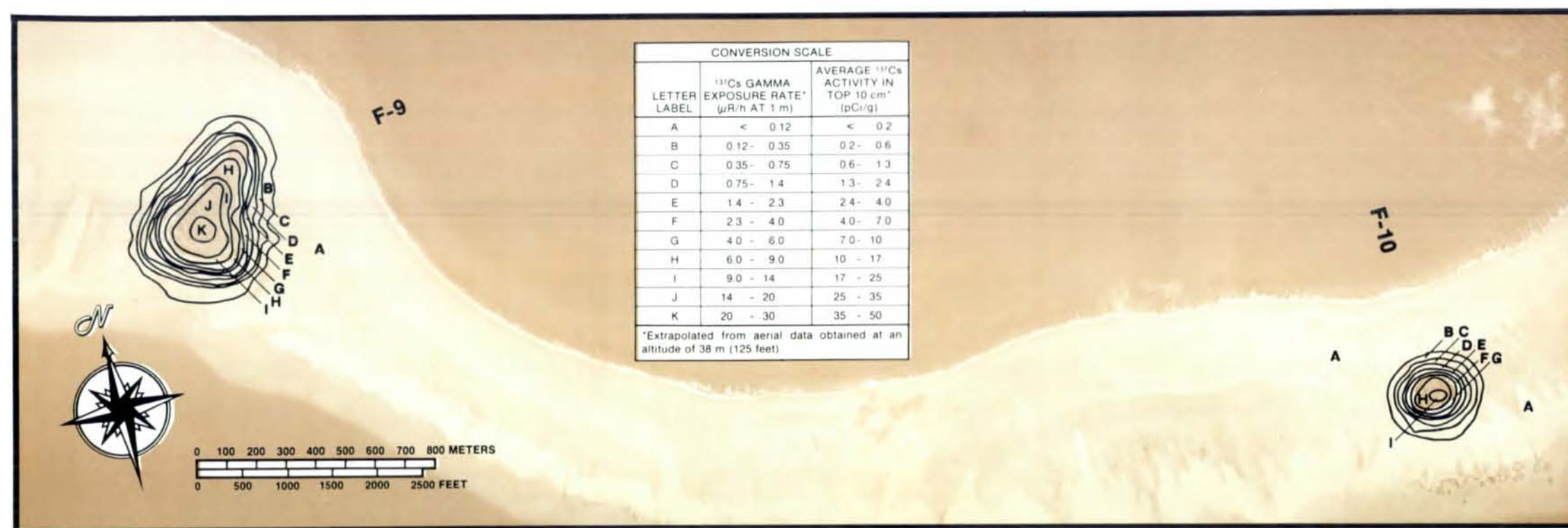


Figure D-12. CESIUM 137 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS F-9 TO F-10 AT RONGELAP ATOLL. (Photograph Frame Number 153)



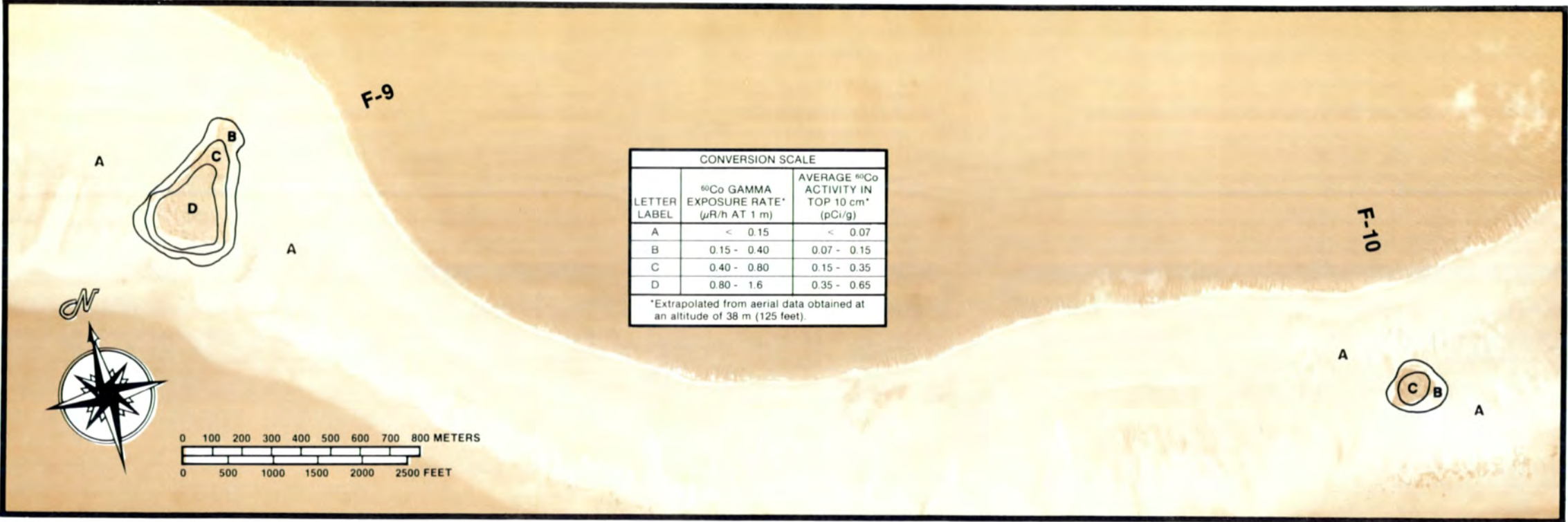


Figure D-13. COBALT 60 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS F-9 TO F-10 AT RONGELAP ATOLL. (Photograph Frame Number 153)



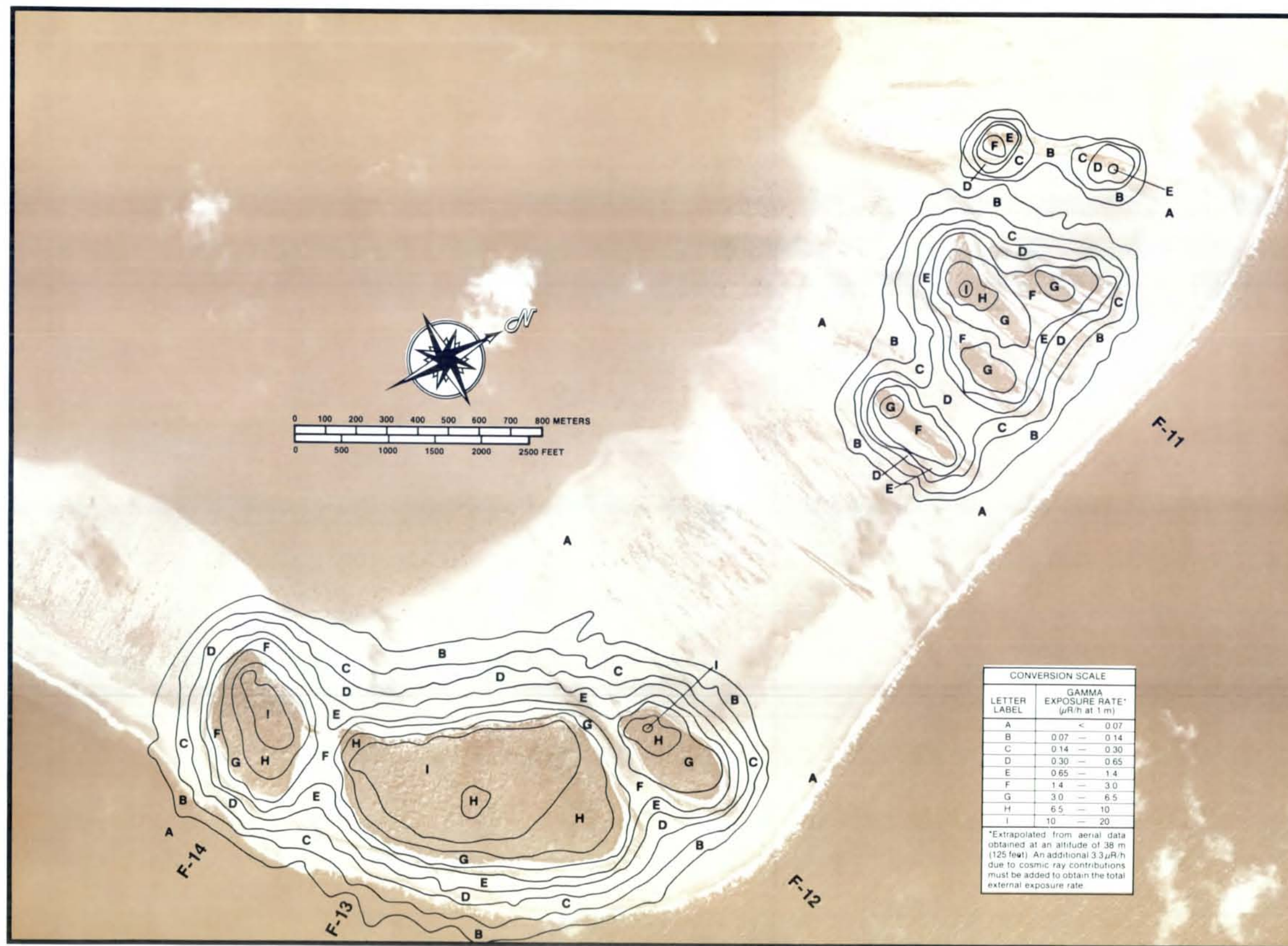


Figure D-14. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS F-11 TO F-14 AT RONGELAP ATOLL. (Photograph Frame Number 139)



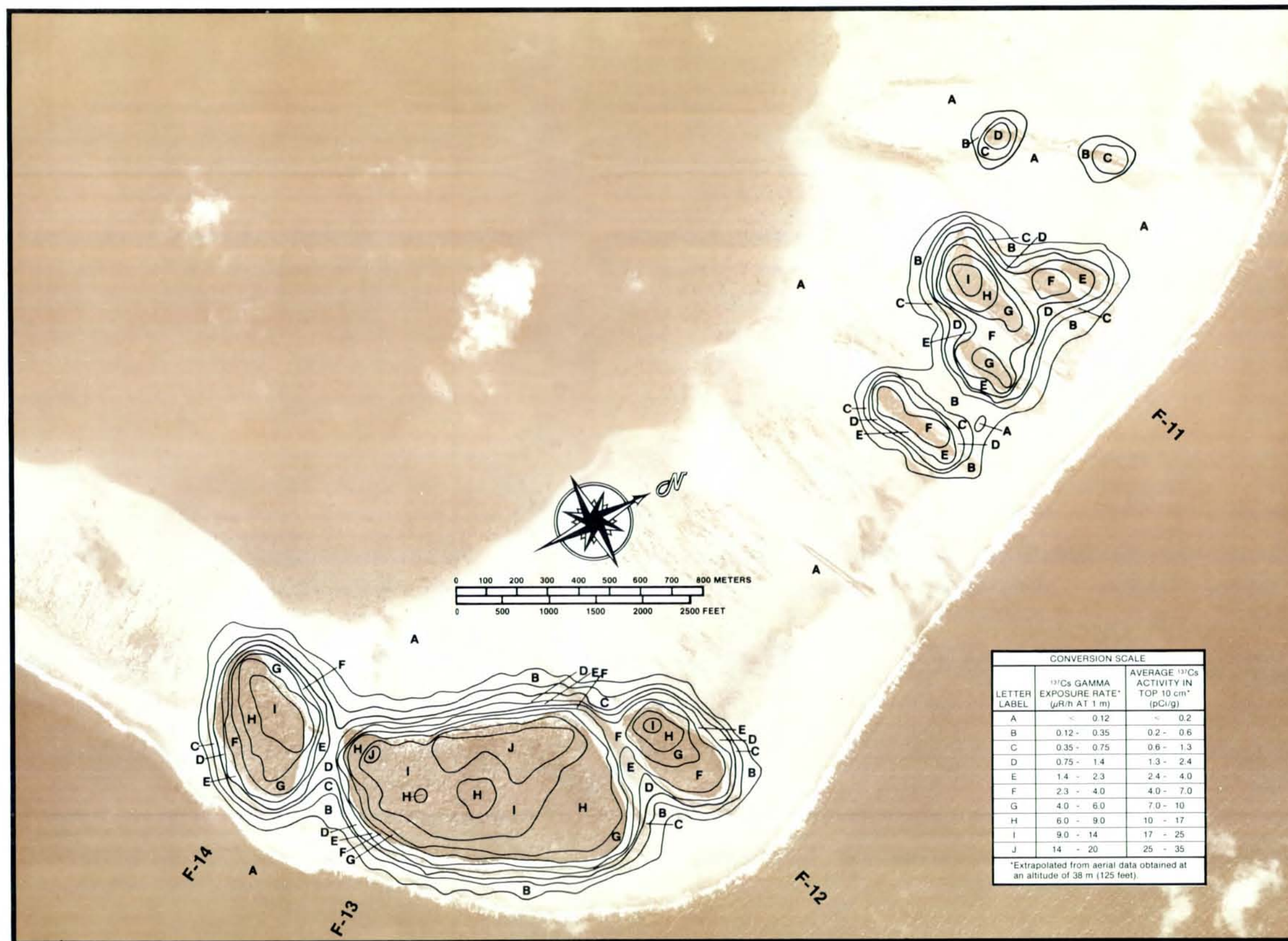


Figure D-15. CESIUM 137 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS F-11 TO F-14 AT RONGELAP ATOLL. (Photograph Frame Number 139)



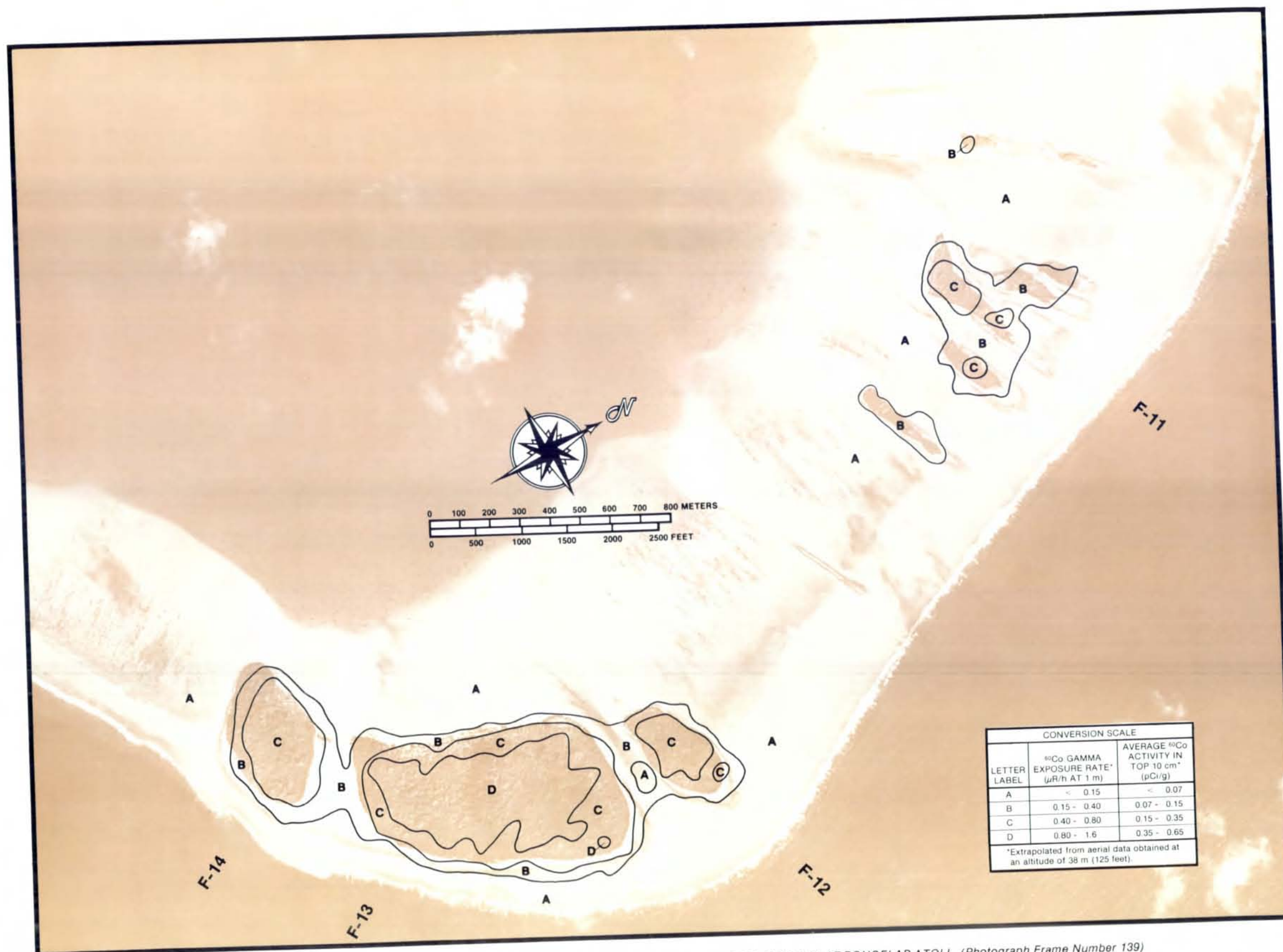


Figure D-16. COBALT 60 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS F-11 TO F-14 AT RONGELAP ATOLL. (Photograph Frame Number 139)



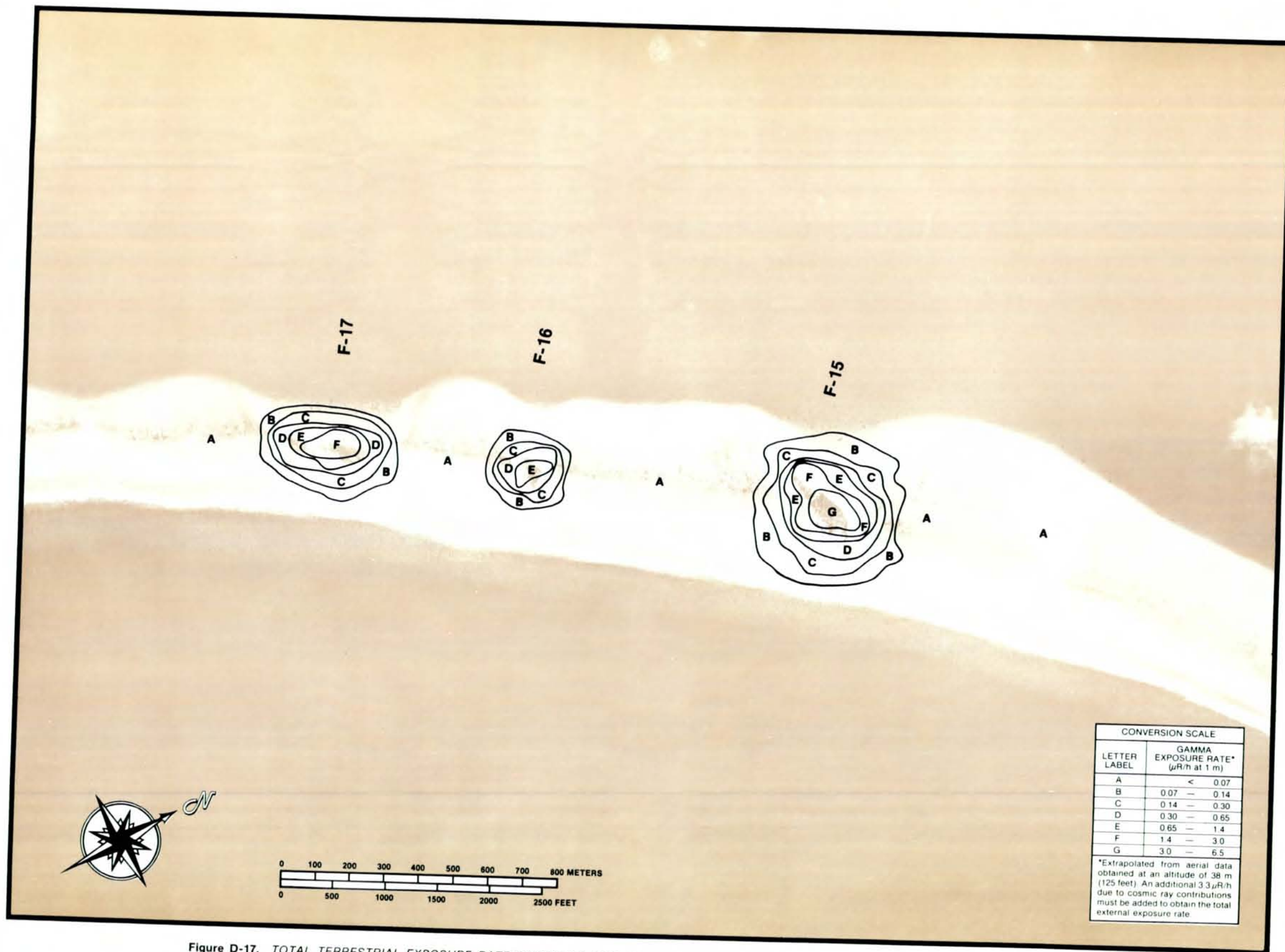


Figure D-17. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS F-15 TO F-17 AT RONGELAP ATOLL. (Photograph Frame Number 136)



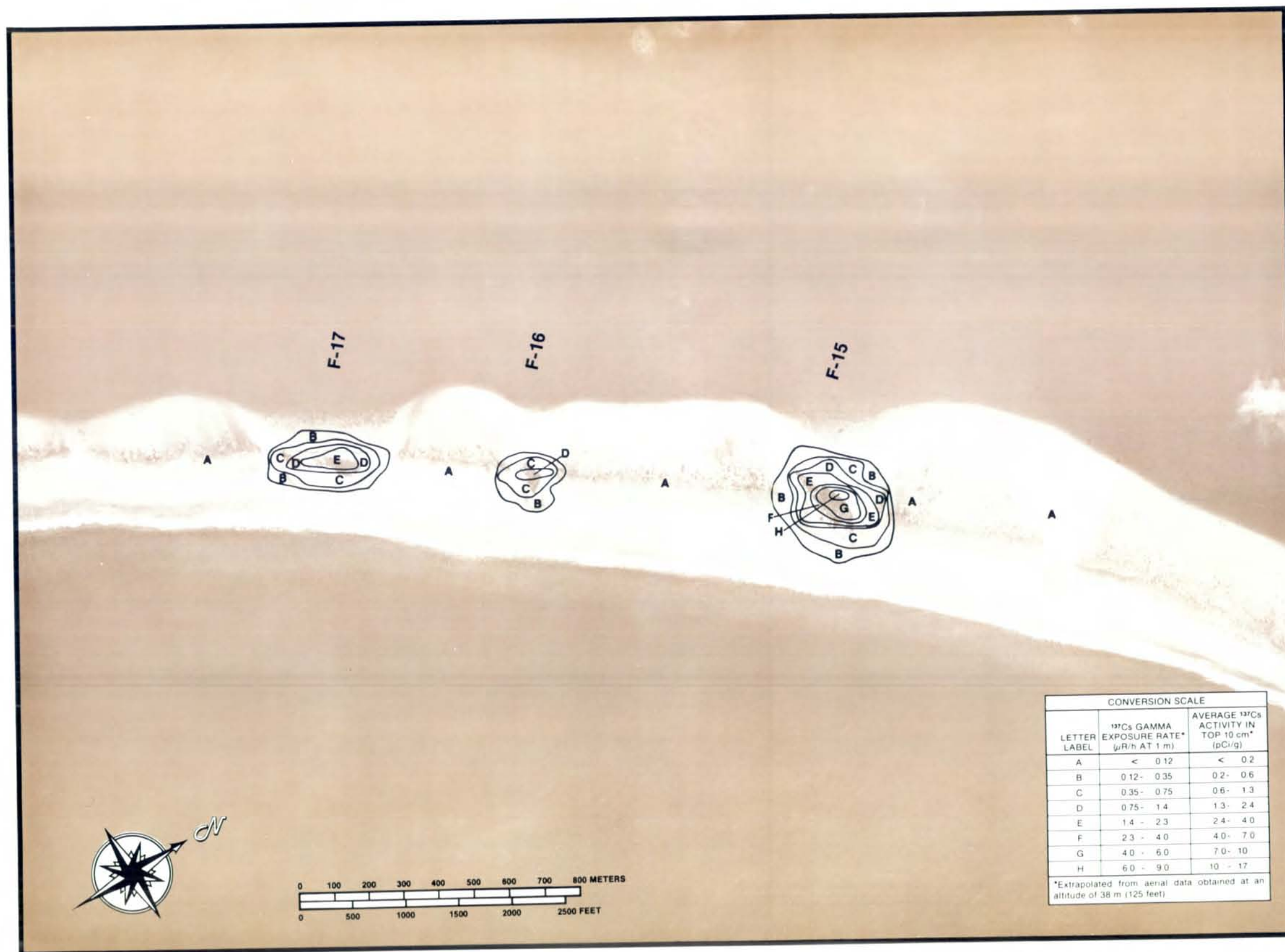


Figure D-18. CESIUM 137 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS F-15 TO F-17 AT RONGELAP ATOLL. (Photograph Frame Number 136)



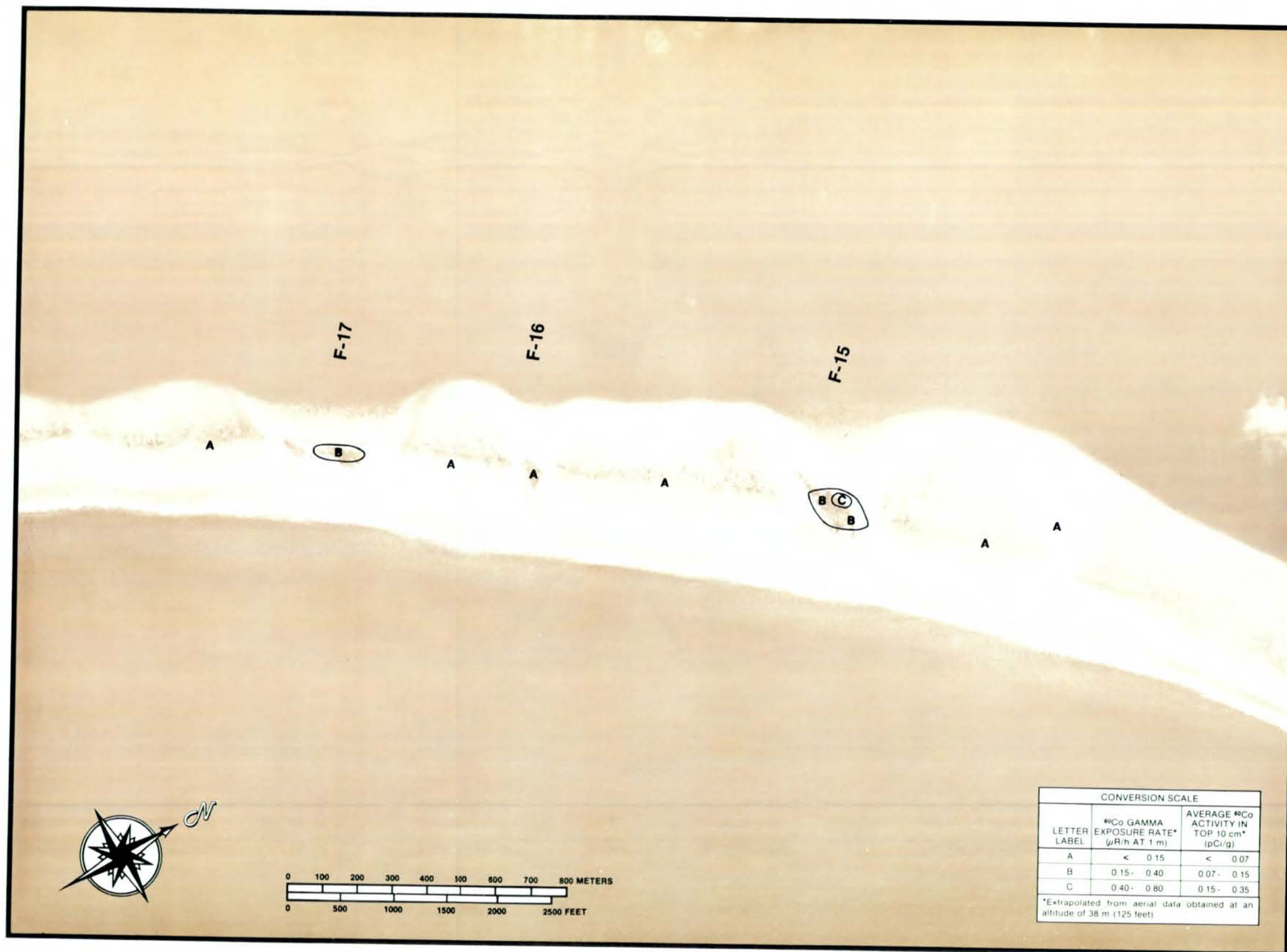


Figure D-19. COBALT 60 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS F-15 TO F-17 AT RONGELAP ATOLL. (Photograph Frame Number 136)



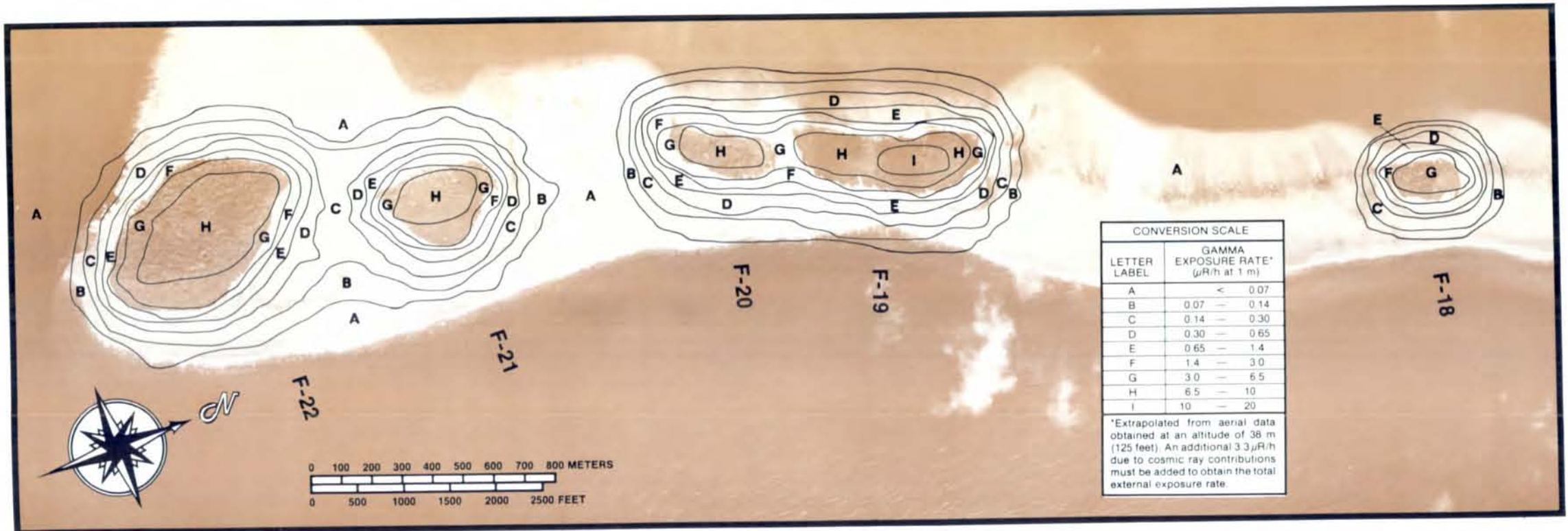


Figure D-20. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS F-18 TO F-22 AT RONGELAP ATOLL. (Photograph Frame Number 179)

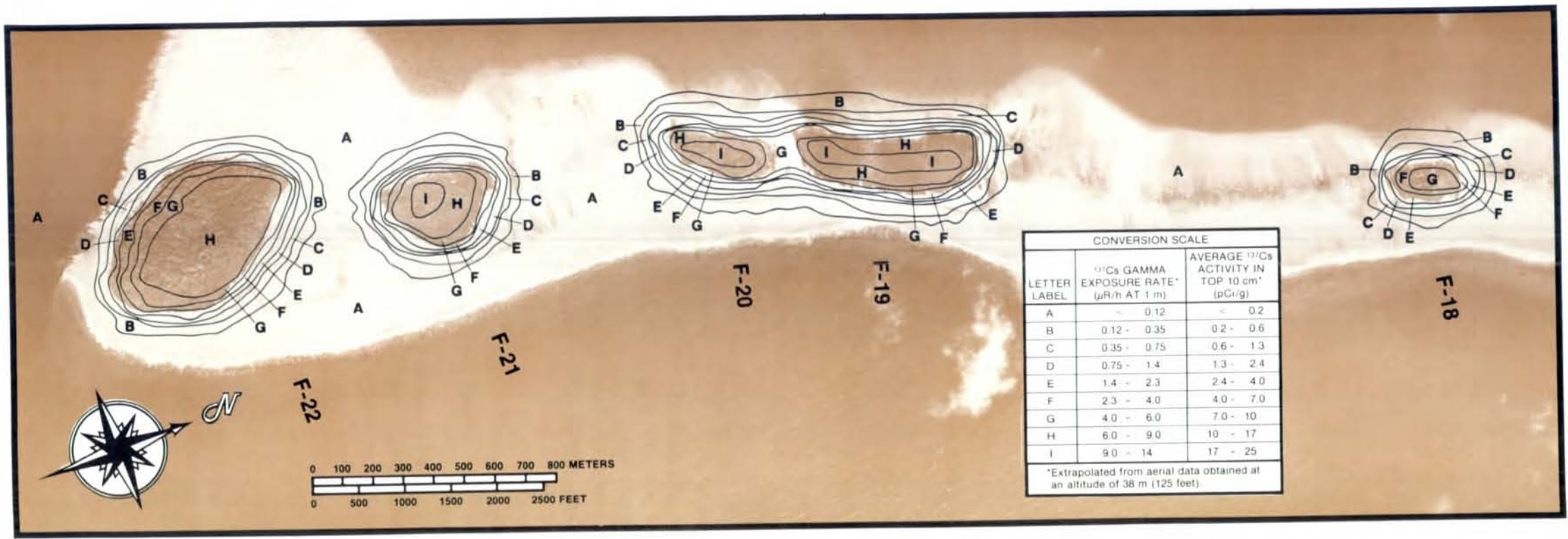


Figure D-21. CESIUM 137 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS F-18 TO F-22 AT RONGELAP ATOLL. (Photograph Frame Number 179)



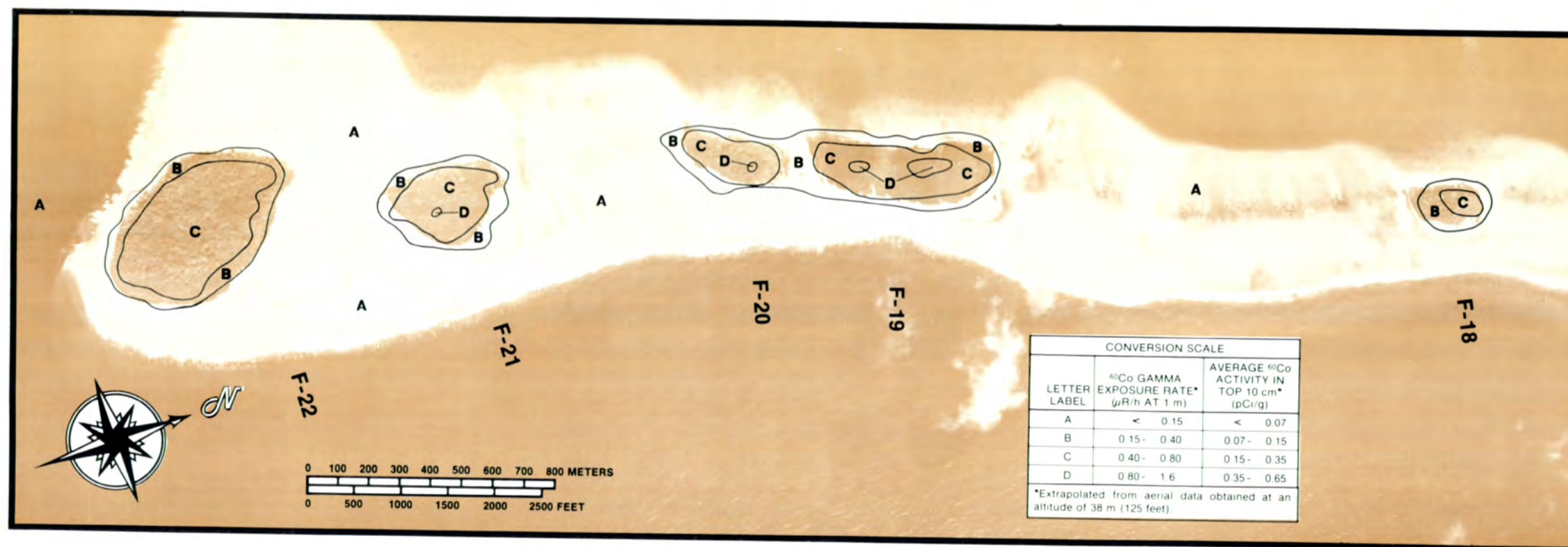


Figure D-22. COBALT 60 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS F-18 TO F-22 AT RONGELAP ATOLL. (Photograph Frame Number 179)



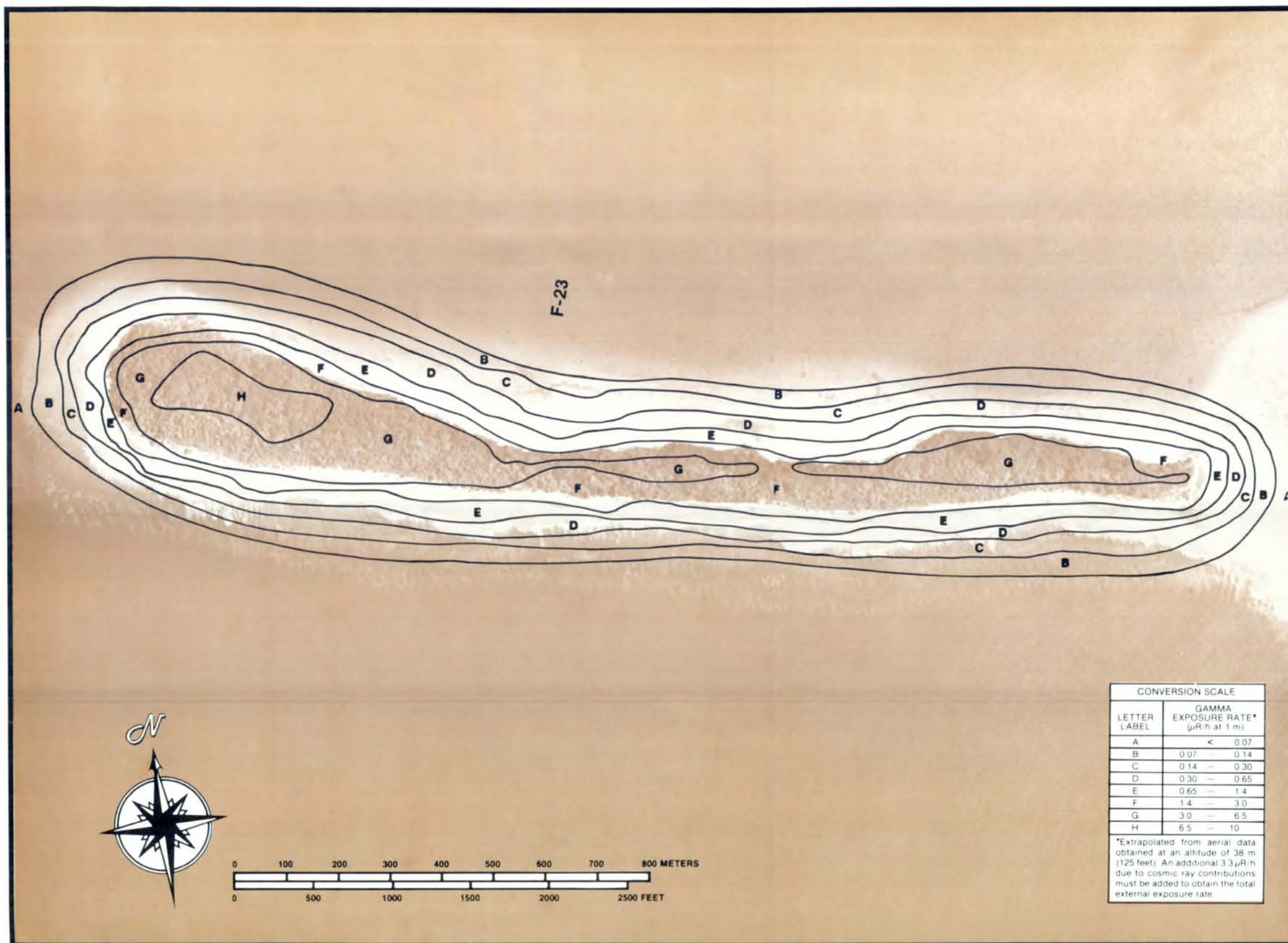


Figure D-23. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLAND F-23 AT RONGELAP ATOLL. (Photograph Frame Number 177)



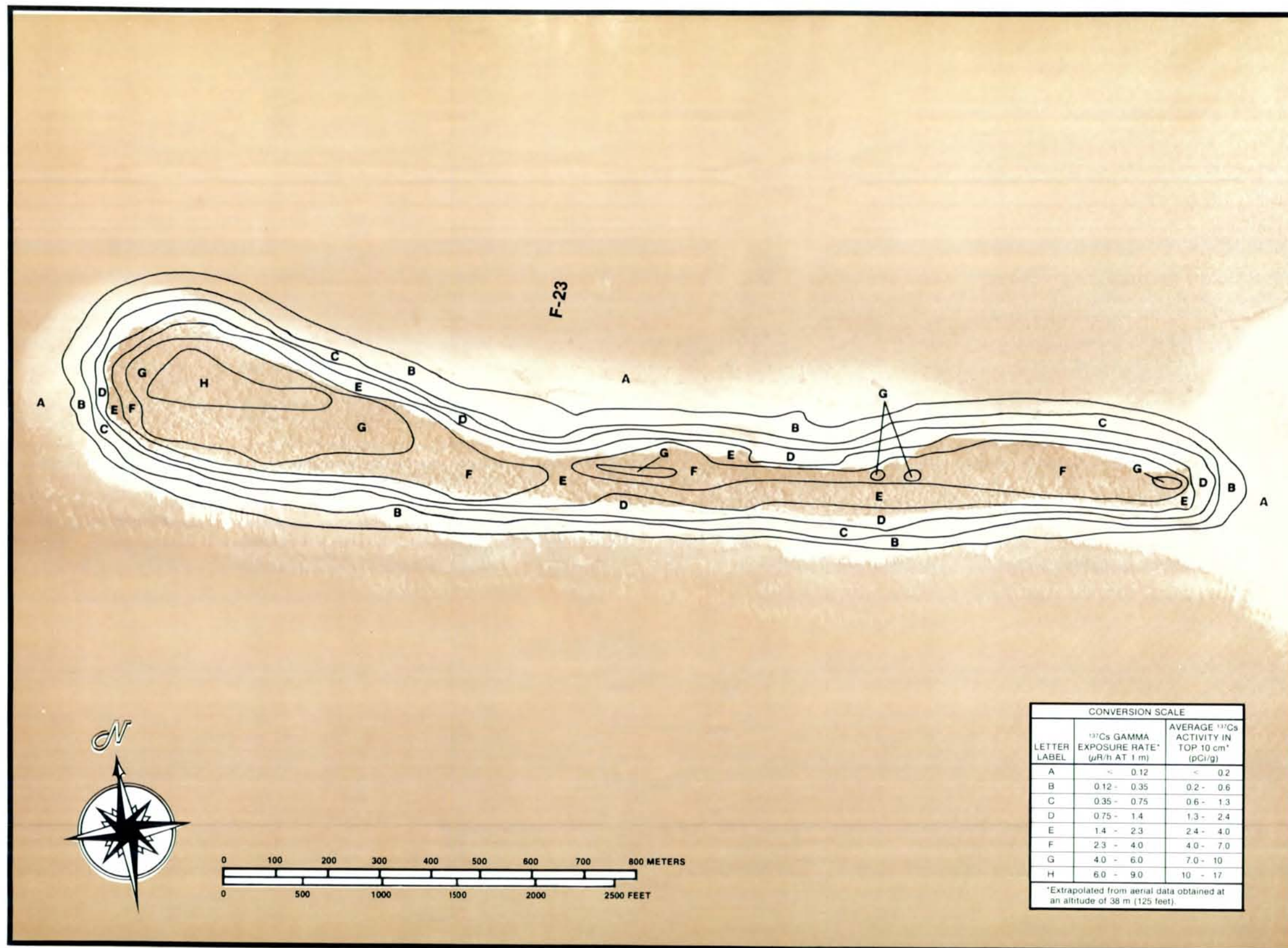


Figure D-24. CESIUM 137 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLAND F-23 AT RONGELAP ATOLL. (Photograph Frame Number 177)



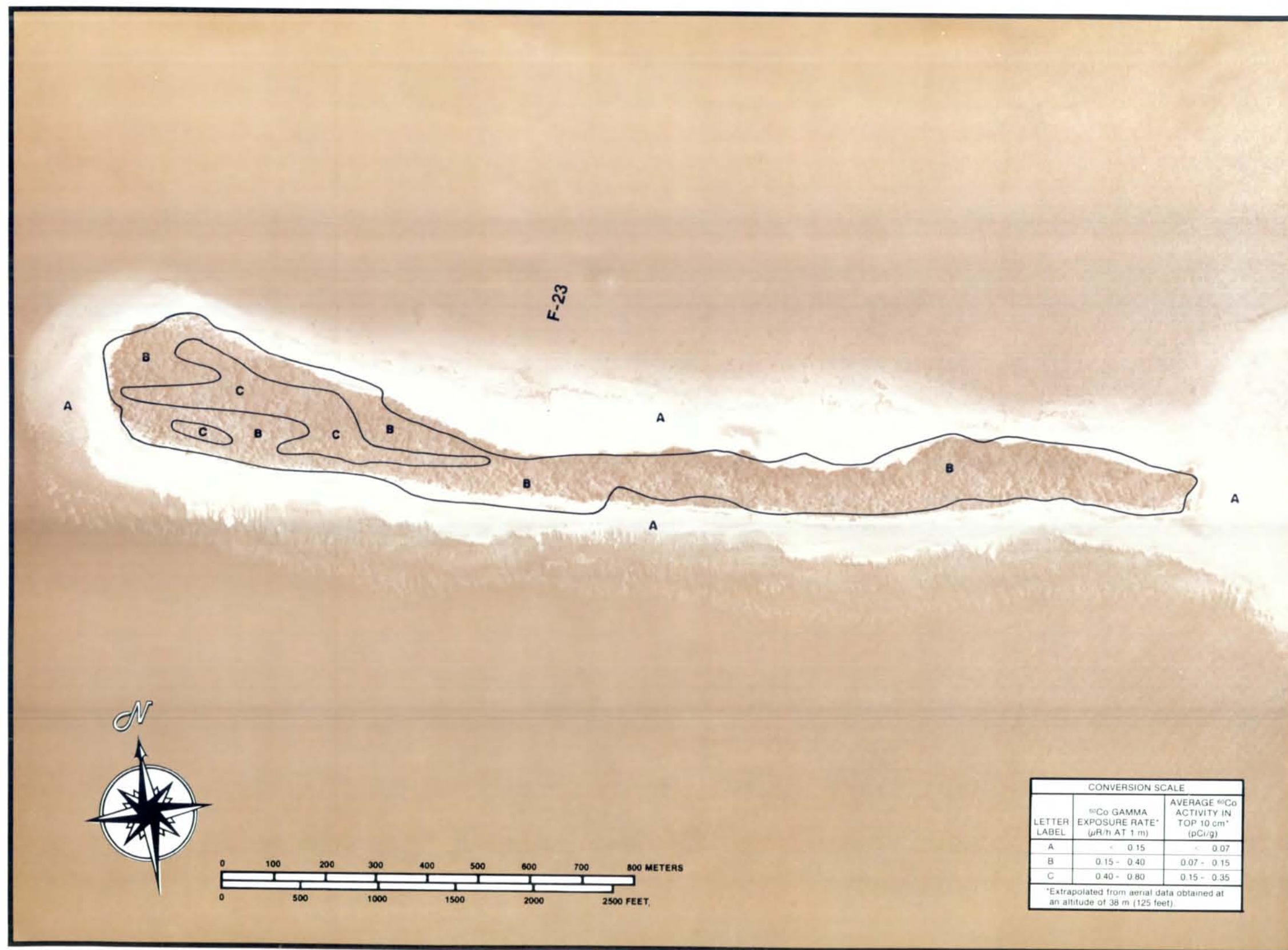


Figure D-25. COBALT 60 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLAND F-23 AT RONGELAP ATOLL. (Photograph Frame Number 177)



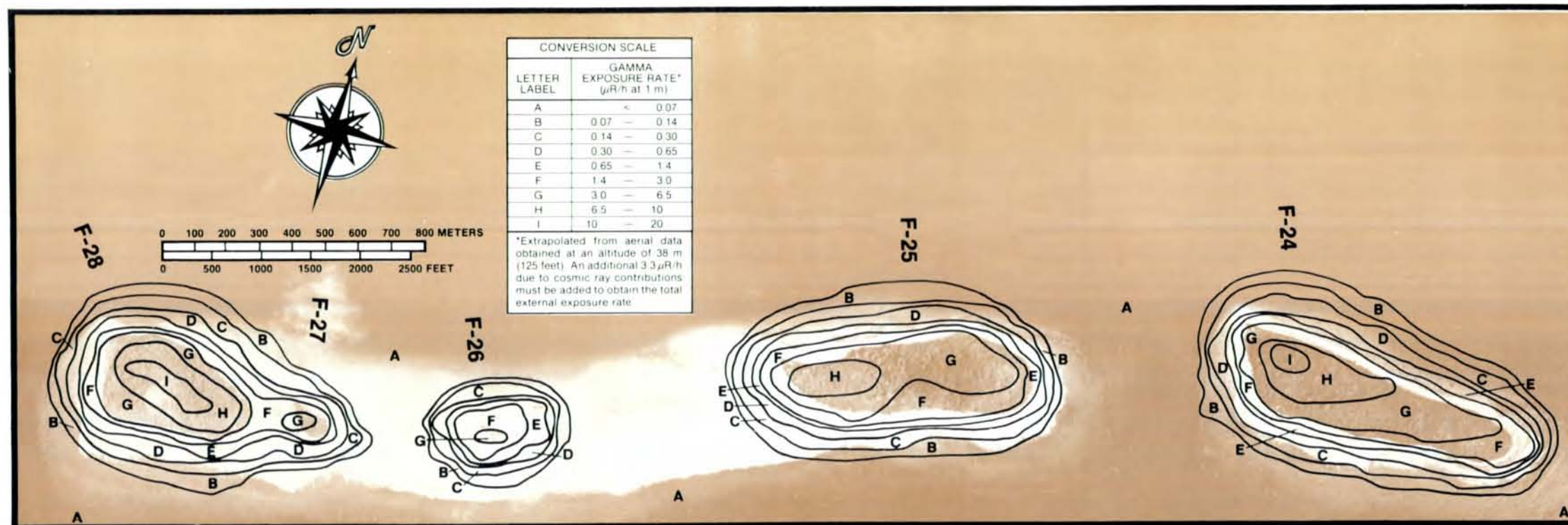


Figure D-26. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS F-24 TO F-28 AT RONGELAP ATOLL. (Photograph Frame Number 175)

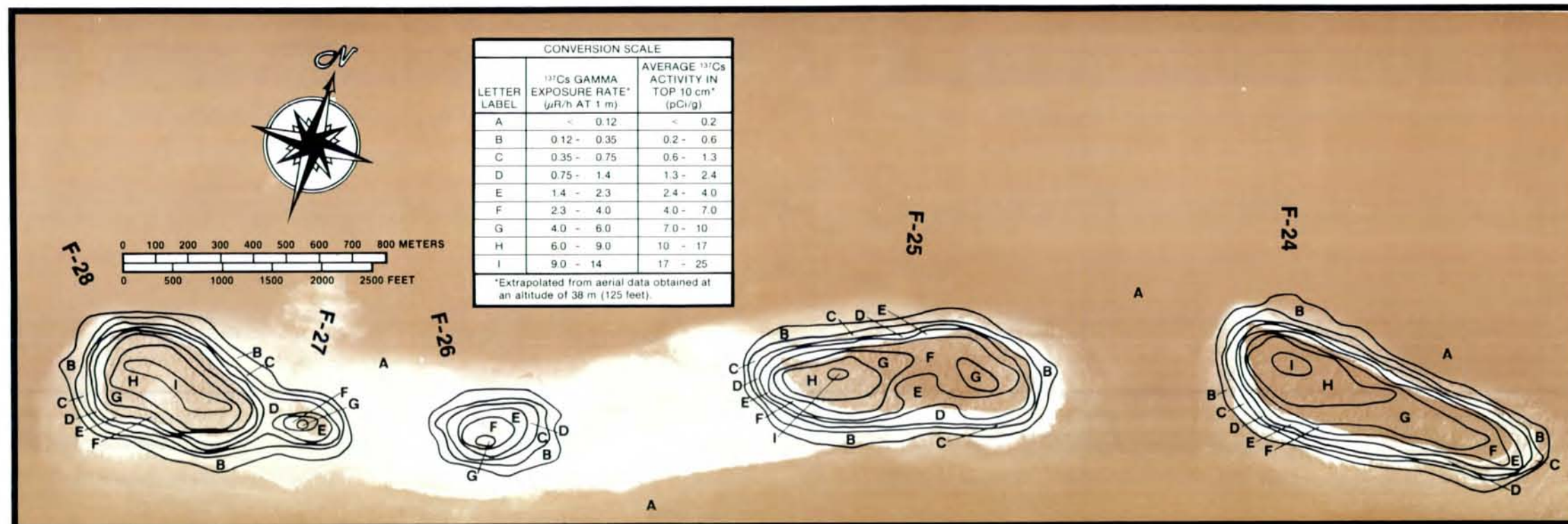


Figure D-27. CESIUM 137 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS F-24 TO F-28 AT RONGELAP ATOLL. (Photograph Frame Number 175)



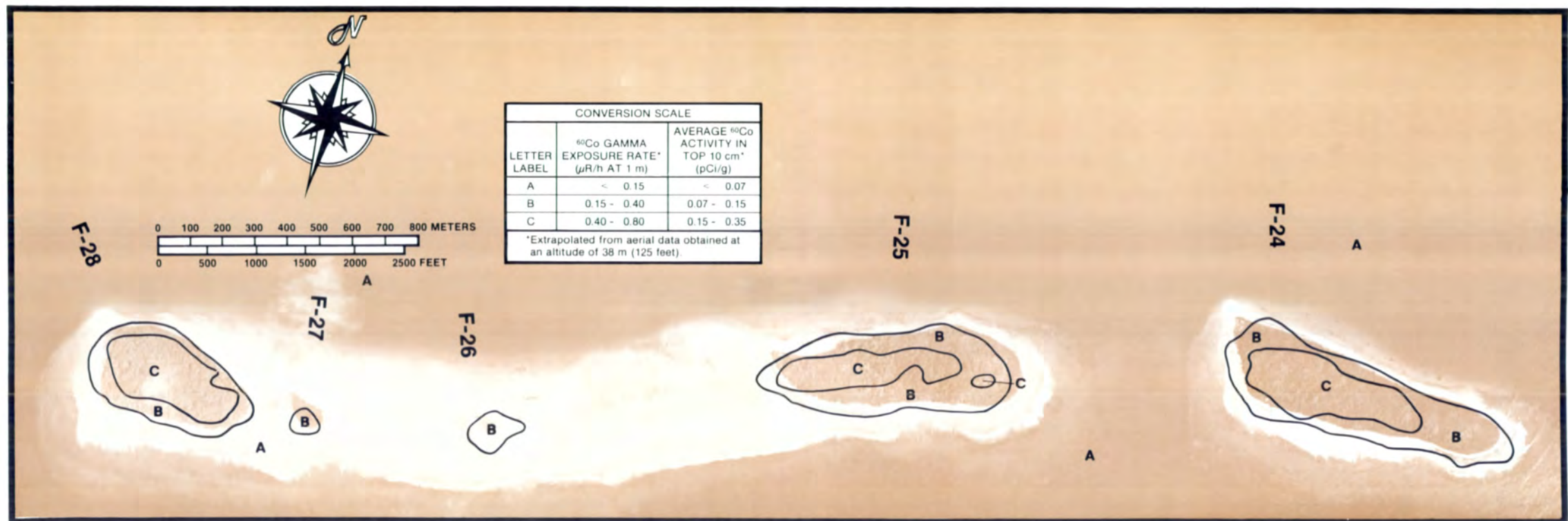


Figure D-28. COBALT 60 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS F-24 TO F-28 AT RONGELAP ATOLL. (Photograph Frame Number 175)



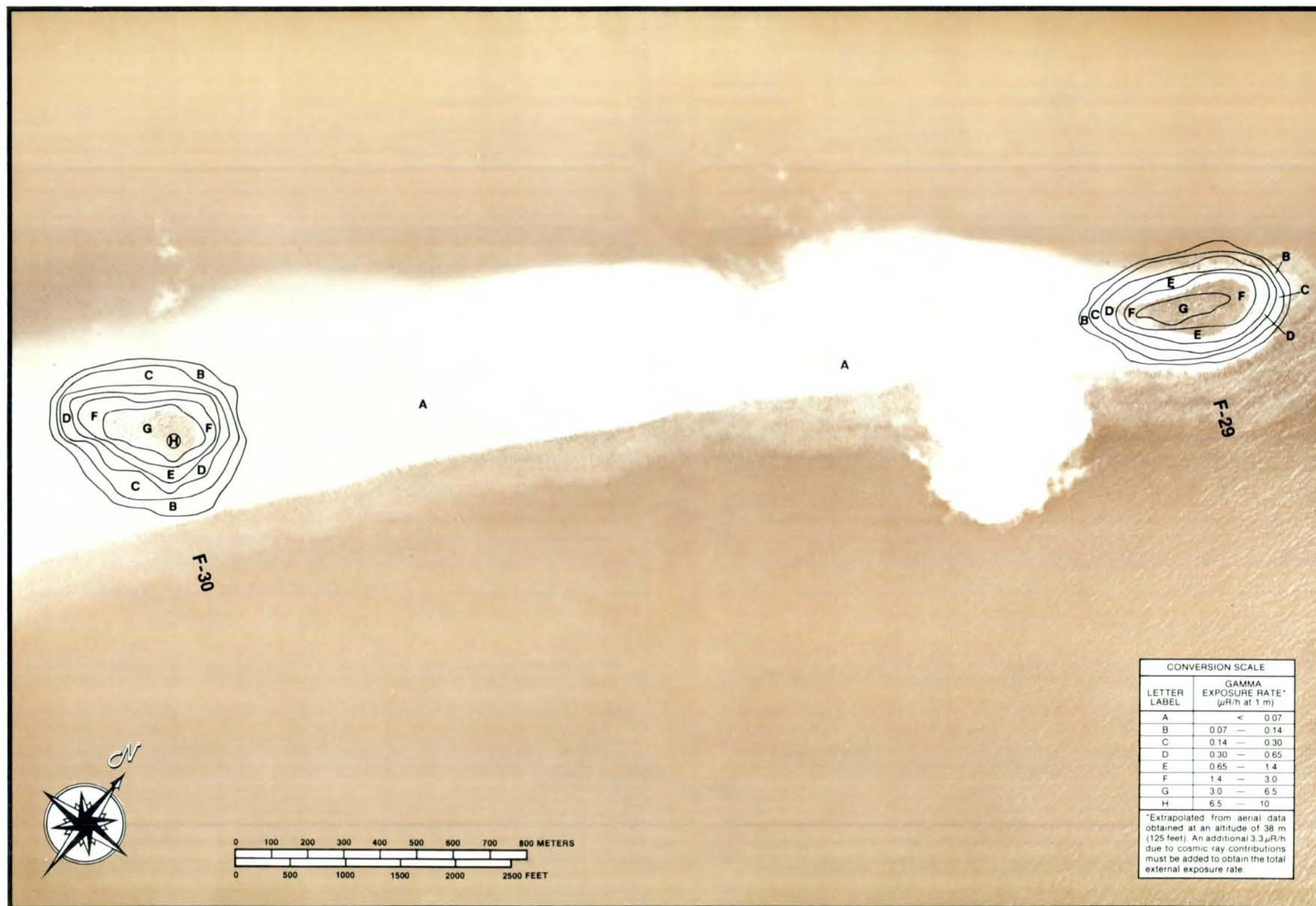


Figure D-29. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS F-29 TO F-30 AT RONGELAP ATOLL. (Photograph Frame Number 172)



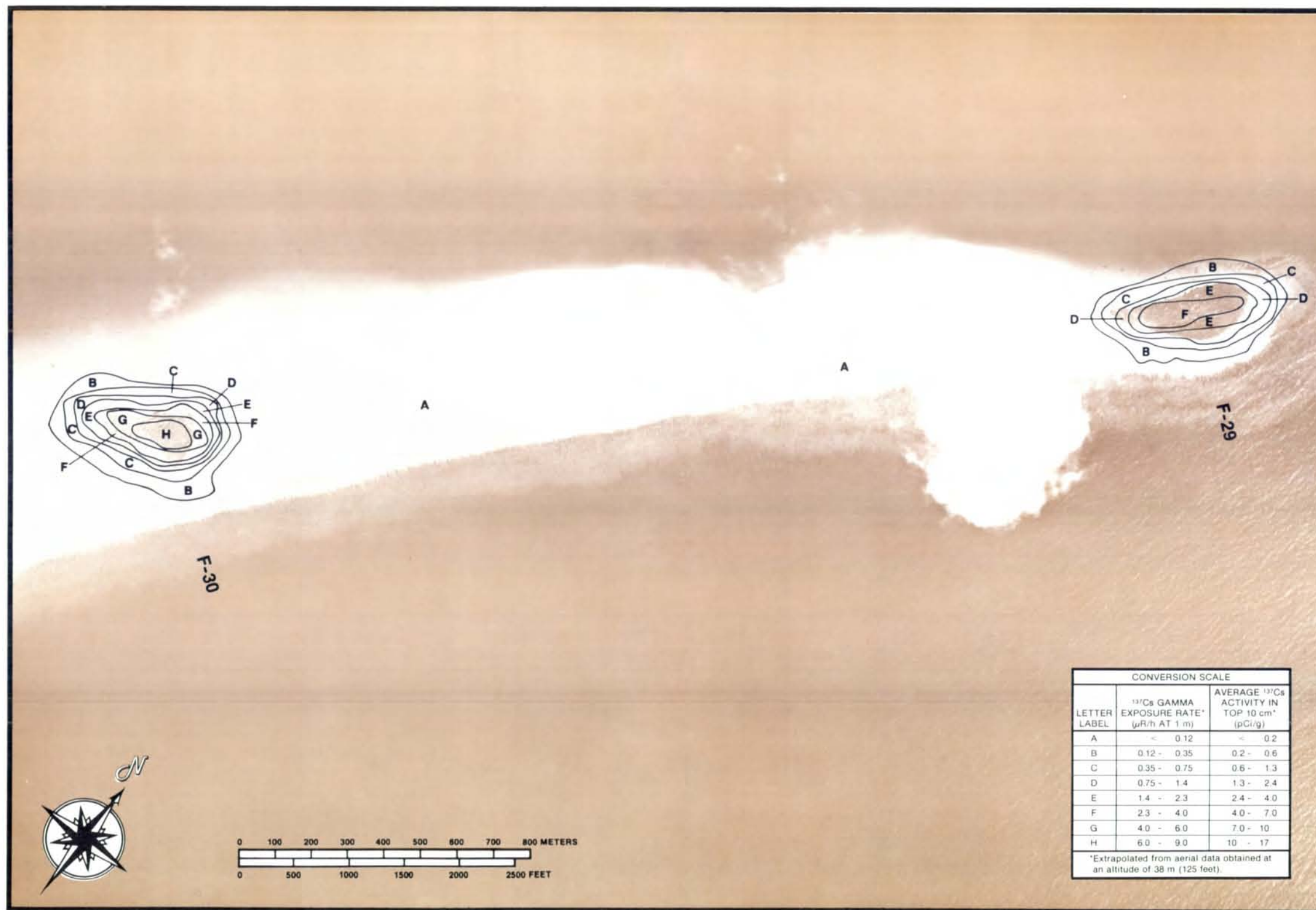


Figure D-30. CESIUM 137 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS F-29 TO F-30 AT RONGELAP ATOLL. (Photograph Frame Number 172)





Figure D-31. COBALT 60 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS F-29 TO F-30 AT RONGELAP ATOLL. (Photograph Frame Number 172)



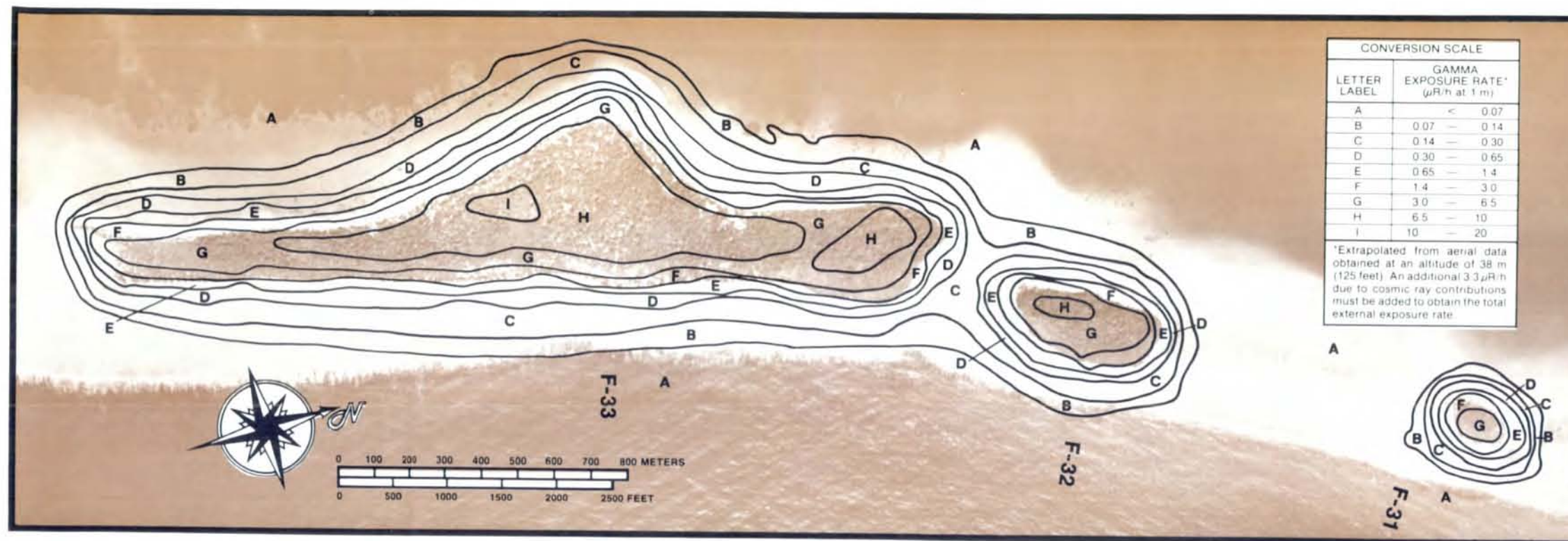


Figure D-32. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS F-31 TO F-33 AT RONGELAP ATOLL. (Photograph Frame Number 80)

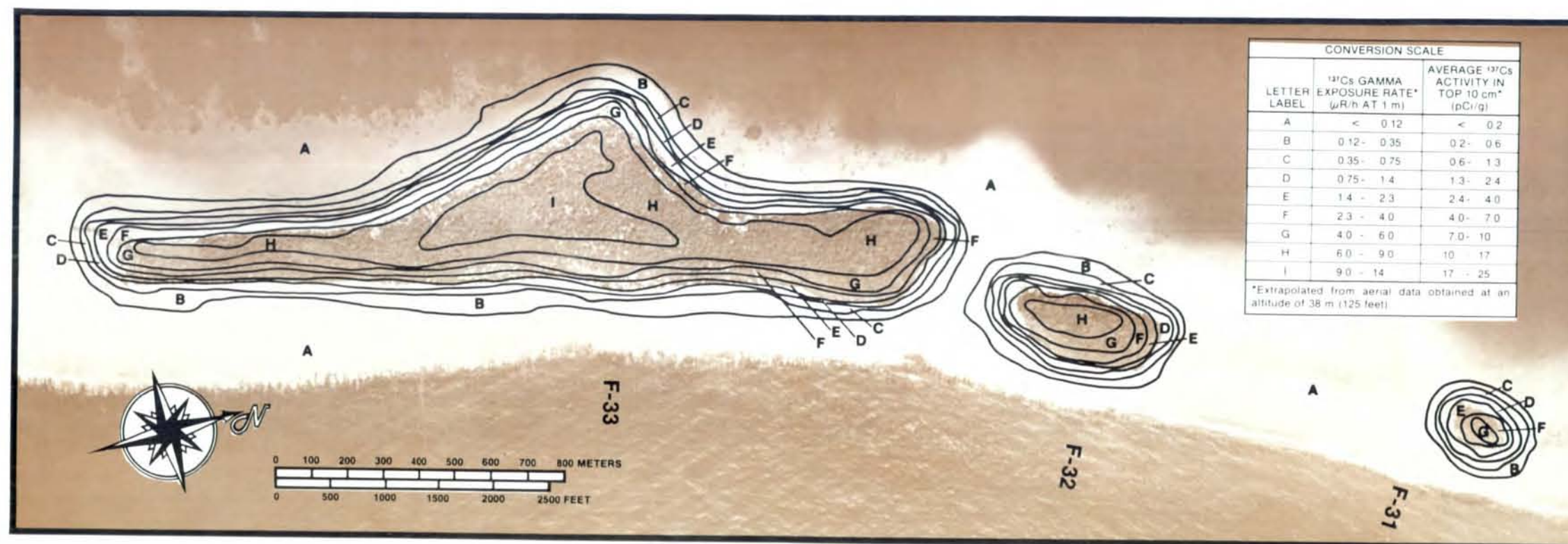


Figure D-33. CESIUM 137 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS F-31 TO F-33 AT RONGELAP ATOLL. (Photograph Frame Number 80)



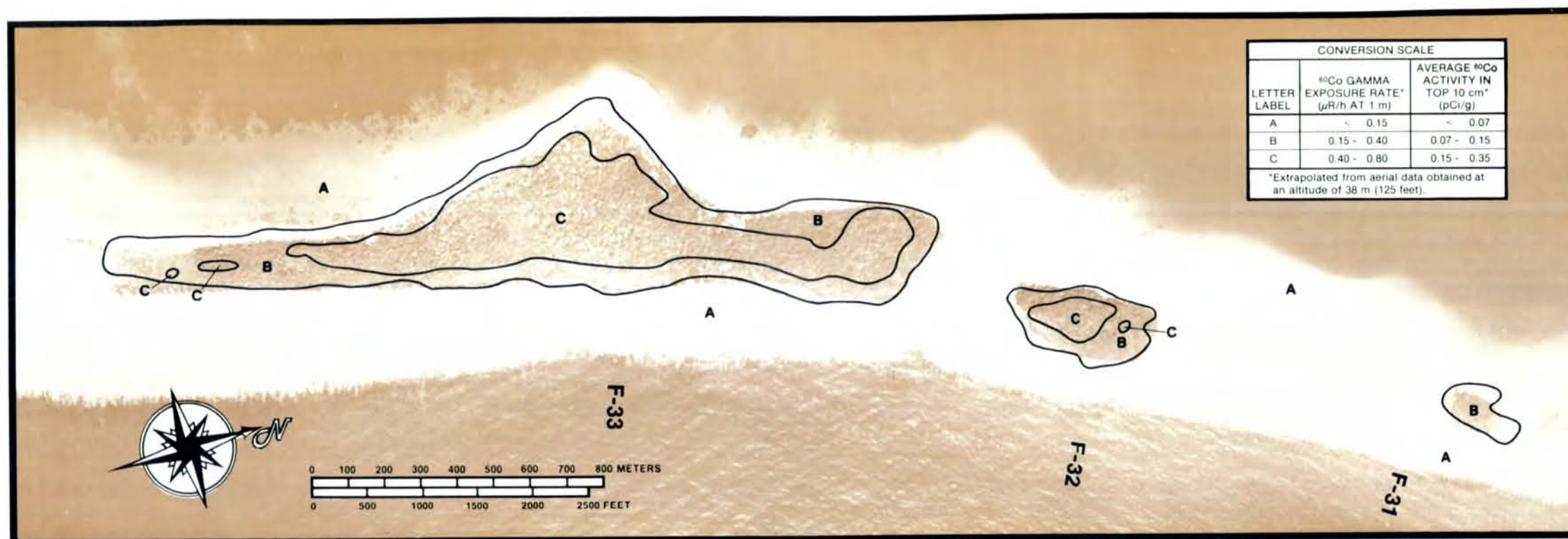


Figure D-34. COBALT 60 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS F-31 TO F-33 AT RONGELAP ATOLL. (Photograph Frame Number 80)

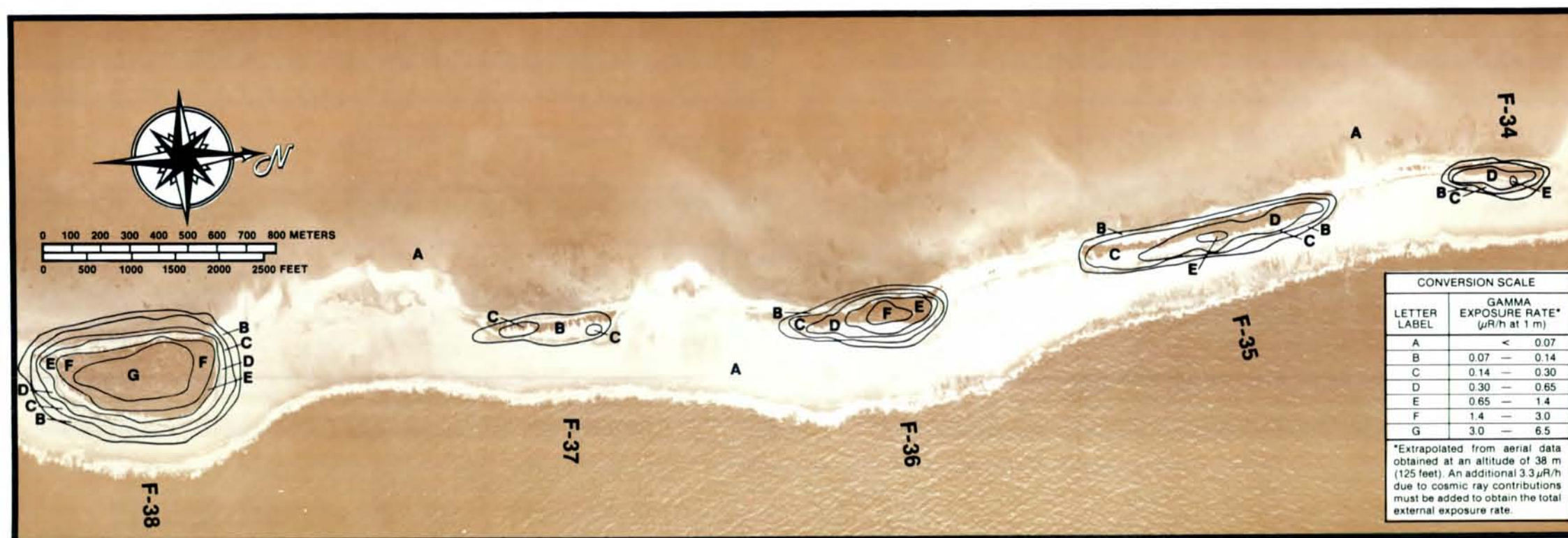


Figure D-35. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS F-34 TO F-38 AT RONGELAP ATOLL. (Photograph Frame Number 200)



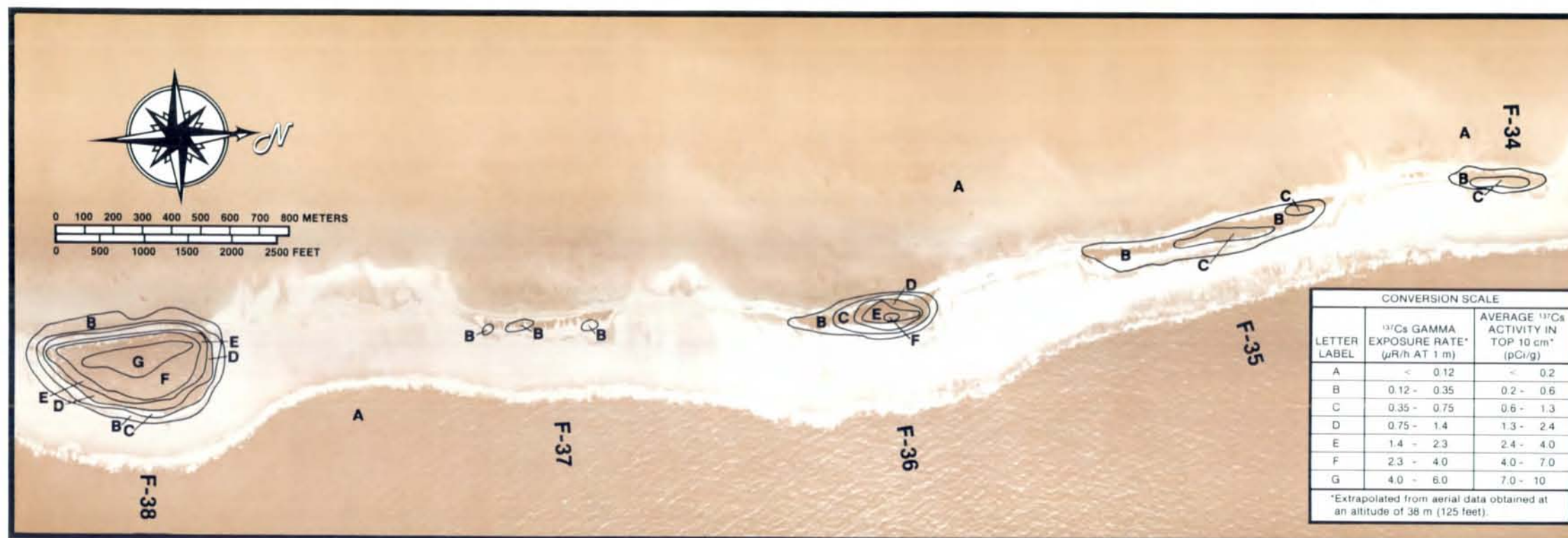


Figure D-36. CESIUM 137 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS F-34 TO F-38 AT RONGELAP ATOLL. (Photograph Frame Number 200)



Figure D-37. COBALT 60 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS F-34 TO F-38 AT RONGELAP ATOLL. (Photograph Frame Number 200)



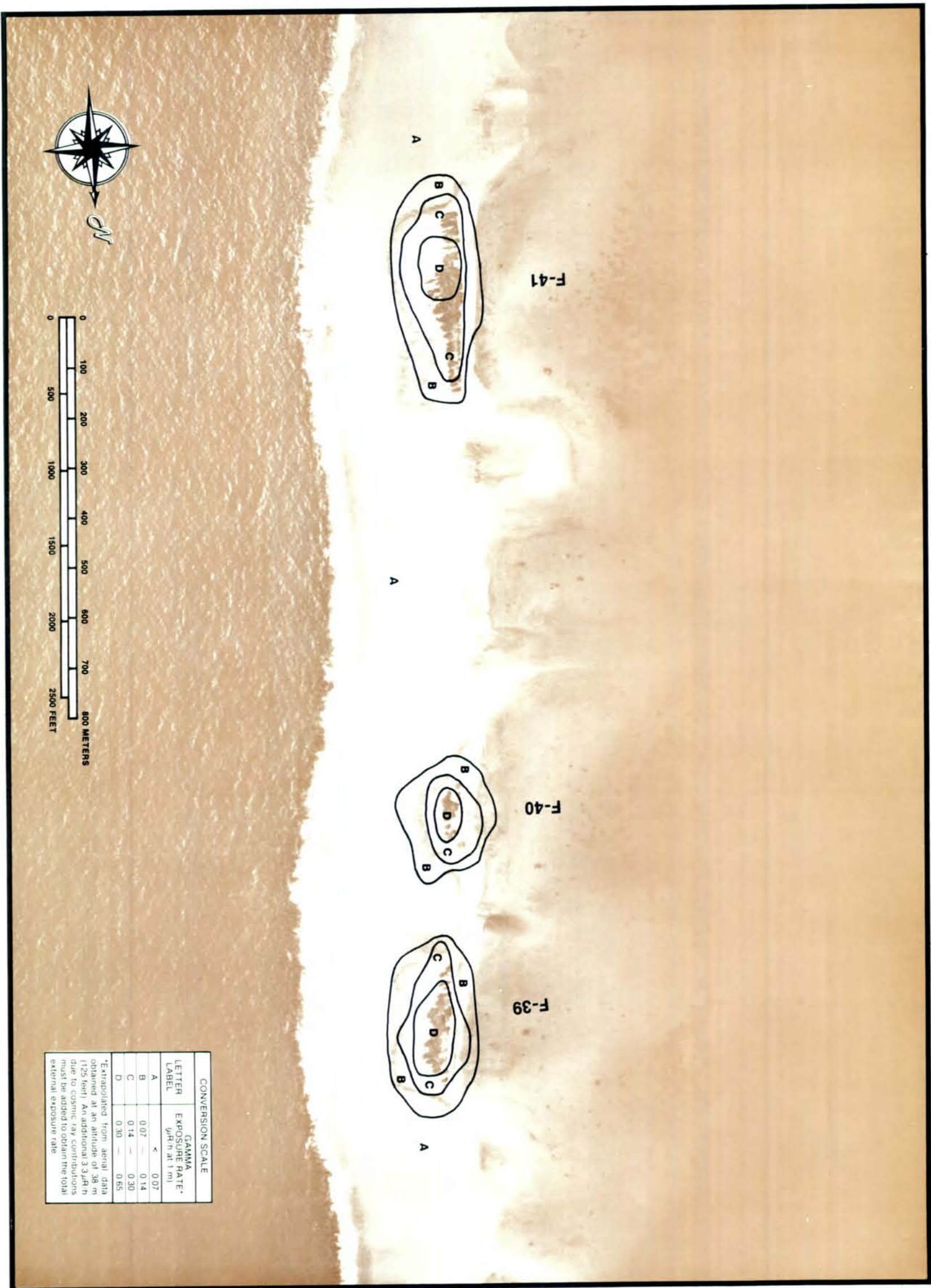


Figure D-38. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS F-39 TO F-41 AT RONGELAP ATOLL. (Photograph Frame Number 196)





Figure D-39. CESIUM 137 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS F-39 TO F-41 AT RONGELAP ATOLL. (Photograph Frame Number 196)





Figure D-40. COBALT 60 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS F-39 TO F-41 AT RONGELAP ATOLL. (Photograph Frame Number 196)



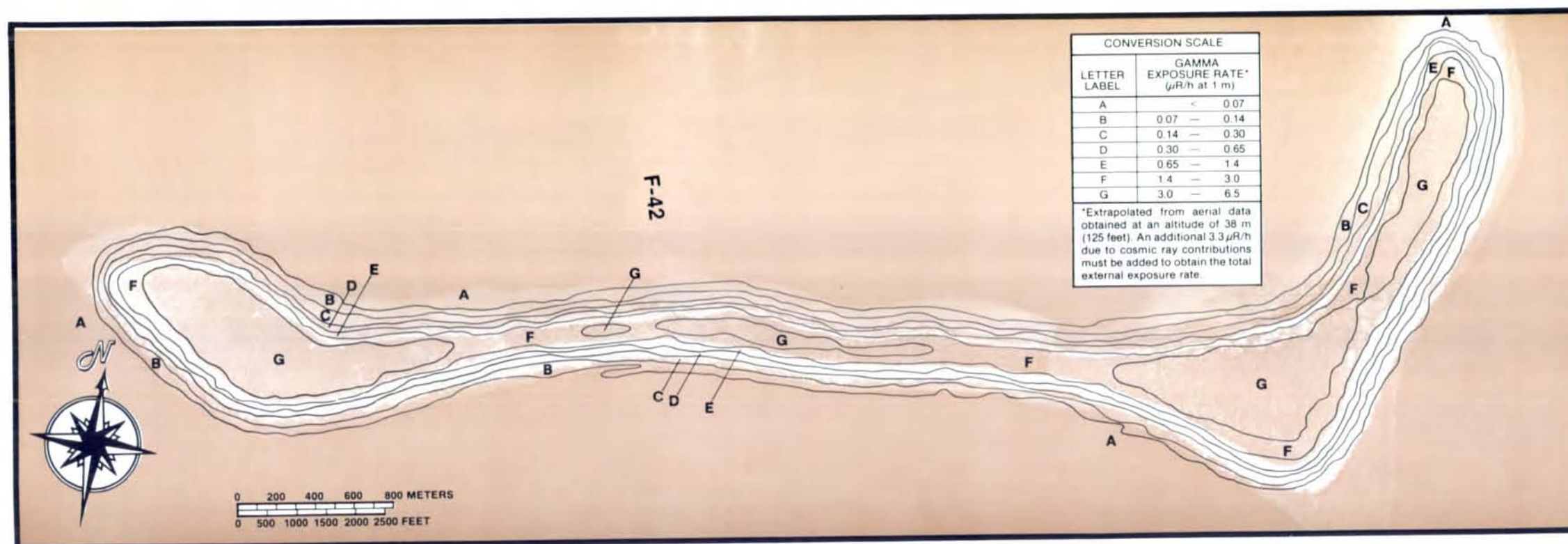


Figure D-41. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLAND F-42 AT RONGELAP ATOLL. (Photograph Frame Number 216)

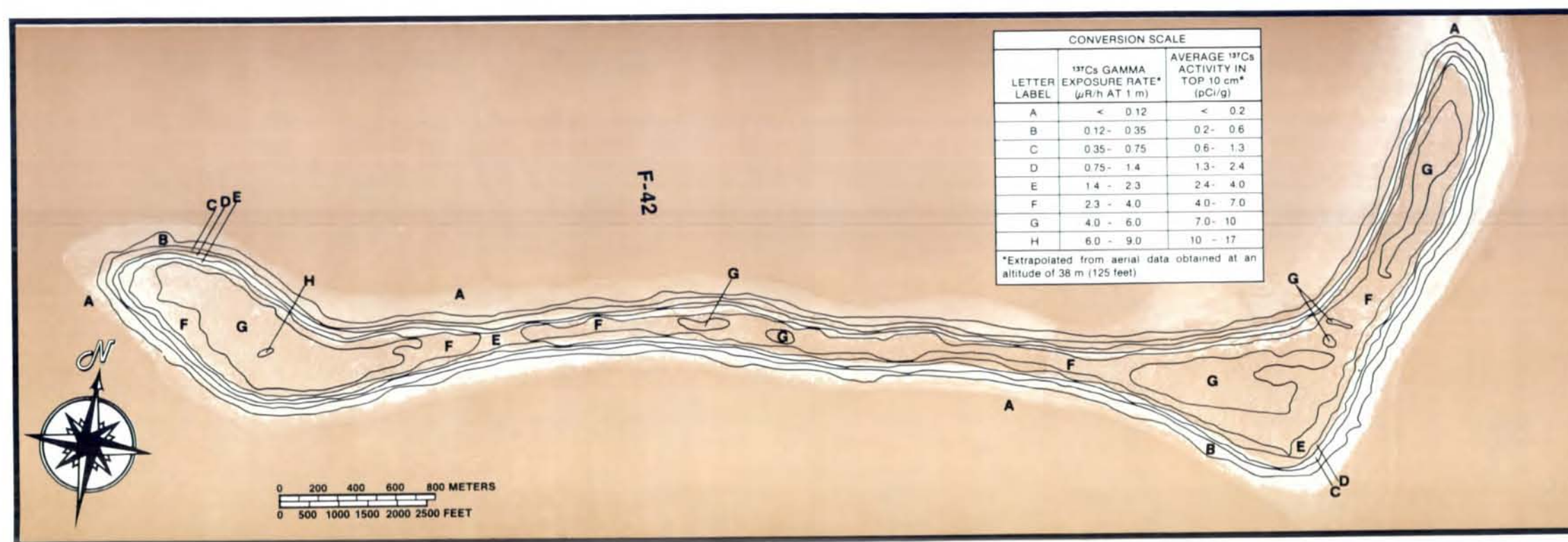


Figure D-42. CESIUM 137 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLAND F-42 AT RONGELAP ATOLL. (Photograph Frame Number 216)



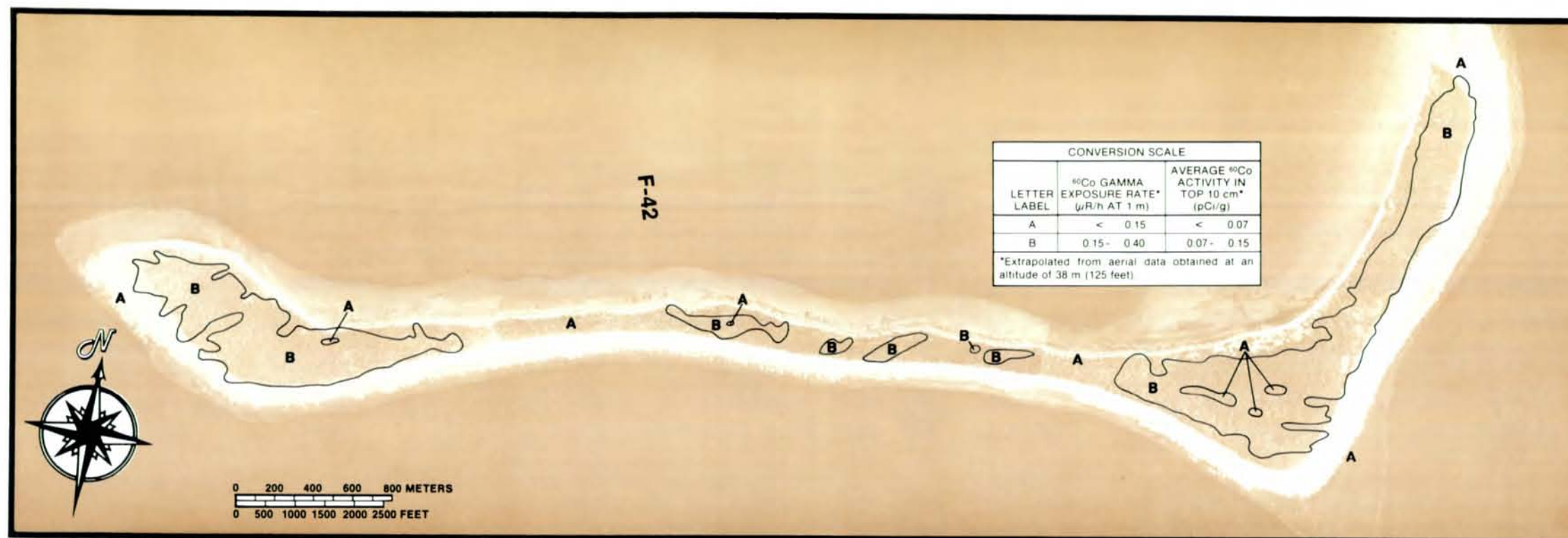


Figure D-43. COBALT 60 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLAND F-42 AT RONGELAP ATOLL. (Photograph Frame Number 216)



Figure D-44. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS F-43 TO F-44 AT RONGELAP ATOLL. (Photograph Frame Number 72)





Figure D-45. CESIUM 137 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS F-43 TO F-44 AT RONGELAP ATOLL. (Photograph Frame Number 72)



Figure D-46. COBALT 60 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS F-43 TO F-44 AT RONGELAP ATOLL. (Photograph Frame Number 72)



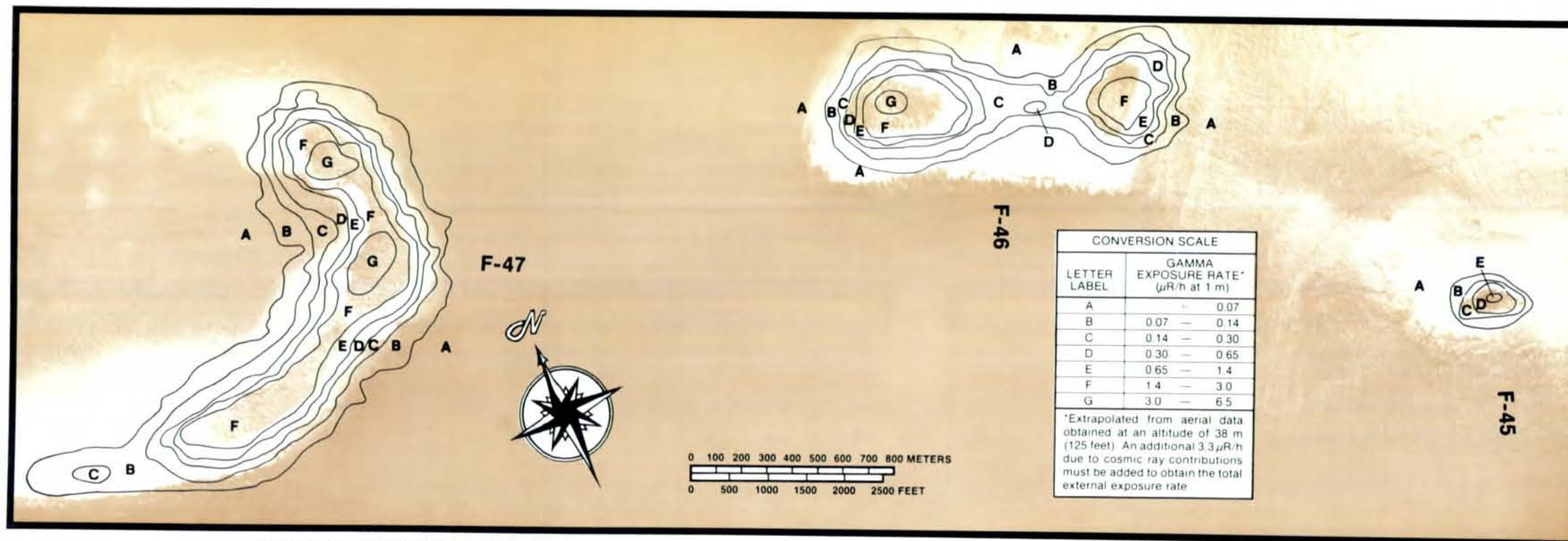


Figure D-47. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS F-45 TO F-47 AT RONGELAP ATOLL. (Photograph Frame Number 50)

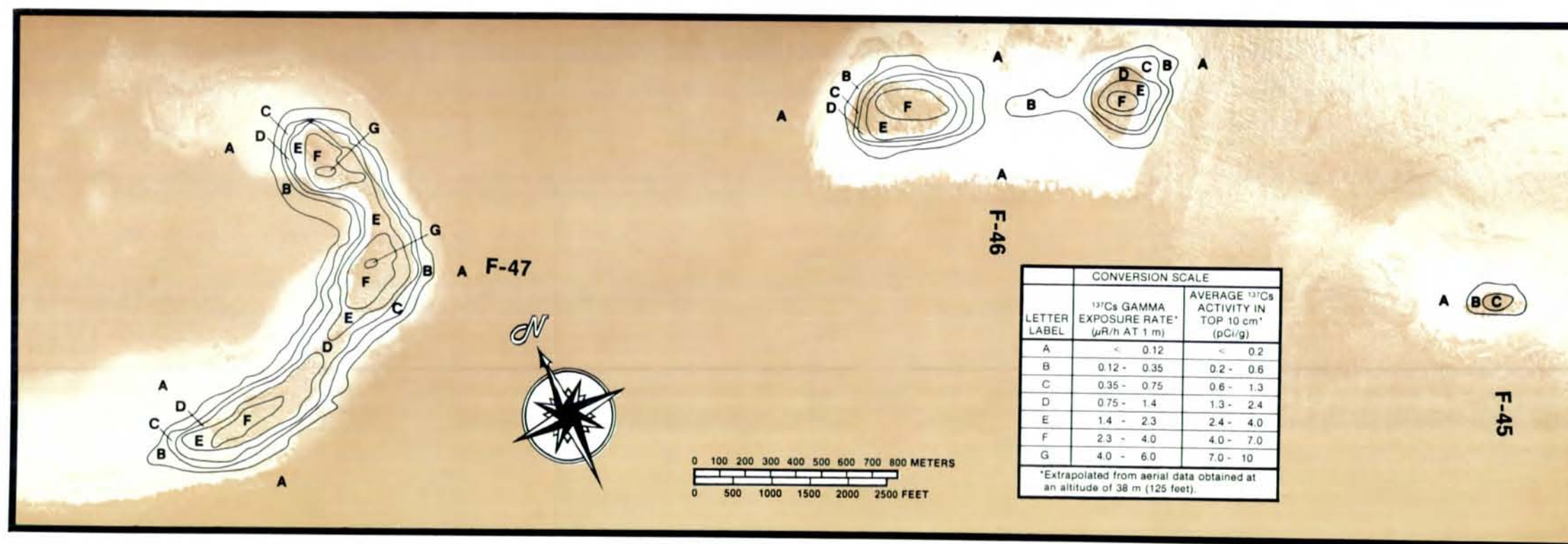


Figure D-48. CESIUM 137 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS F-45 TO F-47 AT RONGELAP ATOLL. (Photograph Frame Number 50)



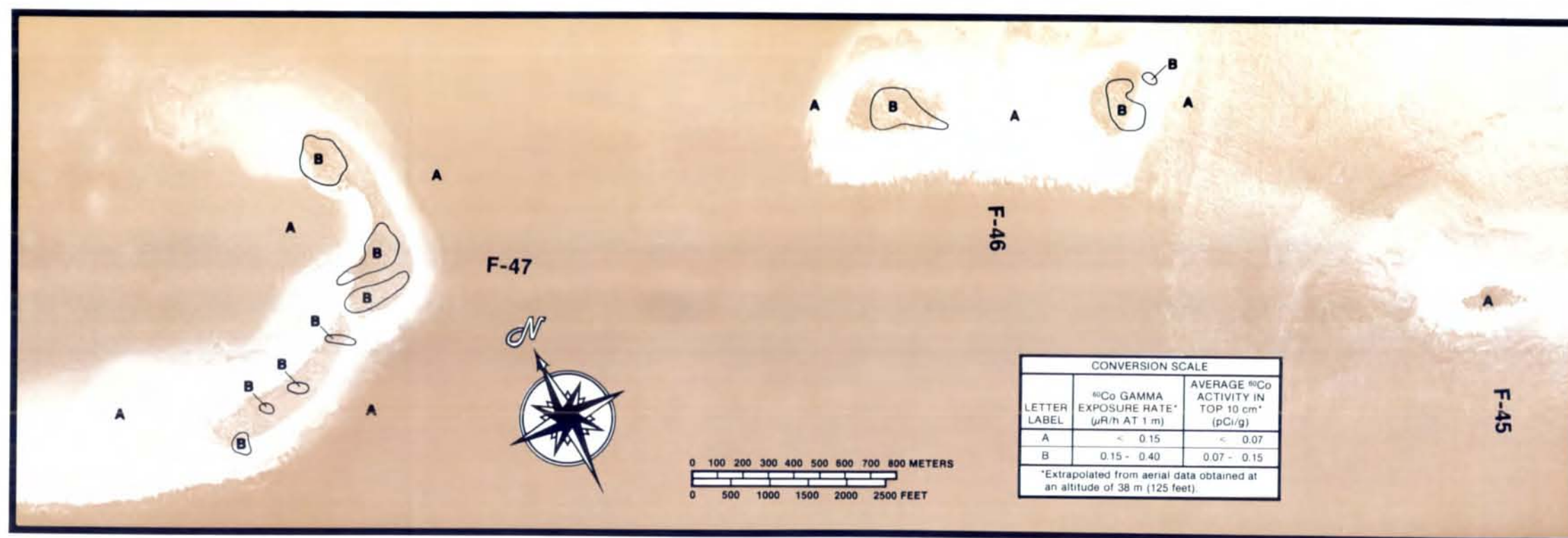


Figure D-49. COBALT 60 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS F-45 TO F-47 AT RONGELAP ATOLL. (Photograph Frame Number 50)

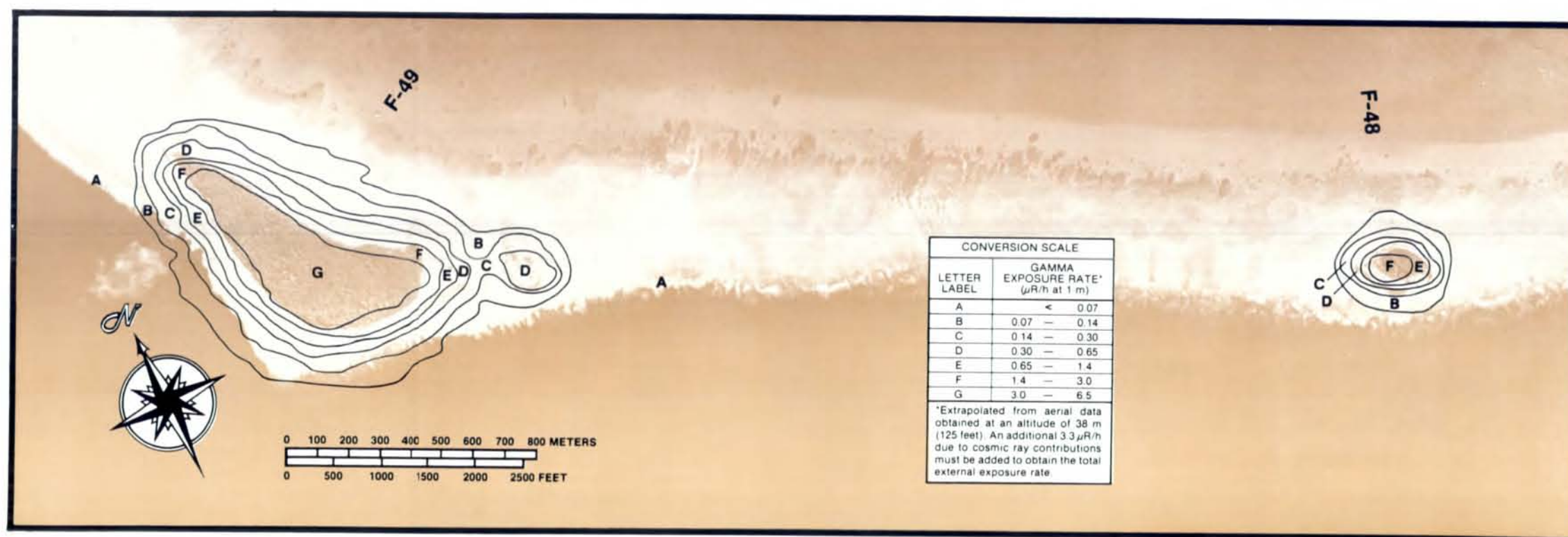


Figure D-50. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS F-48 TO F-49 AT RONGELAP ATOLL. (Photograph Frame Number 56)



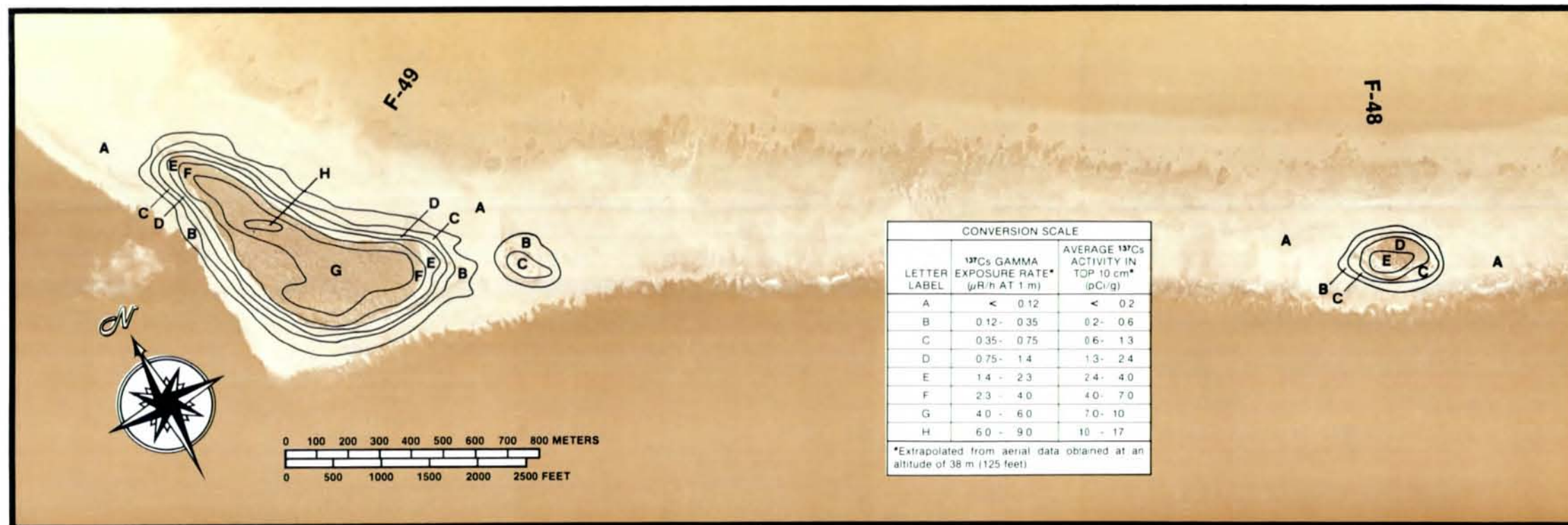


Figure D-51. CESIUM 137 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS F-48 TO F-49 AT RONGELAP ATOLL. (Photograph Frame Number 56)

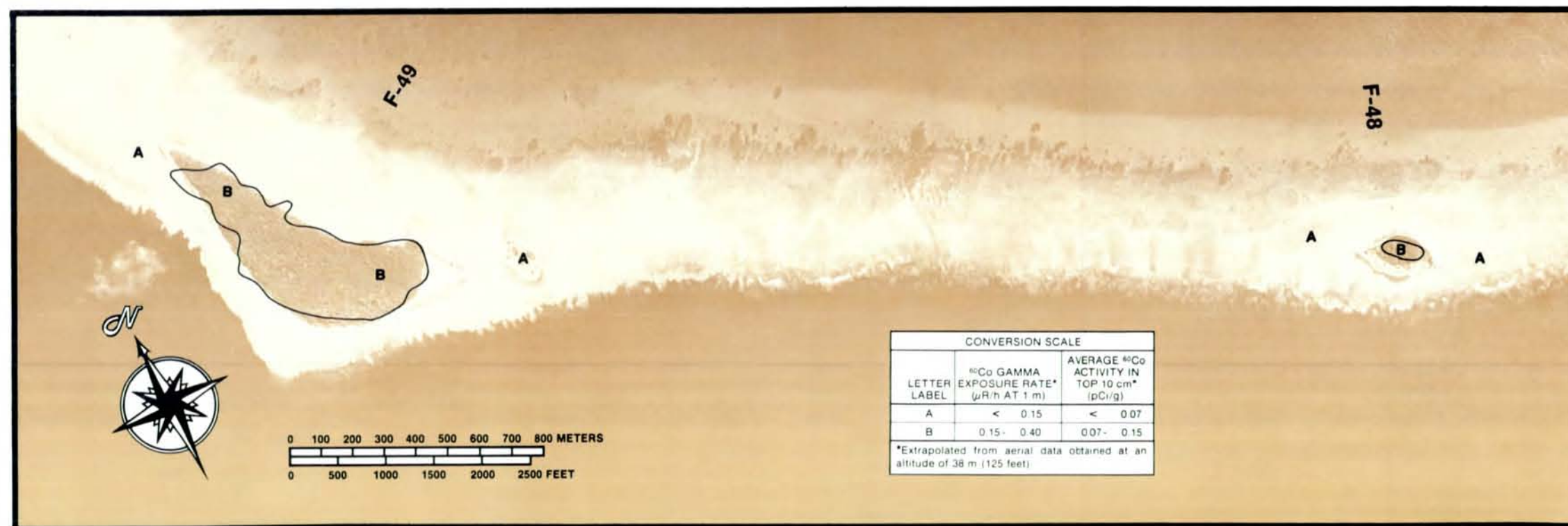


Figure D-52. COBALT 60 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS F-48 TO F-49 AT RONGELAP ATOLL. (Photograph Frame Number 56)



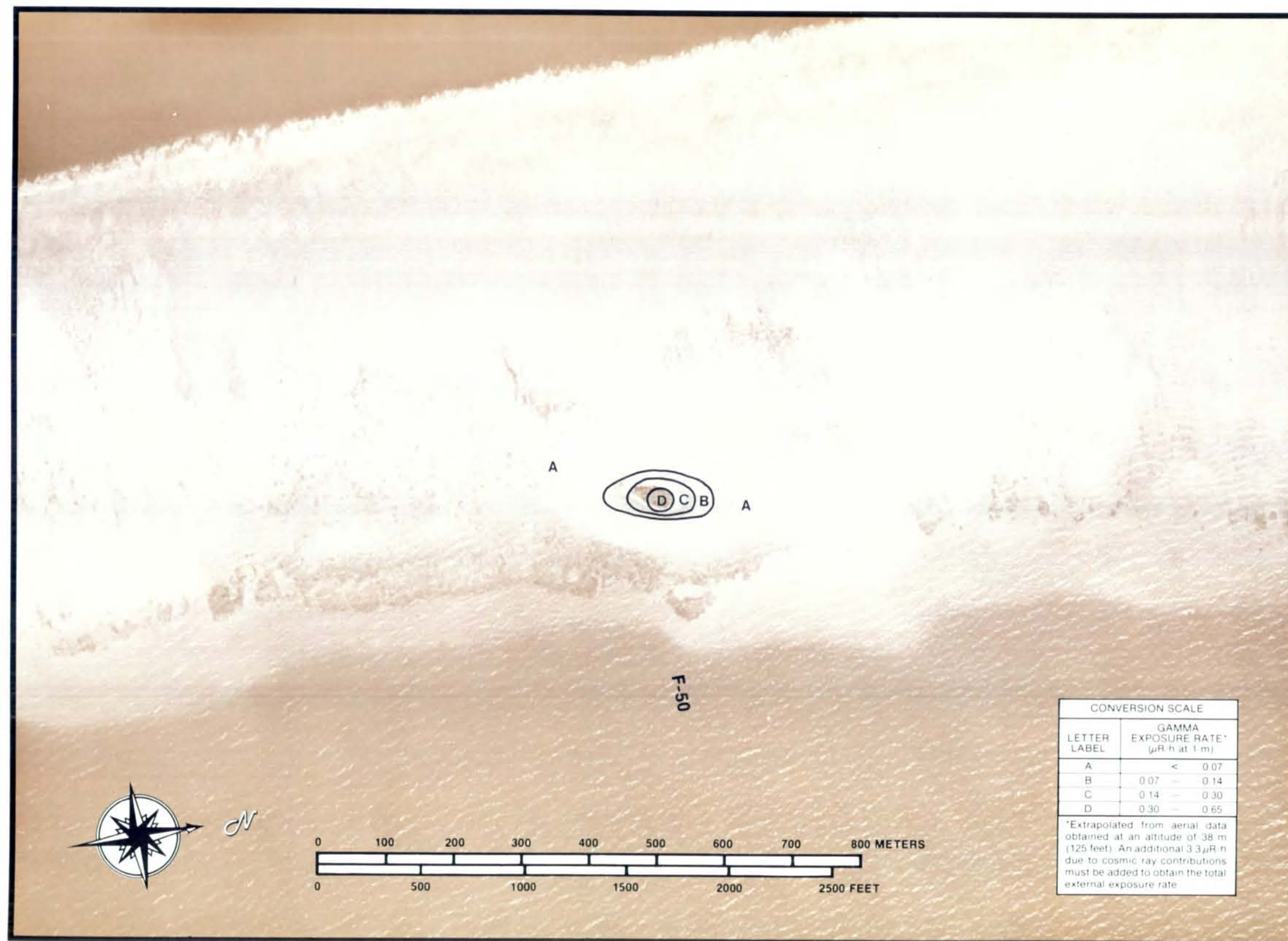


Figure D-53. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLAND F-50 AT RONGELAP ATOLL. (Photograph Frame Number 7)



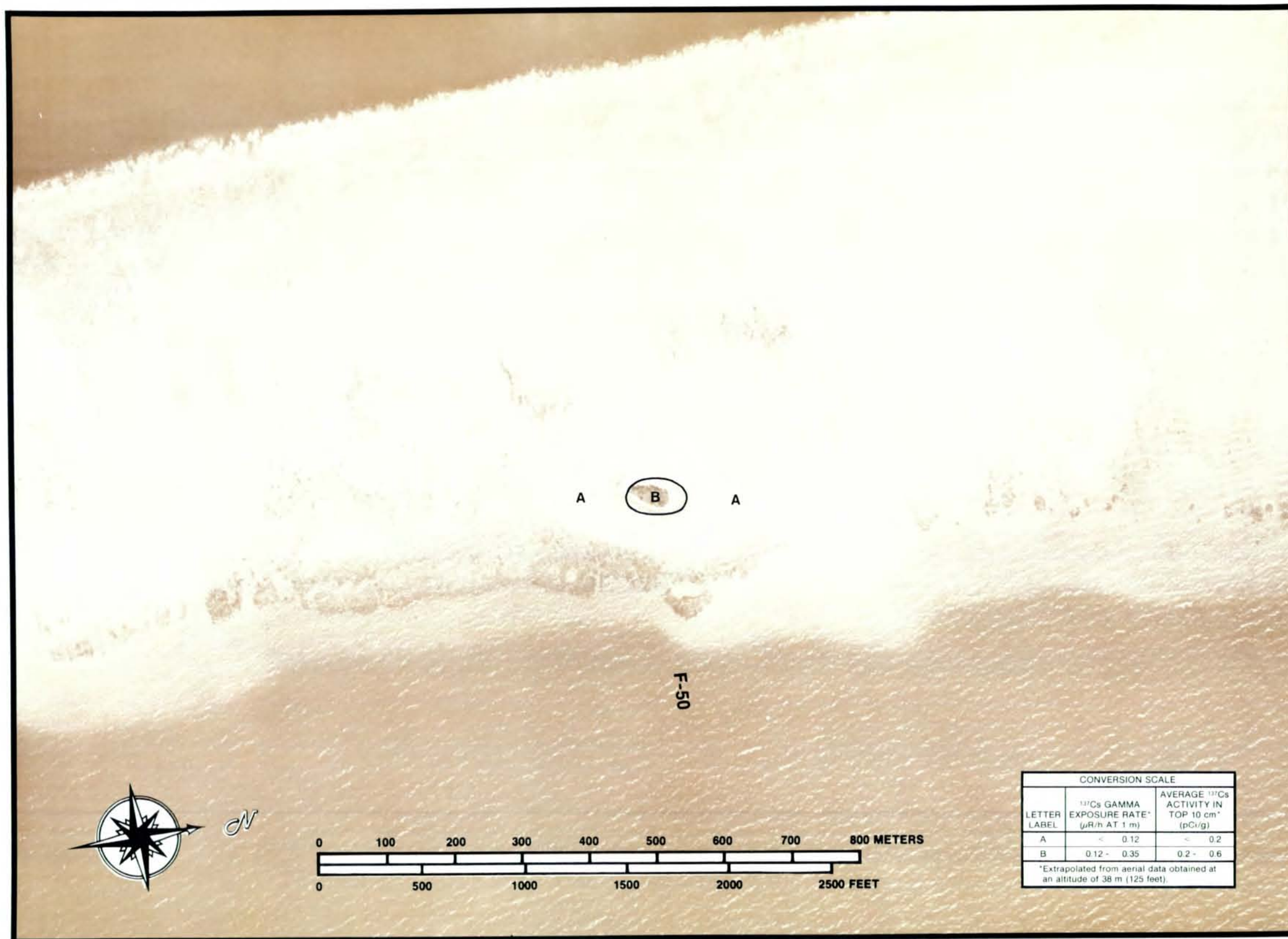


Figure D-54. CESIUM 137 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLAND F-50 AT RONGELAP ATOLL. (Photograph Frame Number 7)



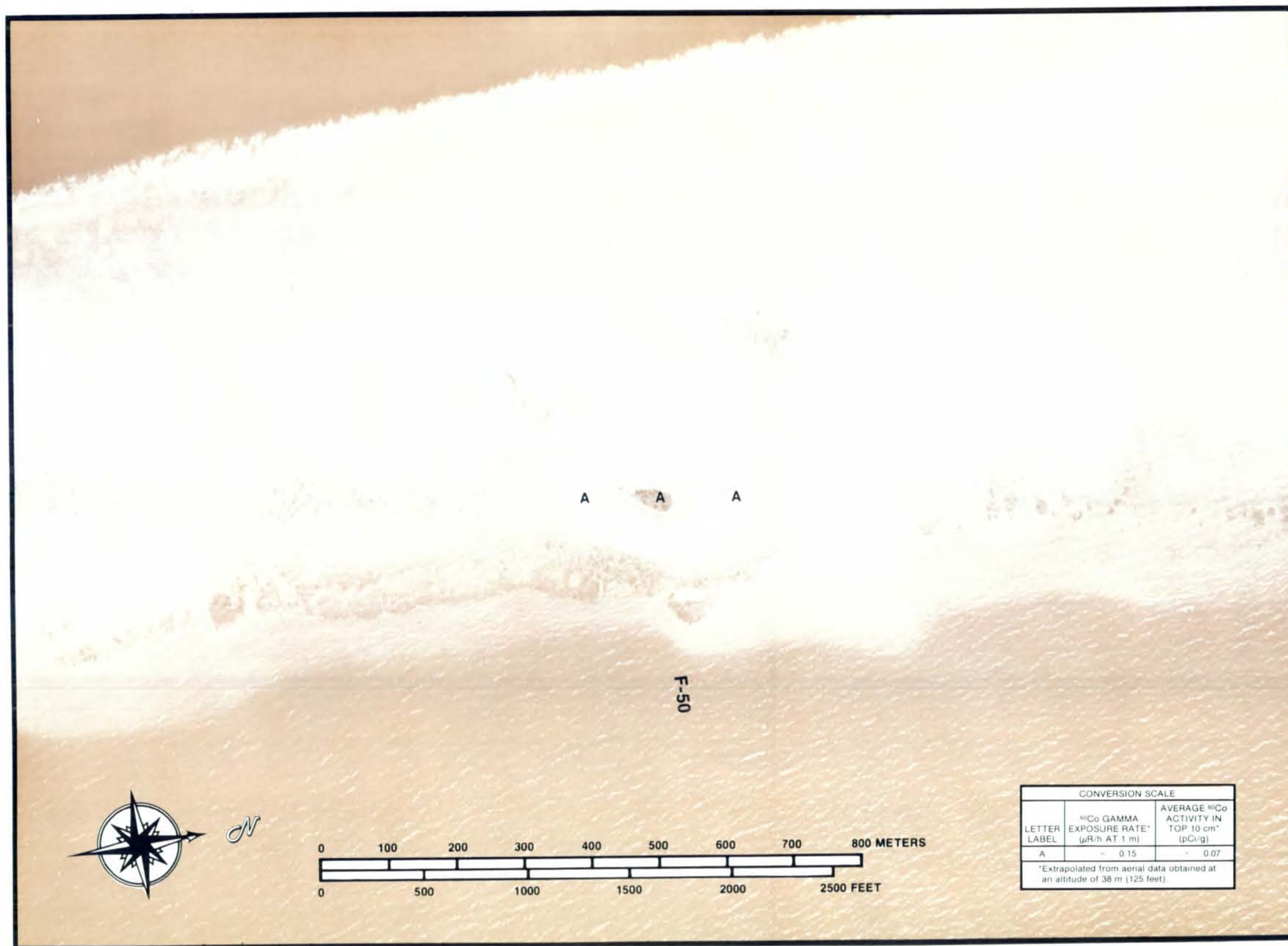


Figure D-55. COBALT 60 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLAND F-50 AT RONGELAP ATOLL. (Photograph Frame Number 7)



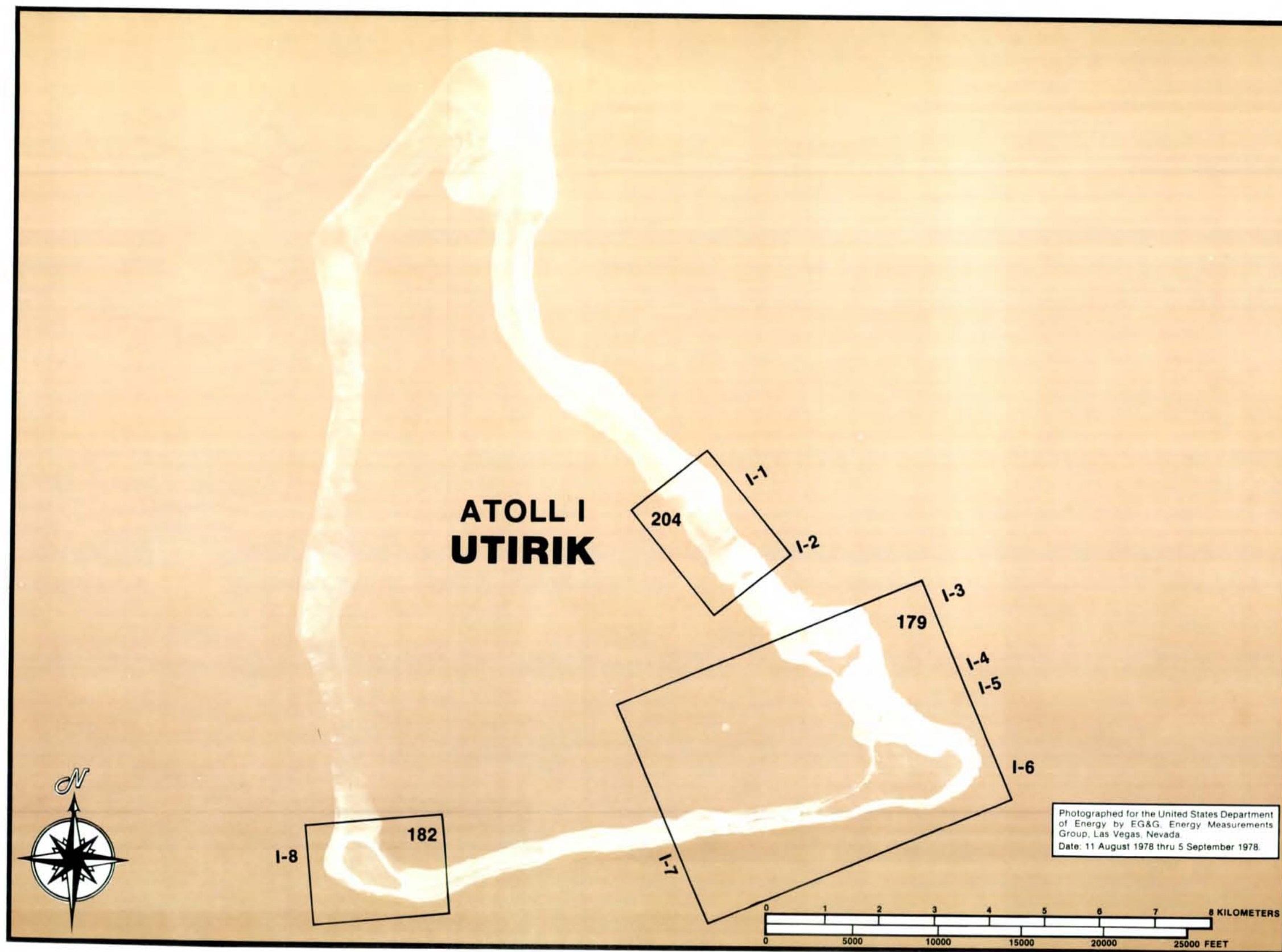


Figure D-56. BASE MAP KEY FOR UTIRIK ATOLL. The photomosaic shows the area covered by each base map photograph and the photograph frame number used to identify each survey area.



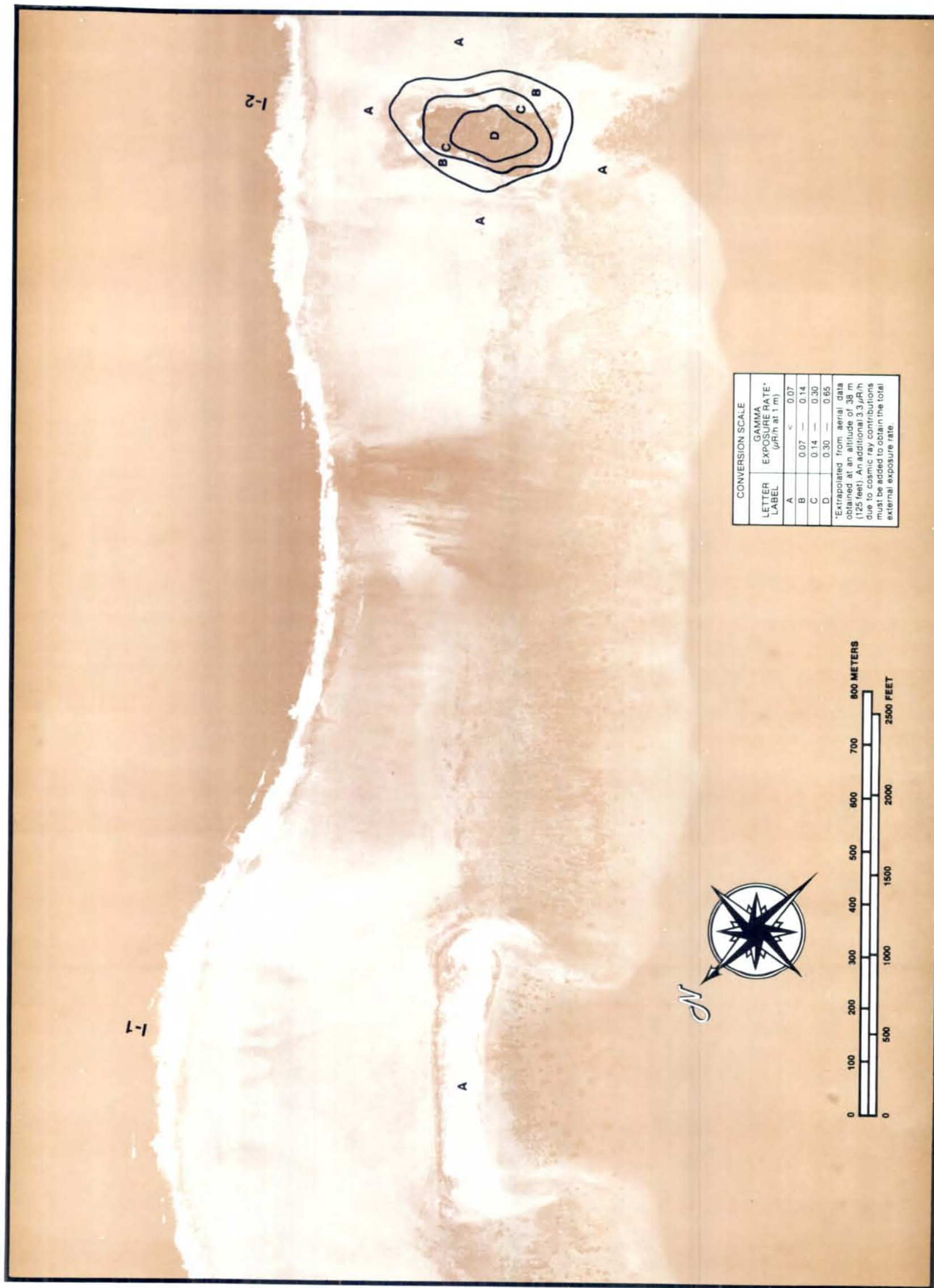


Figure D-57. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS I-1 TO I-2 AT UTIRIK ATOLL. (Photograph Frame Number 204)



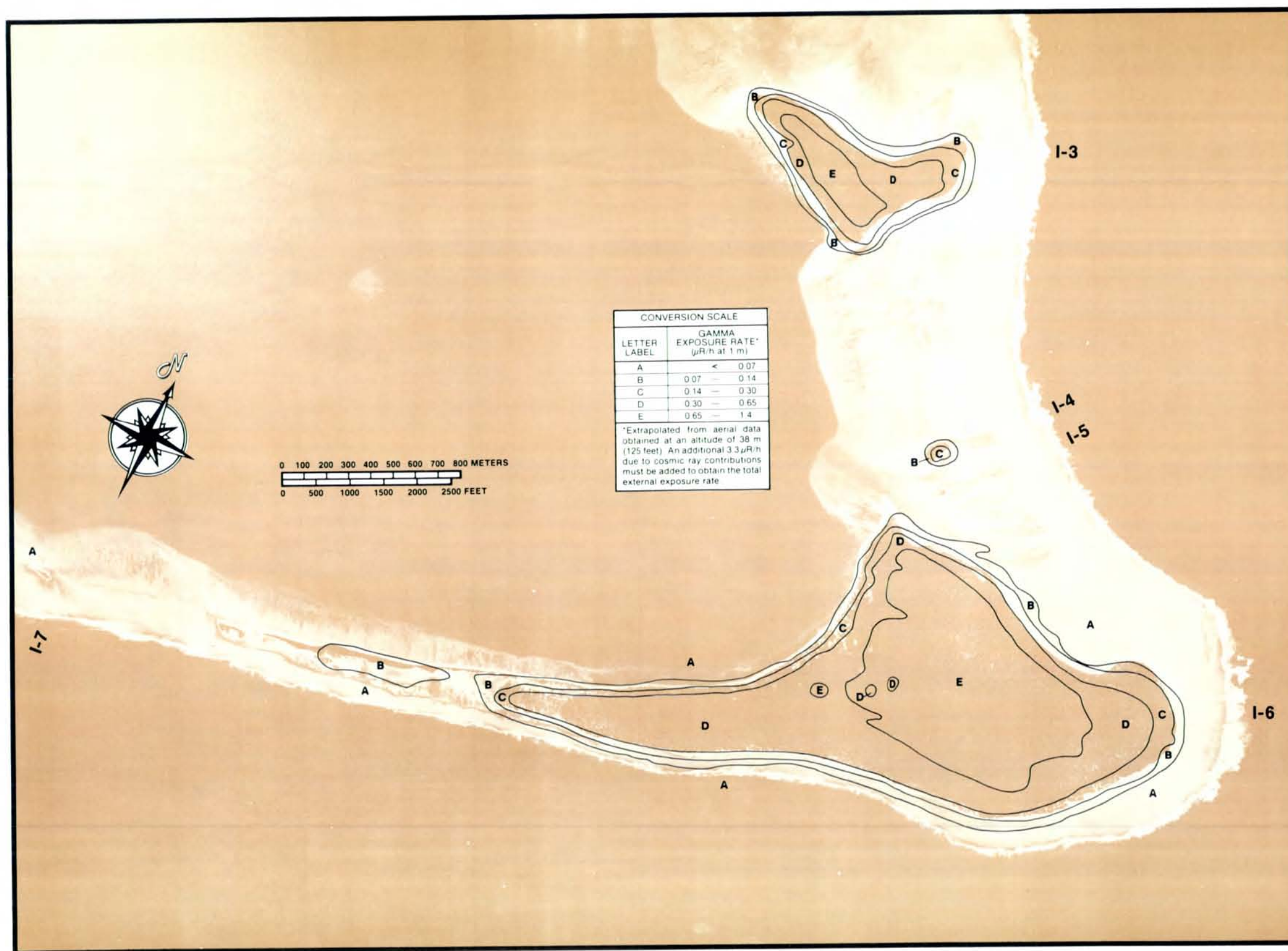


Figure D-58. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS I-3 TO I-7 AT UTIRIK ATOLL. (Photograph Frame Number 179)



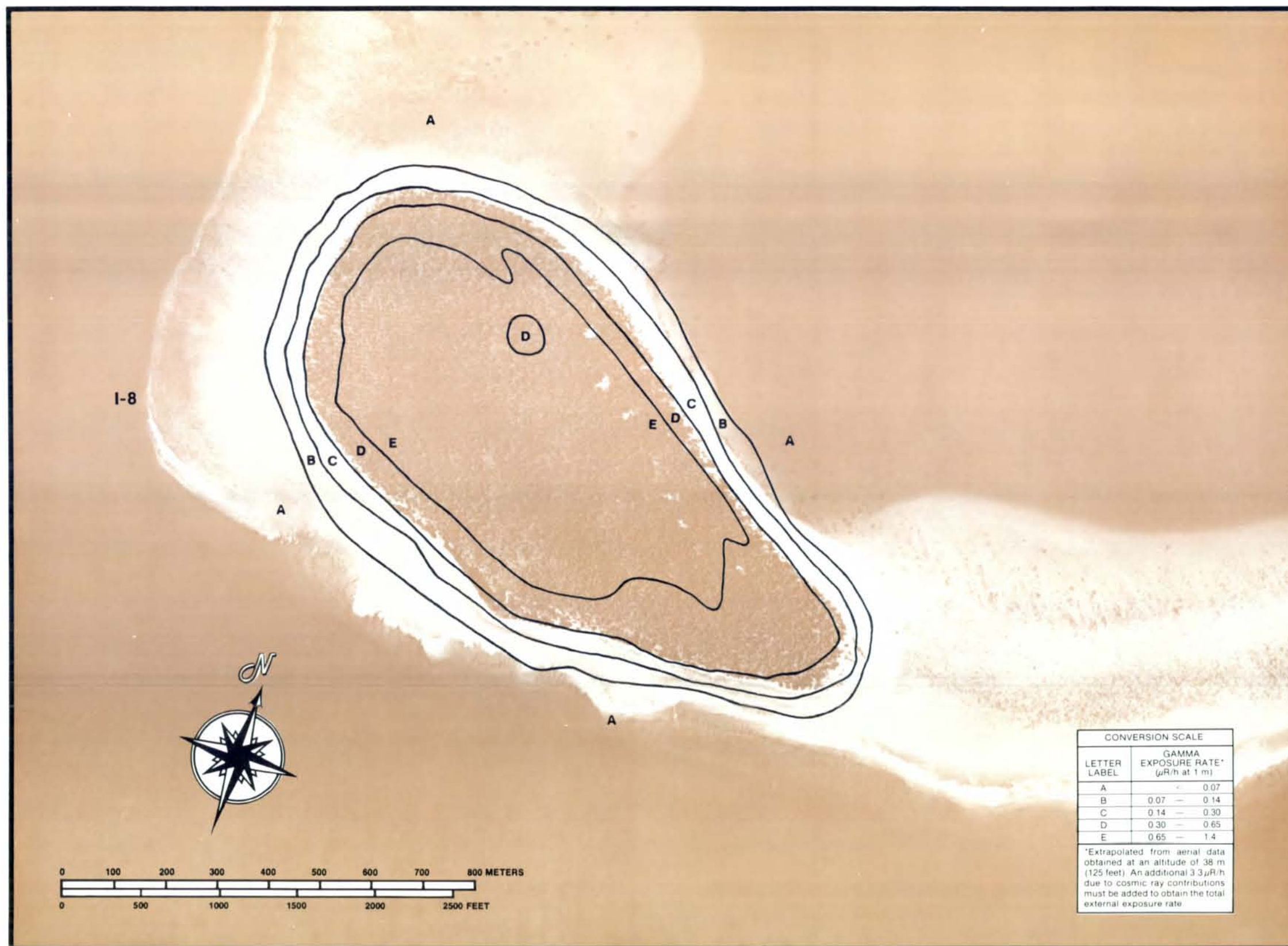


Figure D-59. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLAND I-8 AT UTIRIK ATOLL. (Photograph Frame Number 182)



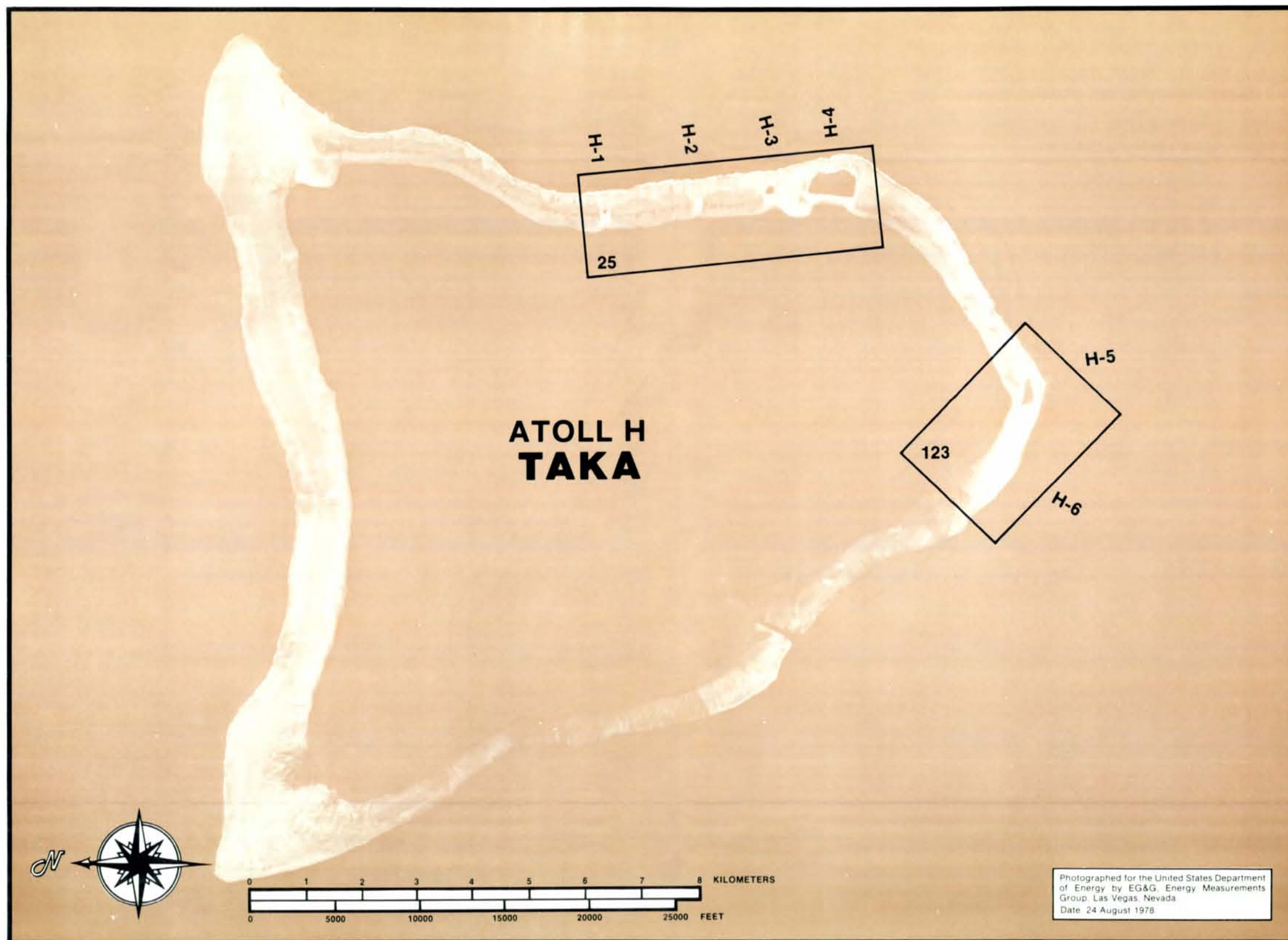


Figure D-60. BASE MAP KEY FOR TAKA ATOLL. The photomosaic shows the area covered by each base map photograph and the photograph frame number used to identify each survey area.



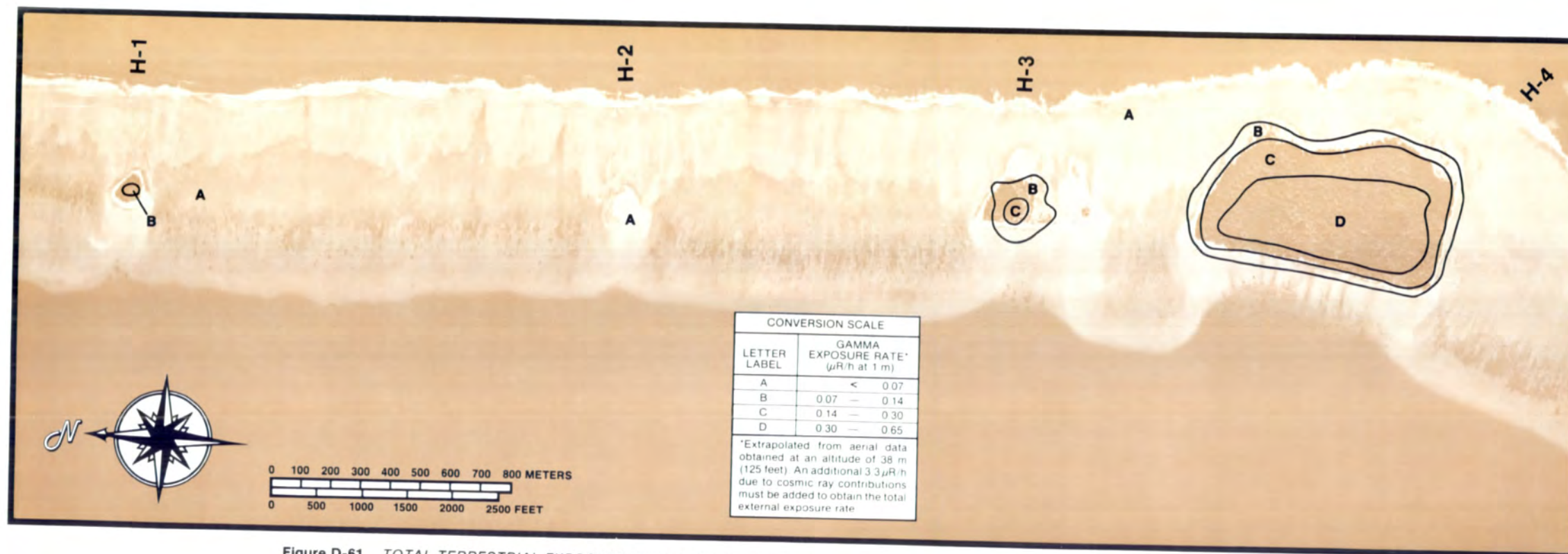


Figure D-61. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS H-1 TO H-4 AT TAKA ATOLL. (Photograph Frame Number 25)



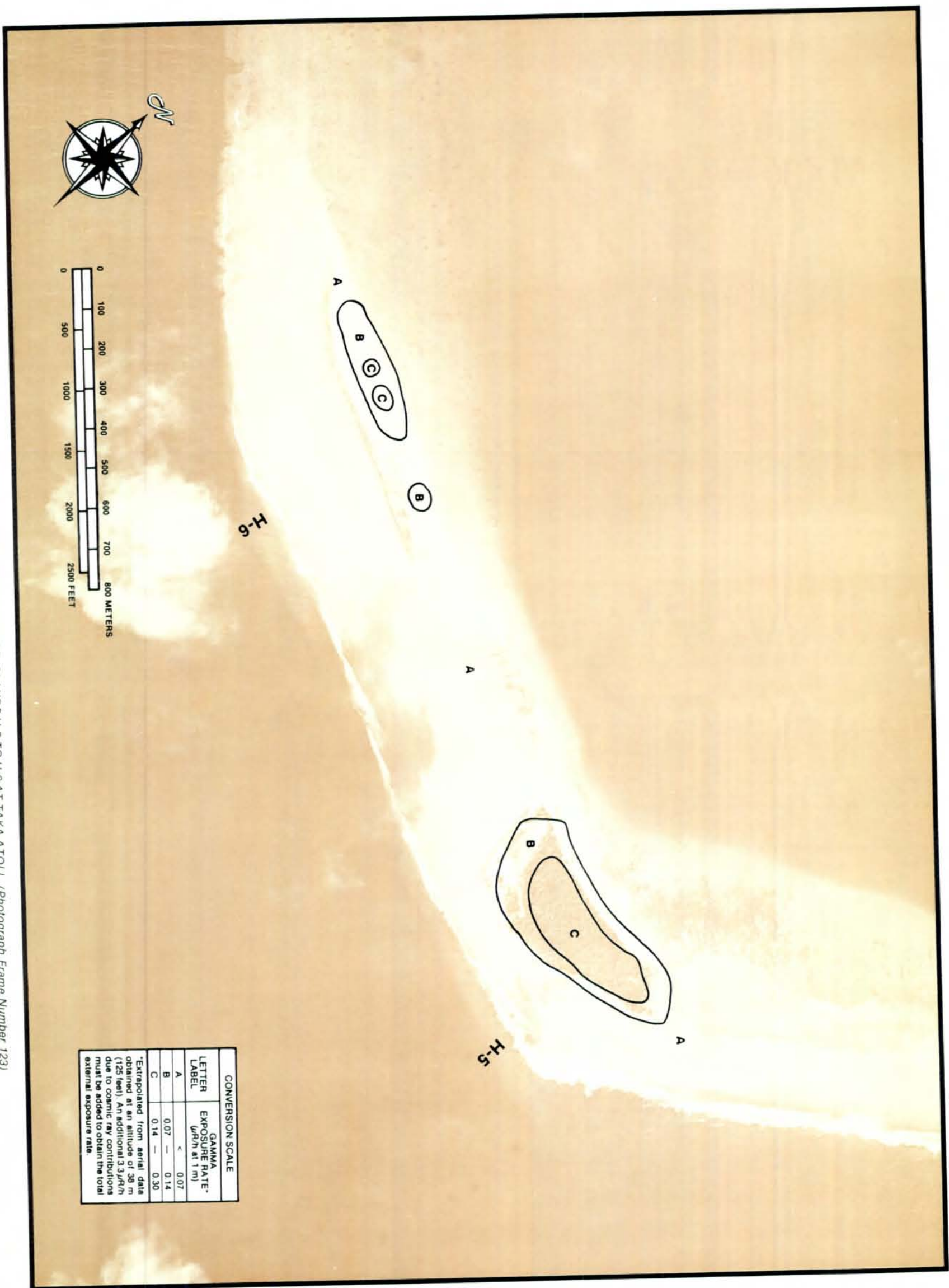


Figure D-62. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS H-5 TO H-6 AT TAKA ATOLL. (Photograph Frame Number 123)



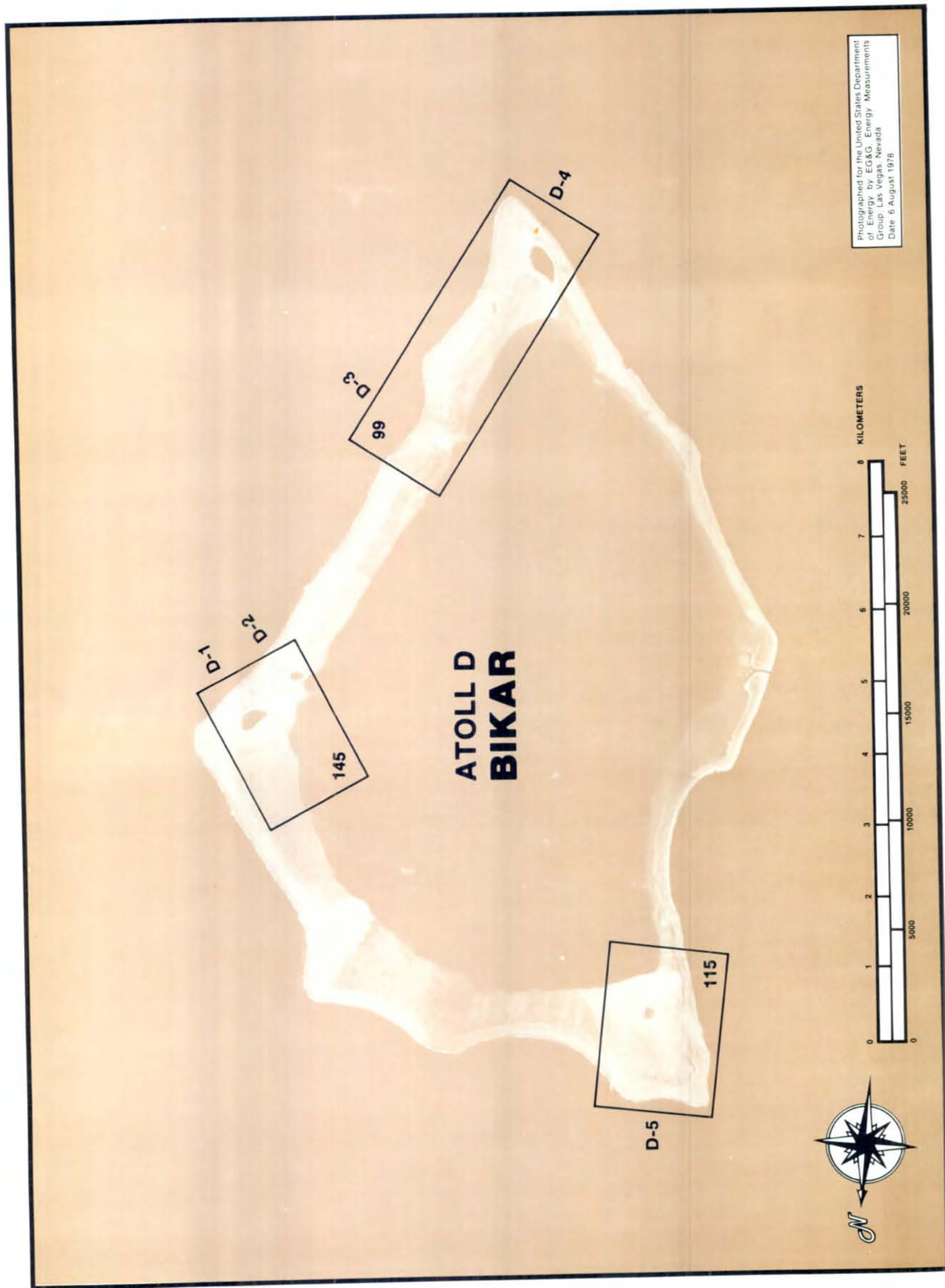


Figure D-63. BASE MAP KEY FOR BIKAR ATOLL. The photomosaic shows the area covered by each base map photograph and the photograph frame number used to identify each survey area.





Figure D-64. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS D-1 TO D-2 AT BIKAR ATOLL. (Photograph Frame Number 145)





Figure D-65. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS D-3 TO D-4 AT BIKAR ATOLL. (Photograph Frame Number 99)



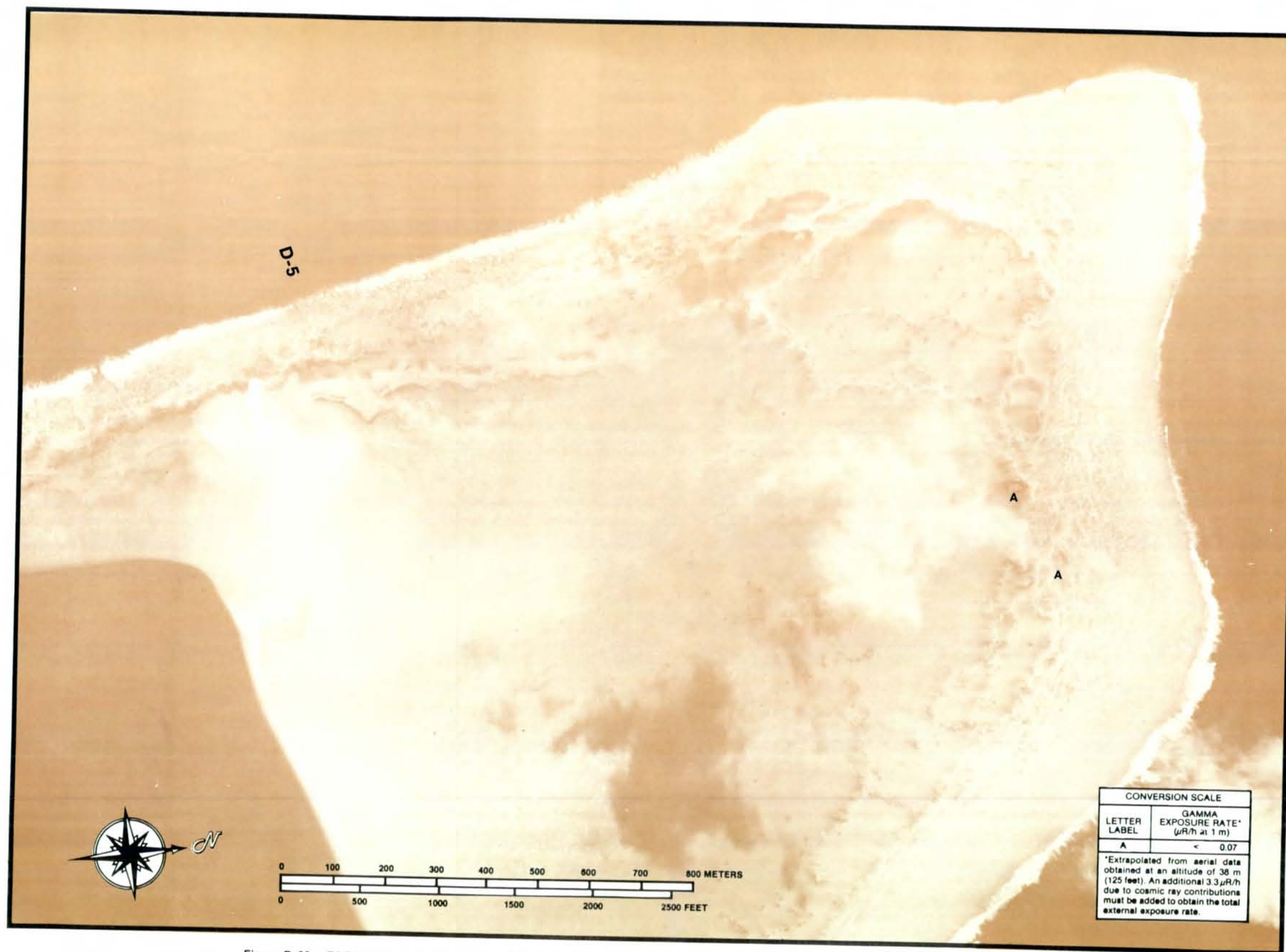


Figure D-66. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLAND D-5 AT BIKAR ATOLL. (Photograph Frame Number 115).



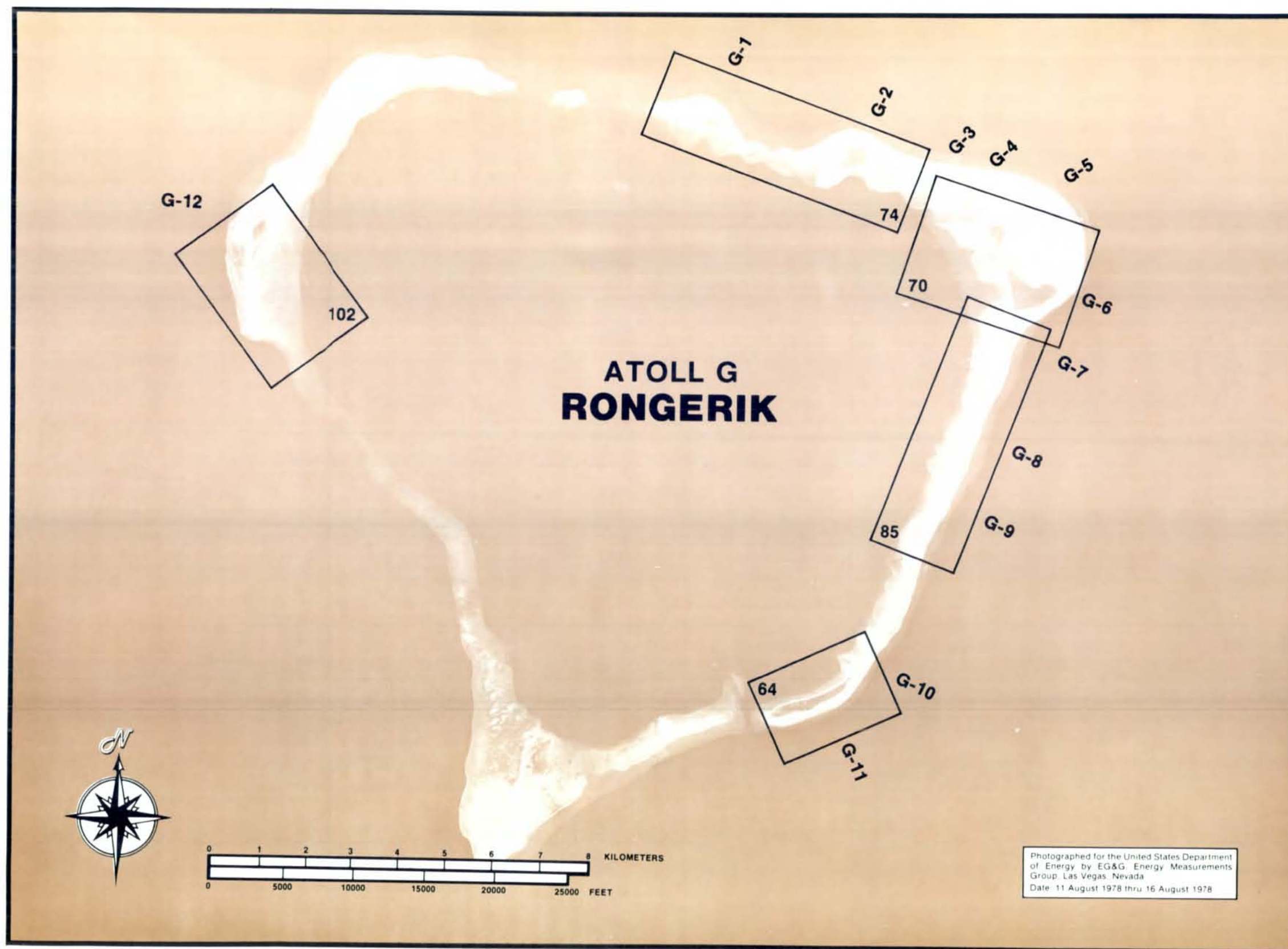


Figure D-67. BASE MAP KEY FOR RONGERIK ATOLL. The photomosaic shows the area covered by each base map photograph and the photograph frame number used to identify each survey area.



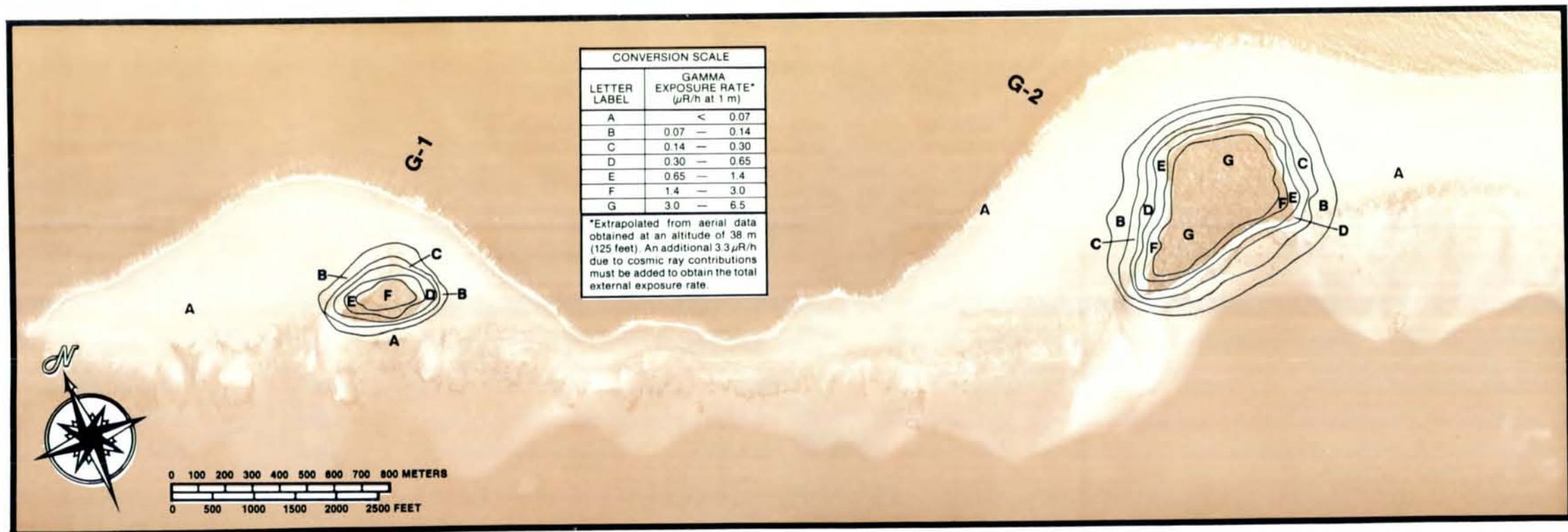


Figure D-68. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS G-1 TO G-2 AT RONGERIK ATOLL. (Photograph Frame Number 74)

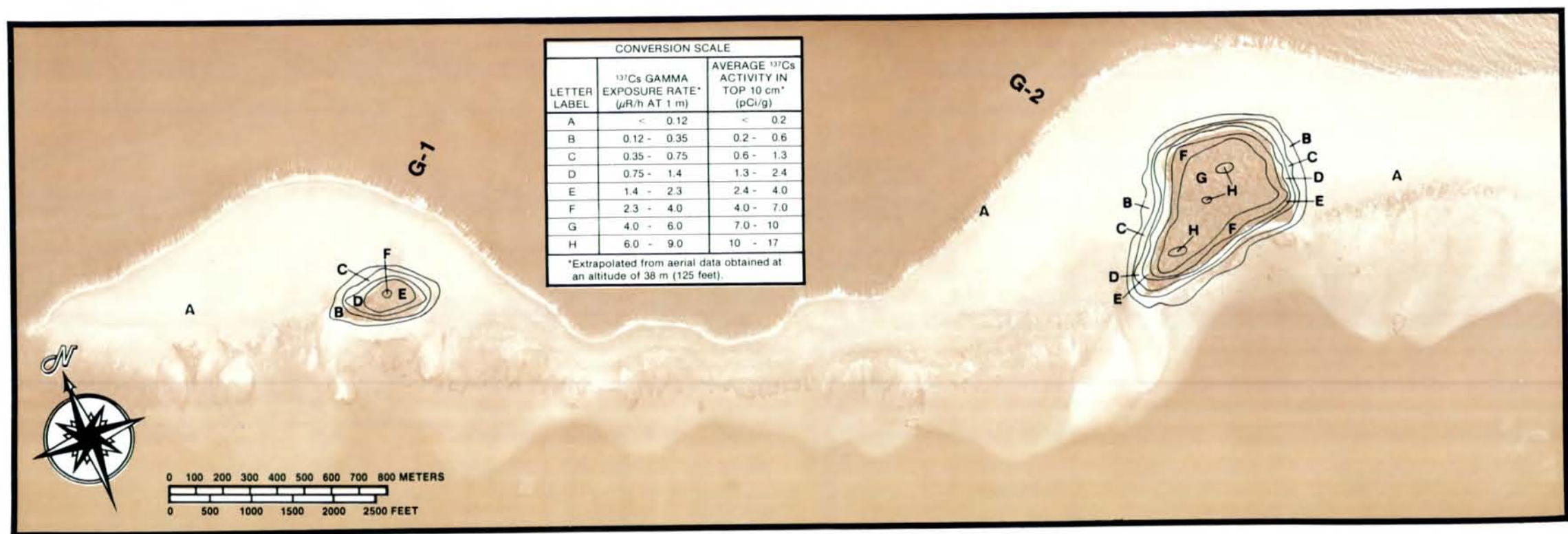


Figure D-69. CESIUM 137 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS G-1 TO G-2 AT RONGERIK ATOLL. (Photograph Frame Number 74)



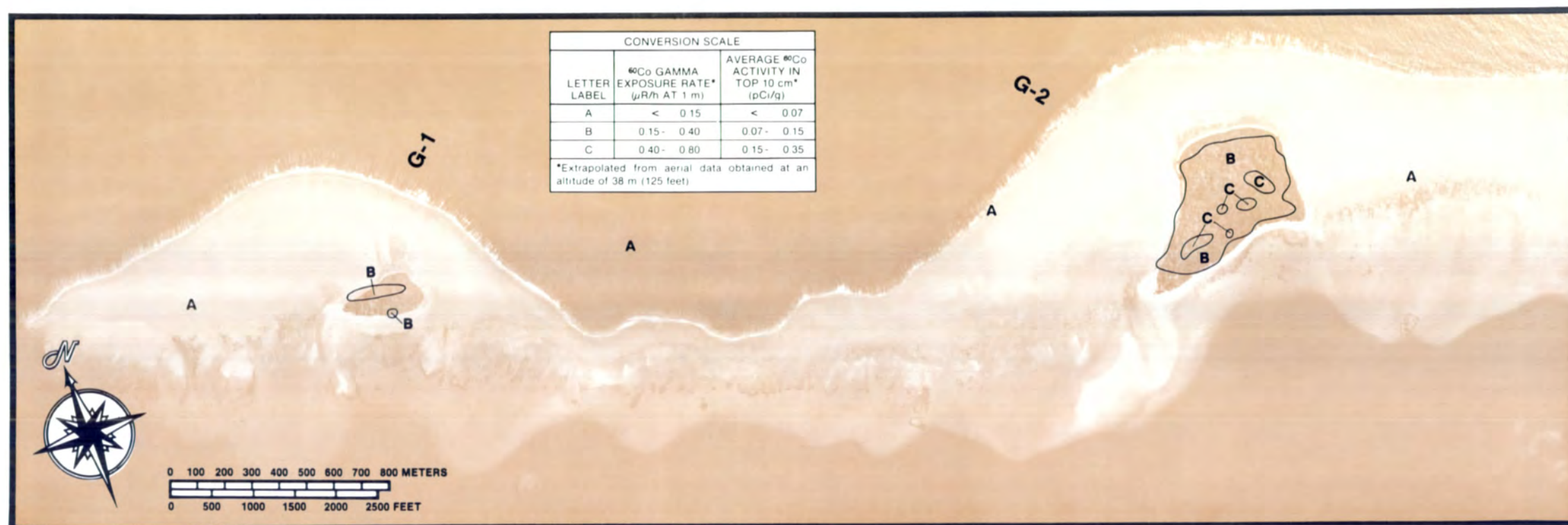


Figure D-70. COBALT 60 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS G-1 TO G-2 AT RONGERIK ATOLL. (Photograph Frame Number 74)



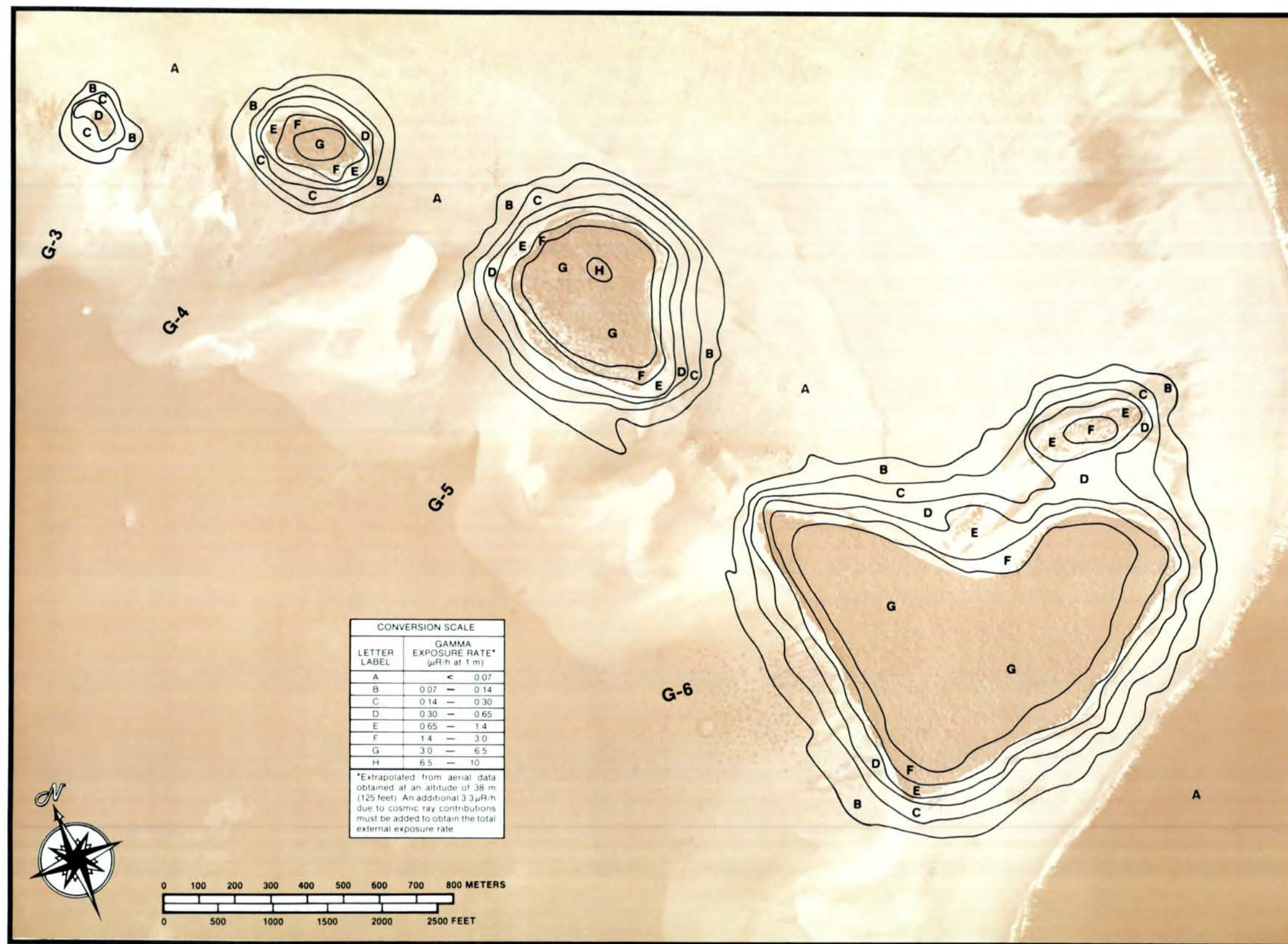


Figure D-71. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS G-3 TO G-6 AT RONGERIK ATOLL. (Photograph Frame Number 70)



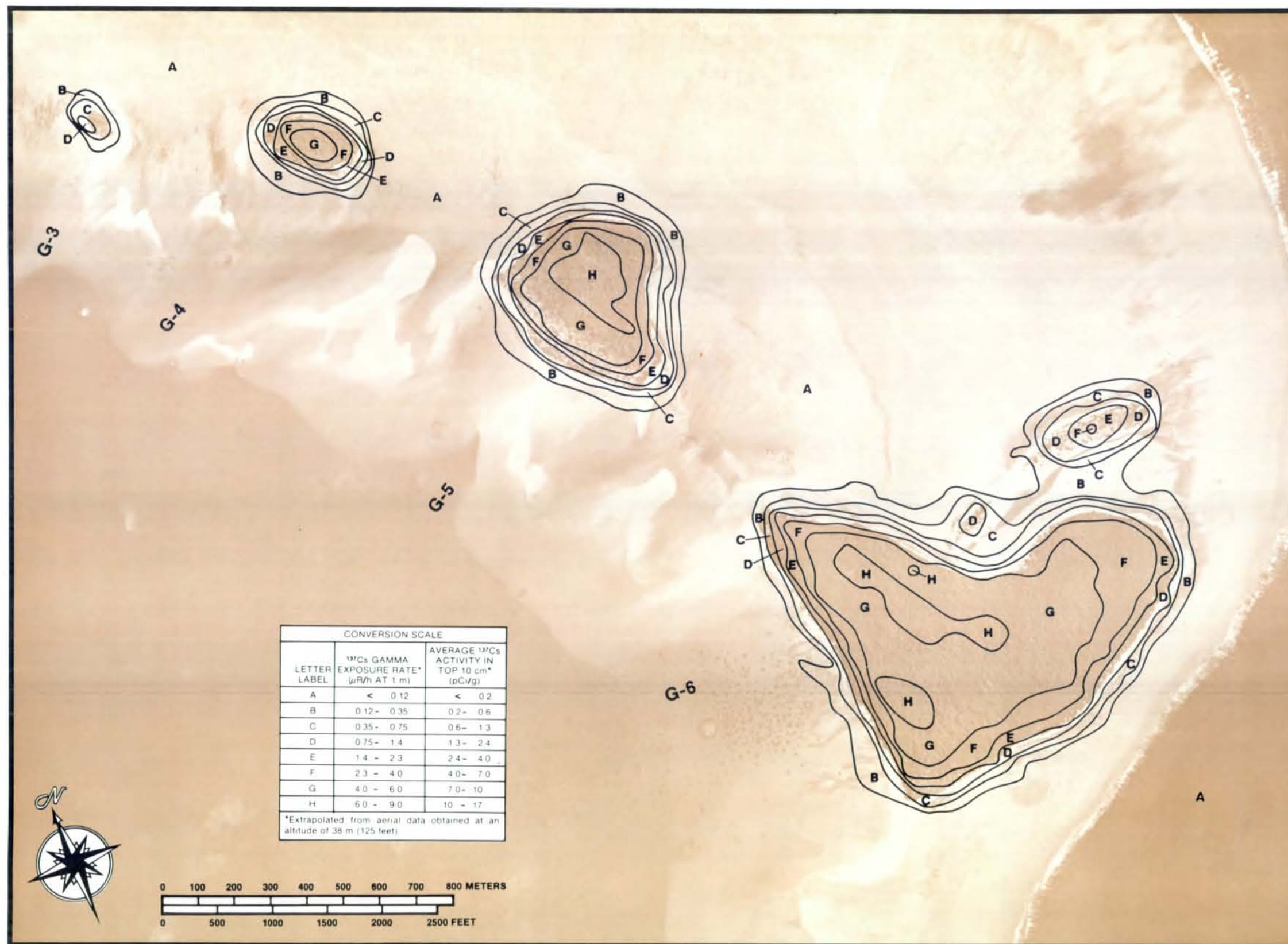


Figure D-72. CESIUM 137 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS G-3 TO G-6 AT RONGERIK ATOLL. (Photograph Frame Number 70)





Figure D-73. COBALT-60 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS G-3 TO G-6 AT RONGERIK ATOLL. (Photograph Frame Number 70)



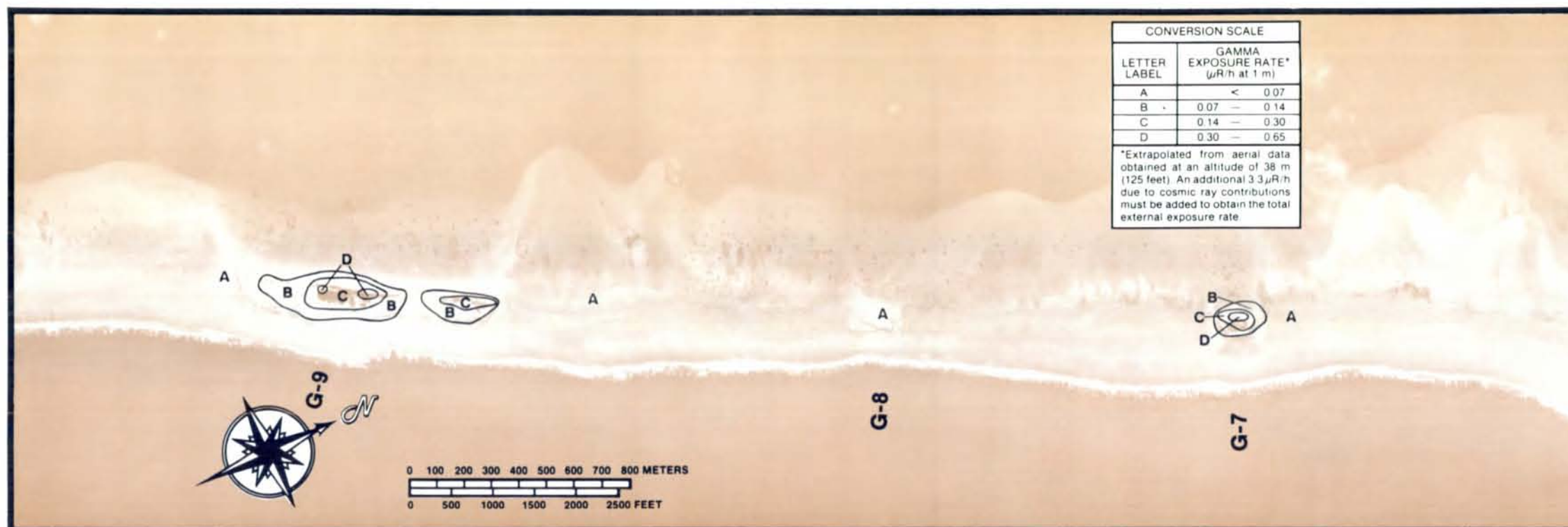


Figure D-74. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS G-7 TO G-9 AT RONGERIK ATOLL. (Photograph Frame Number 85)

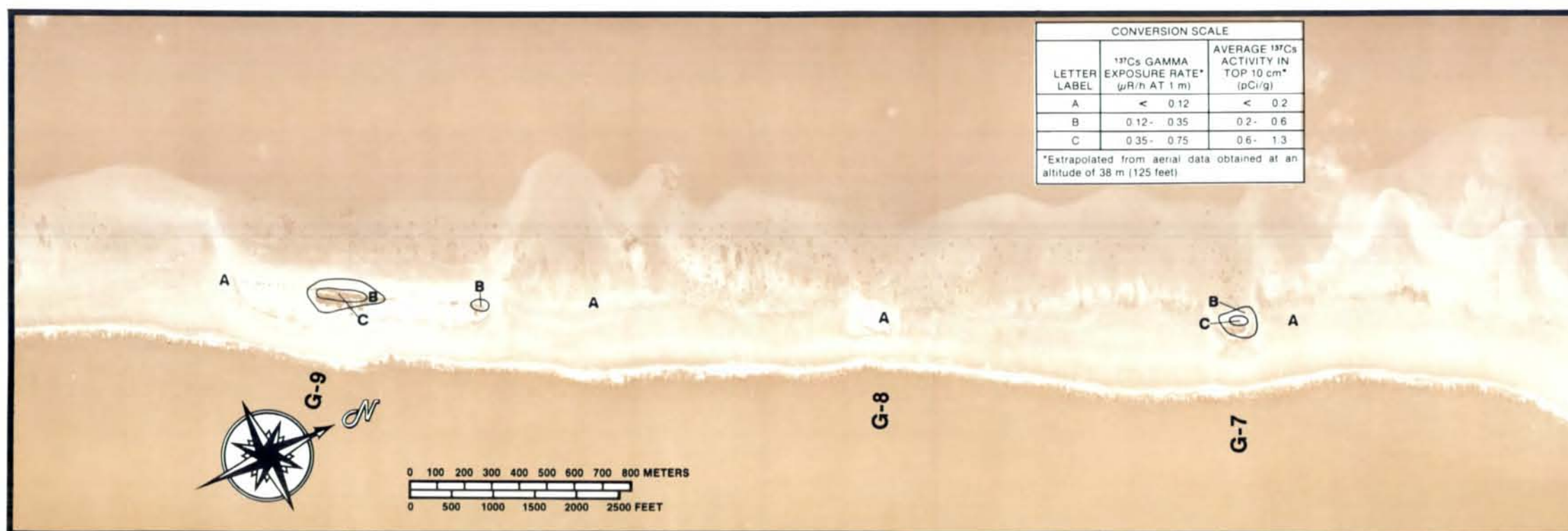


Figure D-75. CESIUM 137 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS G-7 TO G-9 AT RONGERIK ATOLL. (Photograph Frame Number 85)



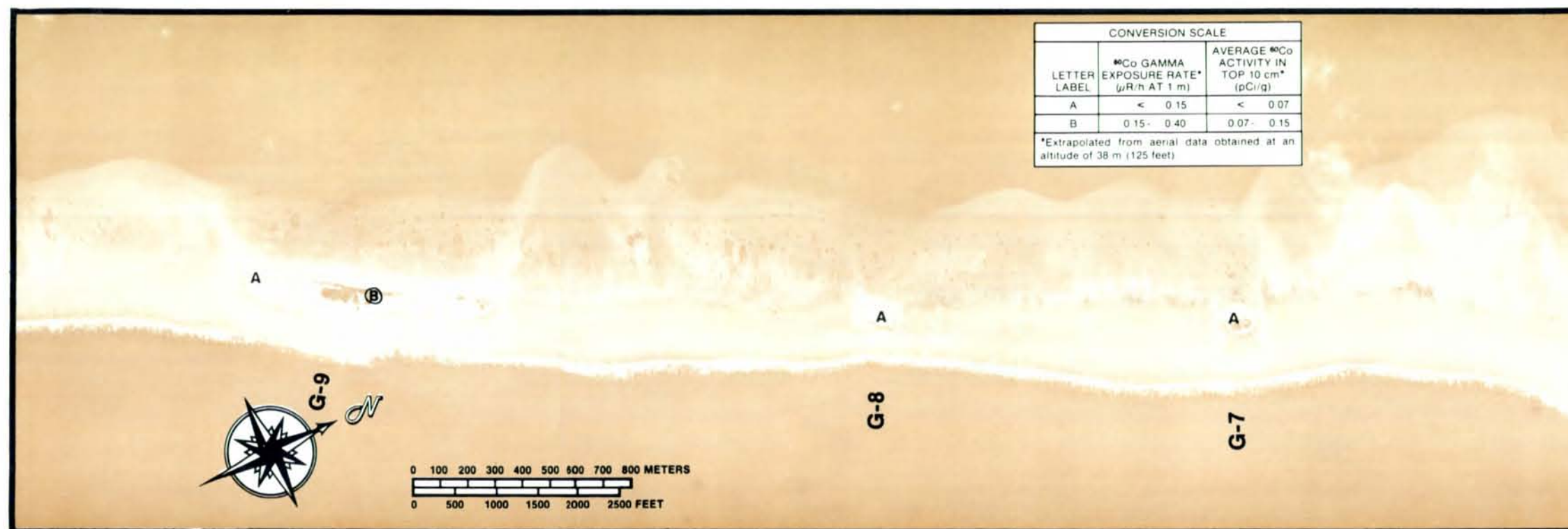


Figure D-76. COBALT 60 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS G-7 TO G-9 AT RONGERIK ATOLL. (Photograph Frame Number 85)



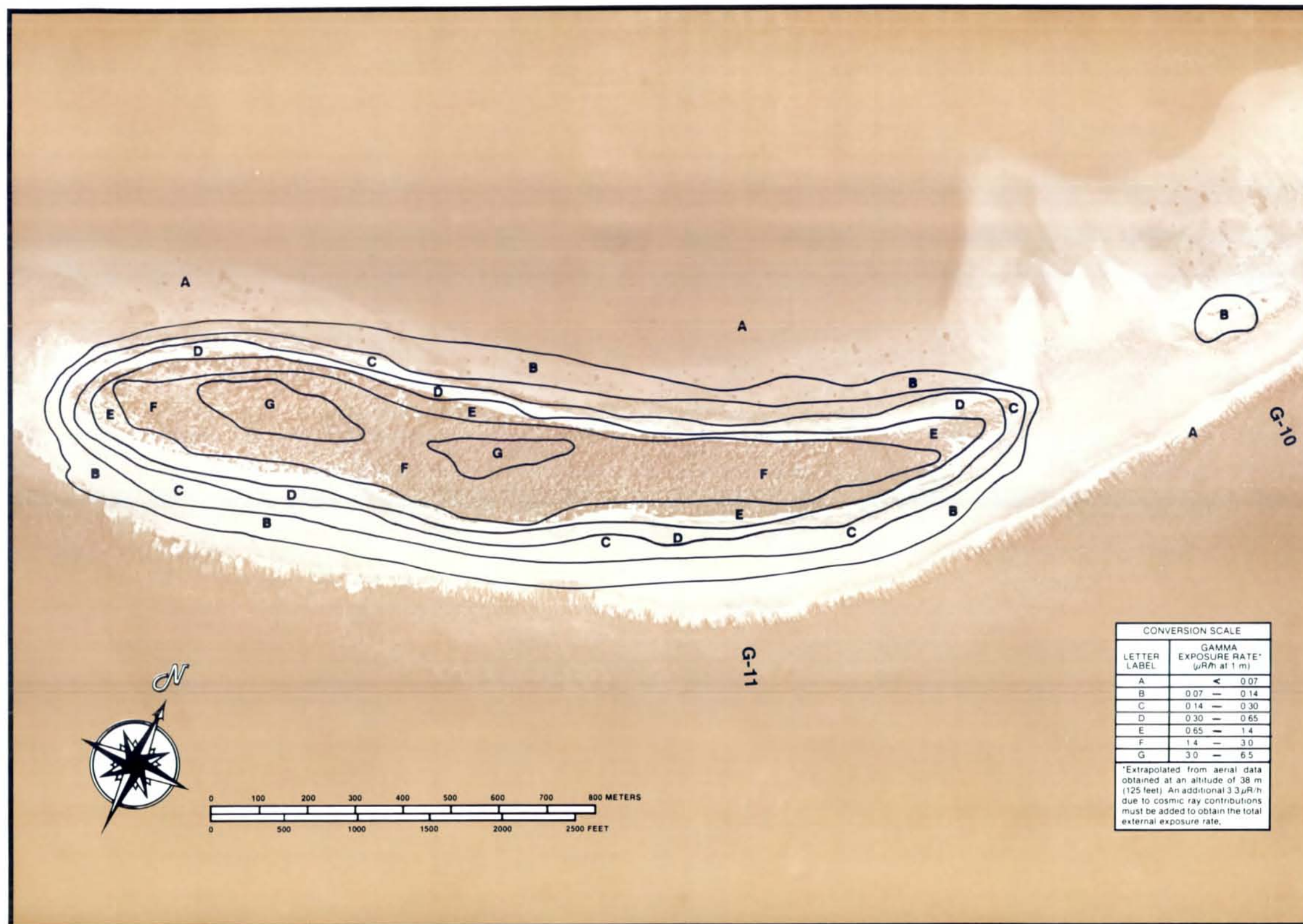


Figure D-77. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS G-10 TO G-11 AT RONGERIK ATOLL. (Photograph Frame Number 64)



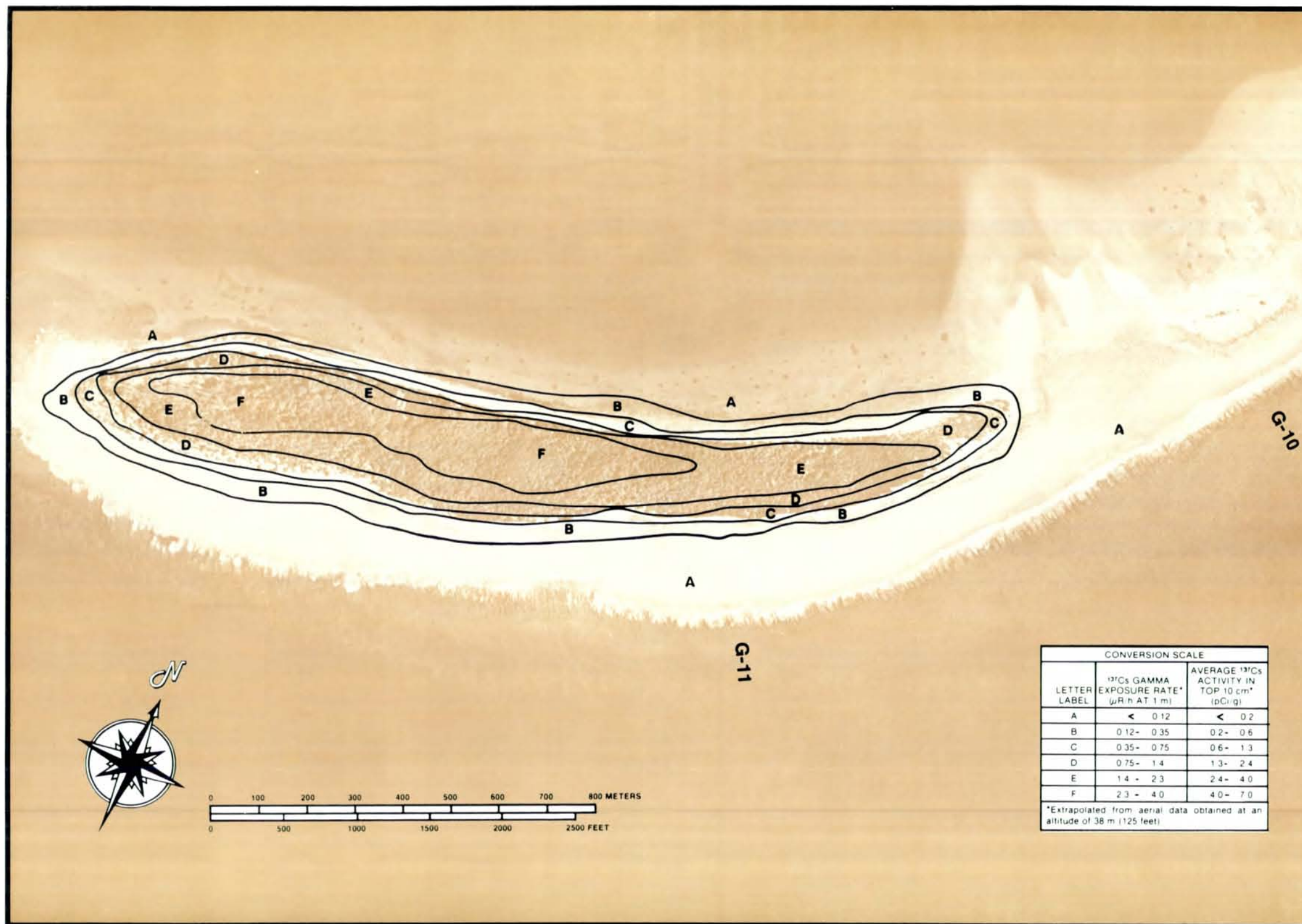


Figure D-78. CESIUM 137 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS G-10 TO G-11 AT RONGERIK ATOLL. (Photograph Frame Number 64)



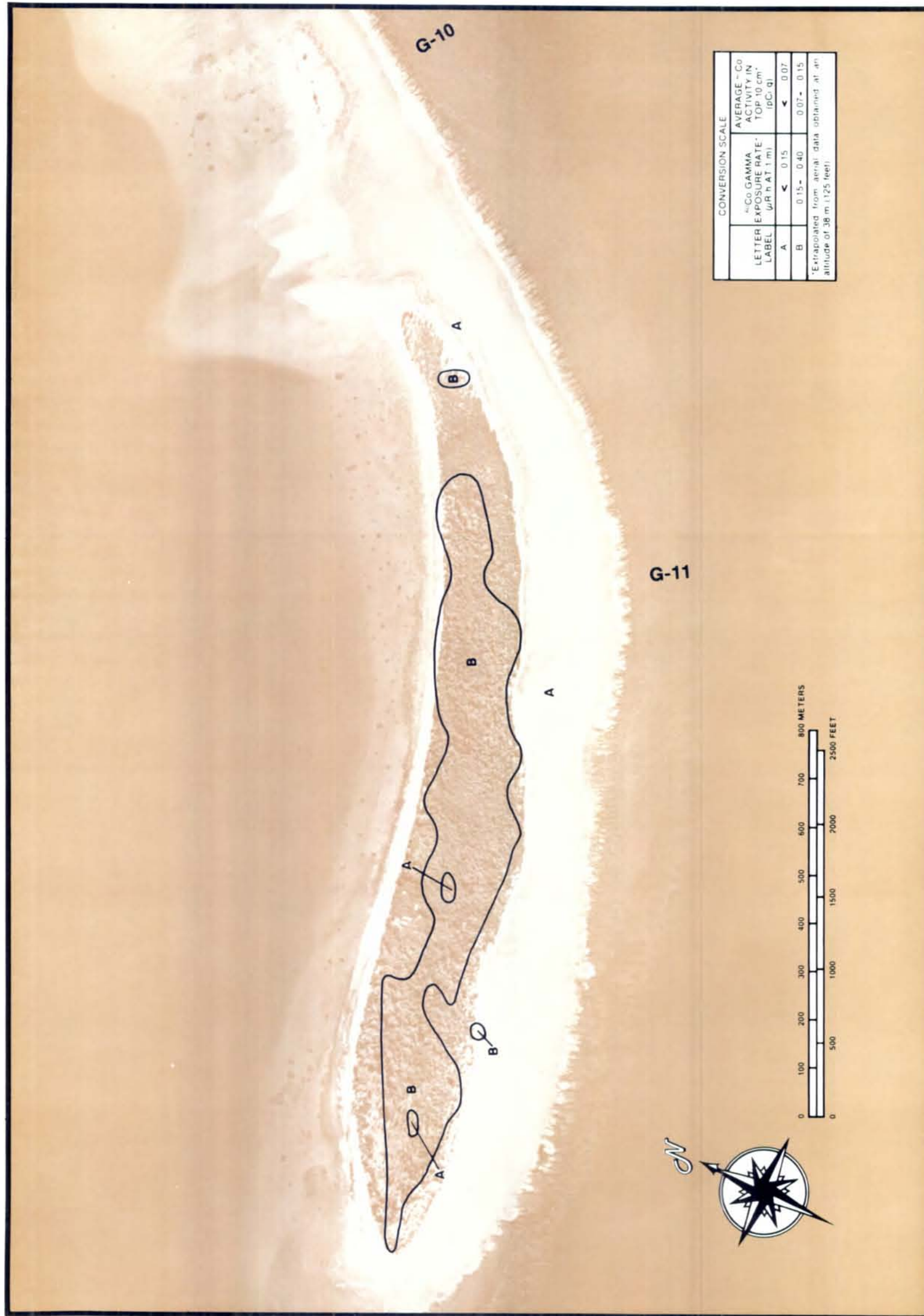


Figure D-79. COBAL T 60 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS G-10 TO G-11 AT RONGERIK ATOLL. (Photograph Frame Number 64)



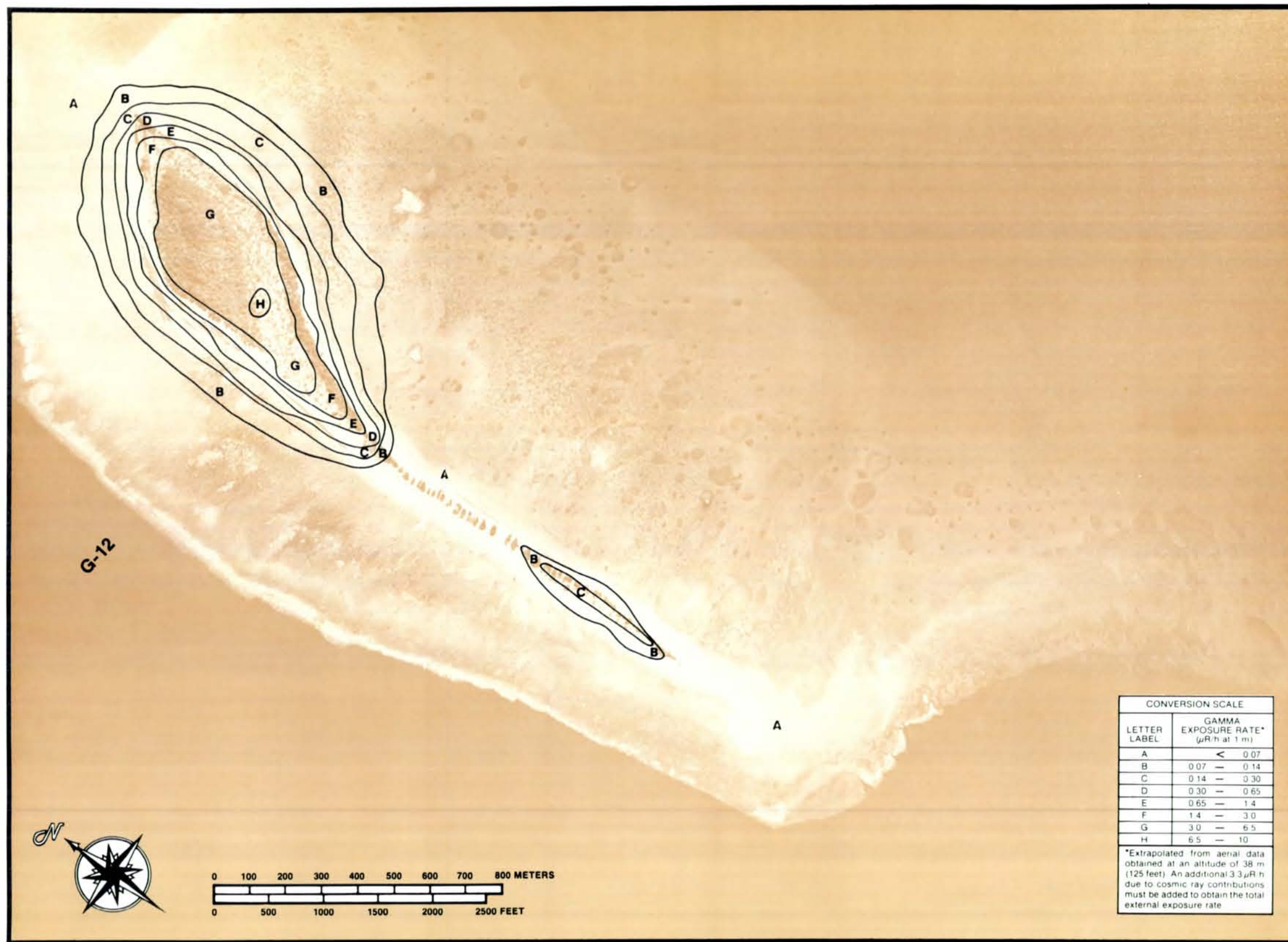


Figure D-80. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLAND G-12 AT RONGERIK ATOLL. (Photograph Frame Number 102)



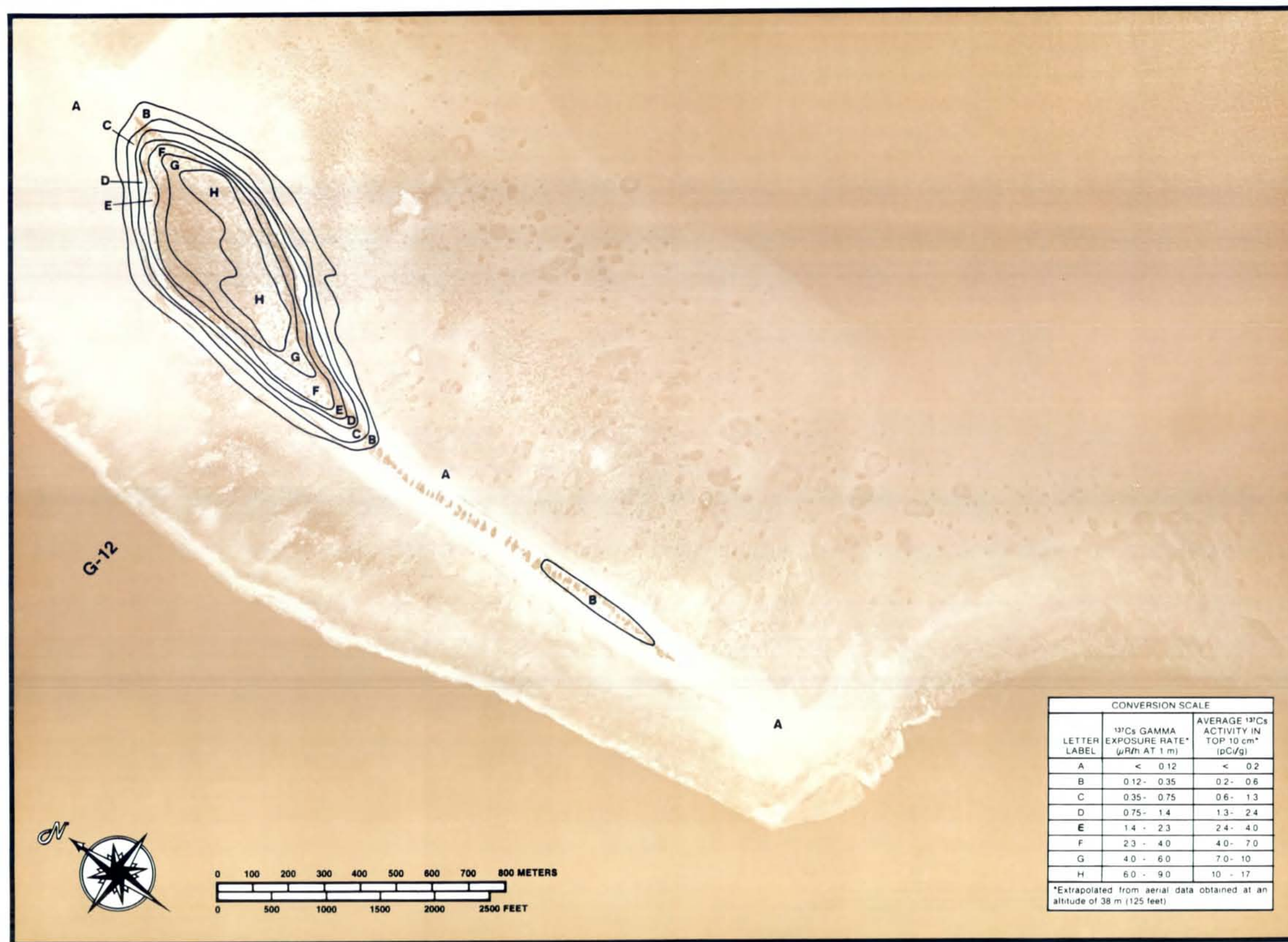


Figure D-81. CESIUM 137 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLAND G-12 AT RONGERIK ATOLL. (Photograph Frame Number 102)



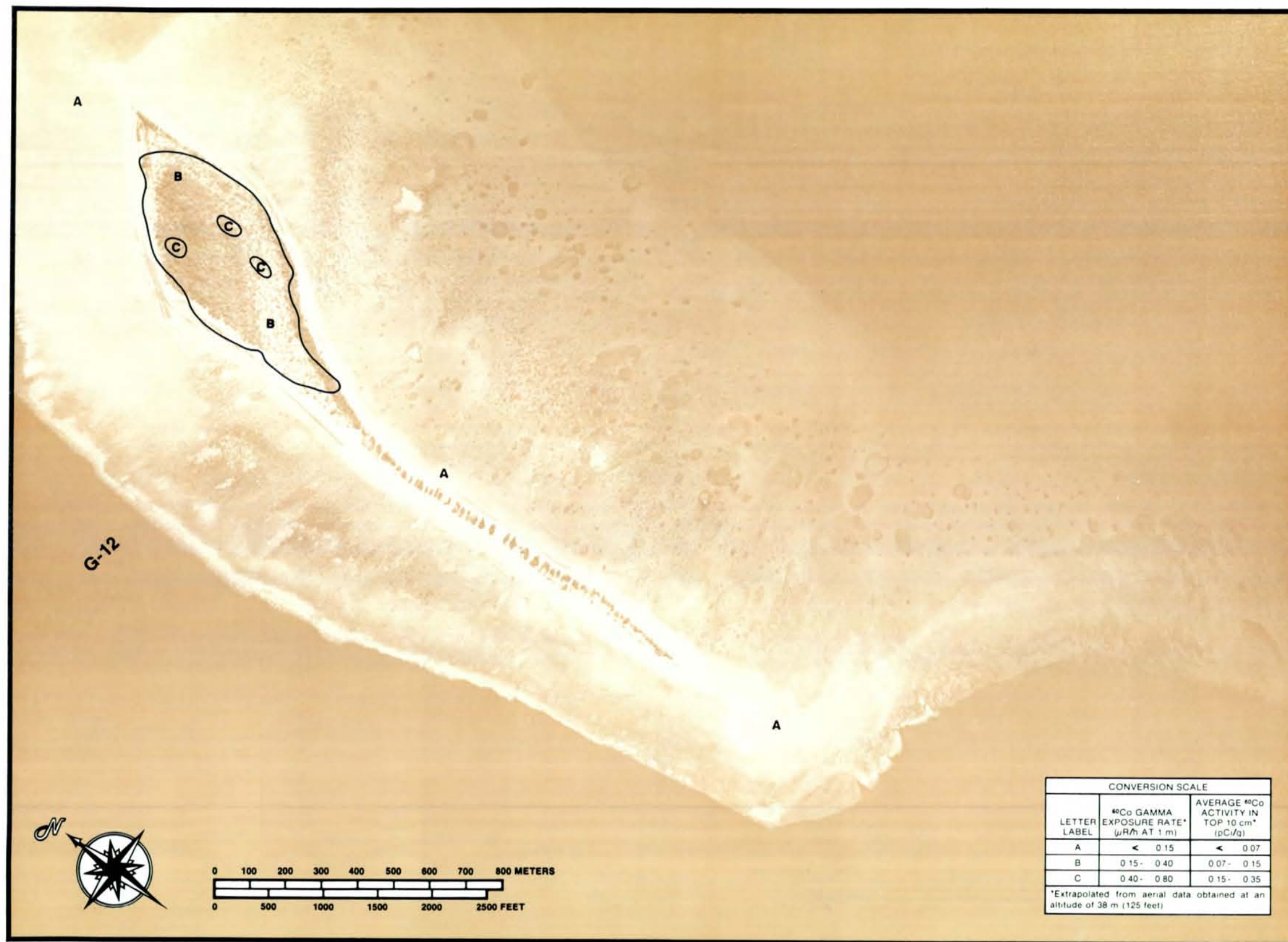


Figure D-82. COBALT 60 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLAND G-12 AT RONGERIK ATOLL. (Photograph Frame Number 102)



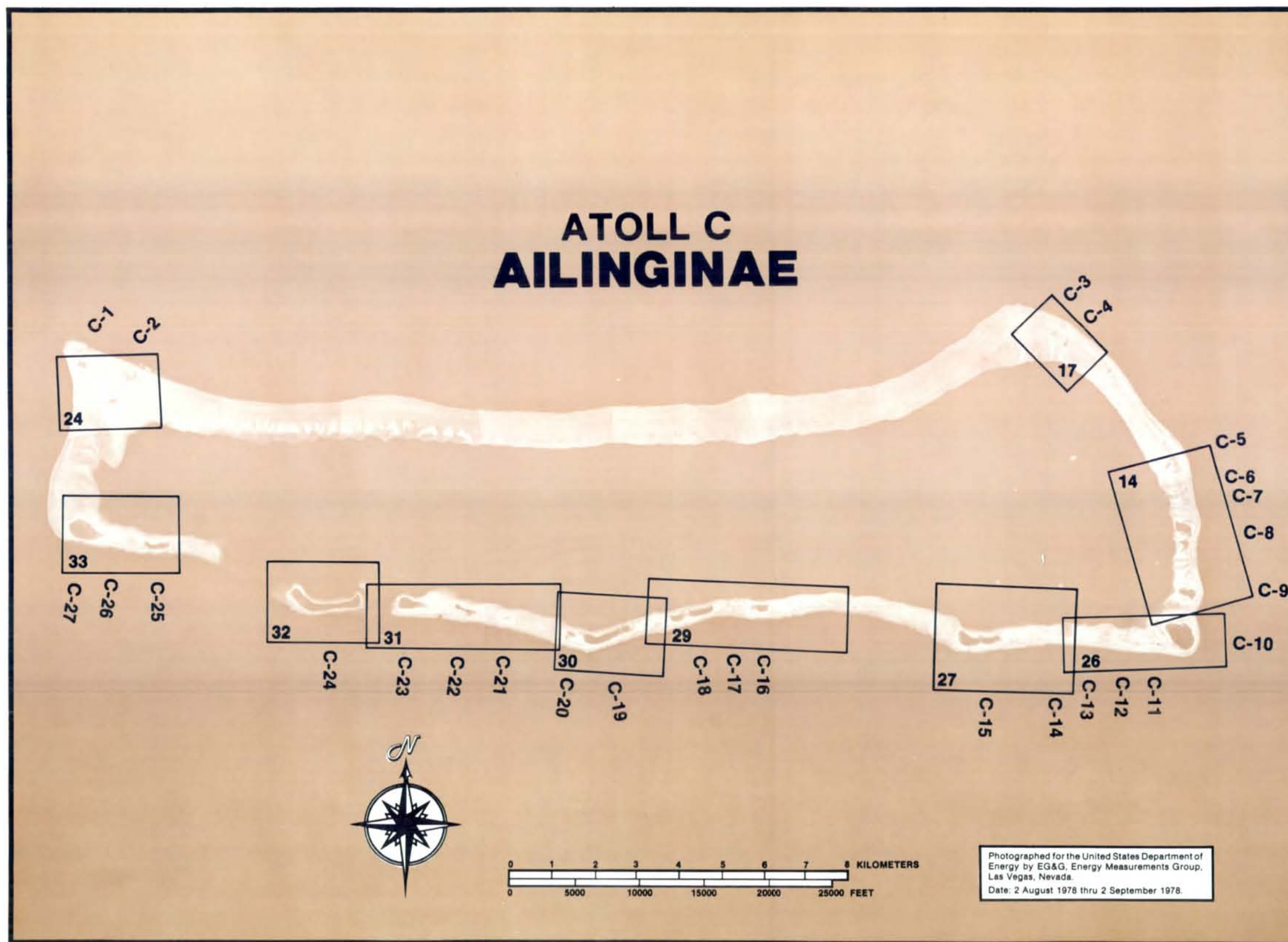


Figure D-83. BASE MAP KEY FOR AILINGINAE ATOLL. The photomosaic shows the area covered by each base map photograph and the photograph frame number used to identify each survey area.





Figure D-84. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS C-1 TO C-2 AT AILINGINAE ATOLL. (Photograph Frame Number 24)





Figure D-85. CESIUM 137 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS C-1 TO C-2 AT AILINGINAE ATOLL. (Photograph Frame Number 24)



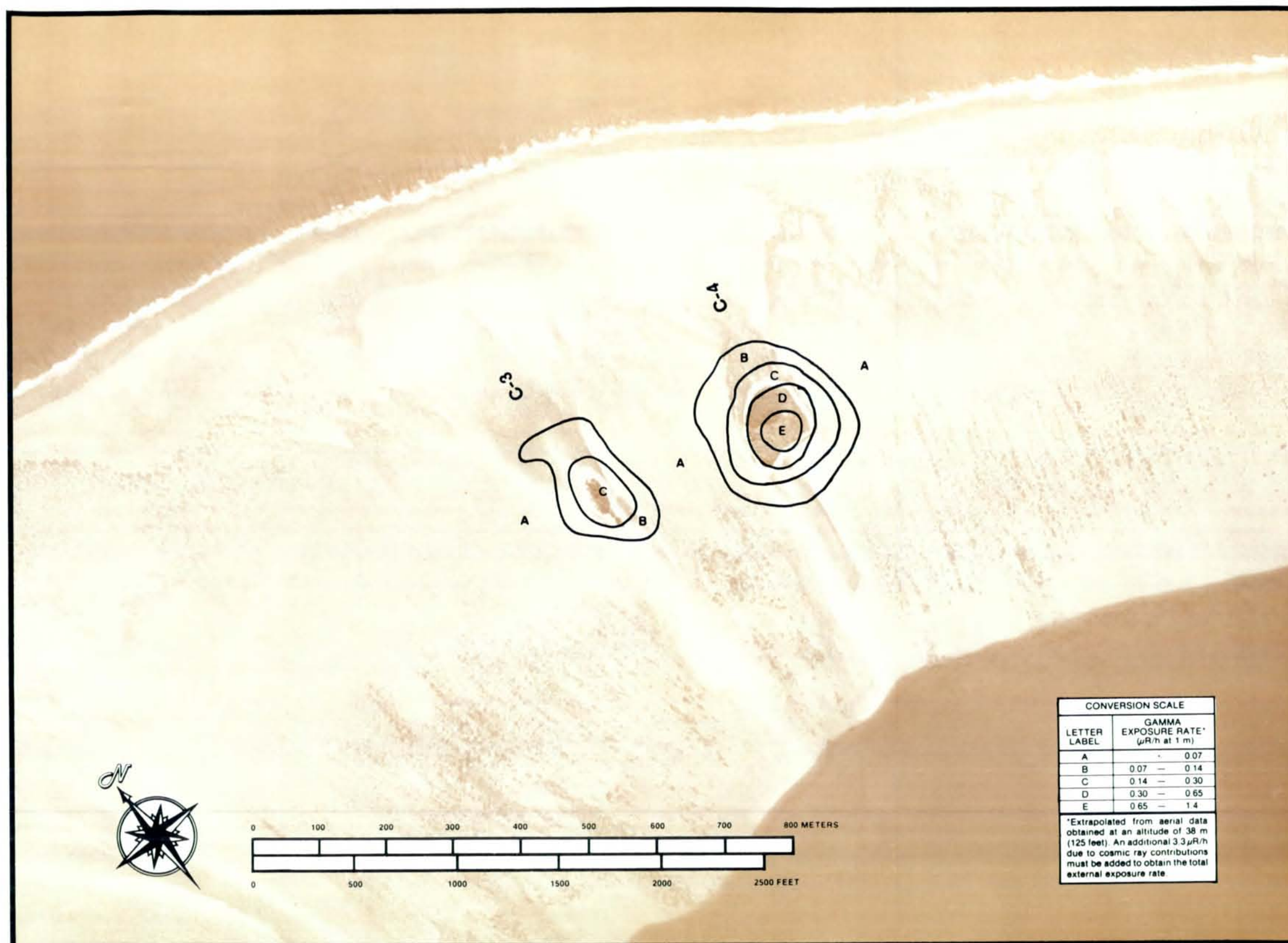


Figure D-86. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS C-3 TO C-4 AT AILINGINAE ATOLL. (Photograph Frame Number 17)





Figure D-87. CESIUM 137 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS C-3 TO C-4 AT AILINGINAE ATOLL. (Photograph Frame Number 17)





Figure D-88. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS C-5 TO C-9 AT AILINGINAE ATOLL. (Photograph Frame Number 14)





Figure D-89. CESIUM 137 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS C-5 TO C-9 AT AILINGINAE ATOLL. (Photograph Frame Number 14)



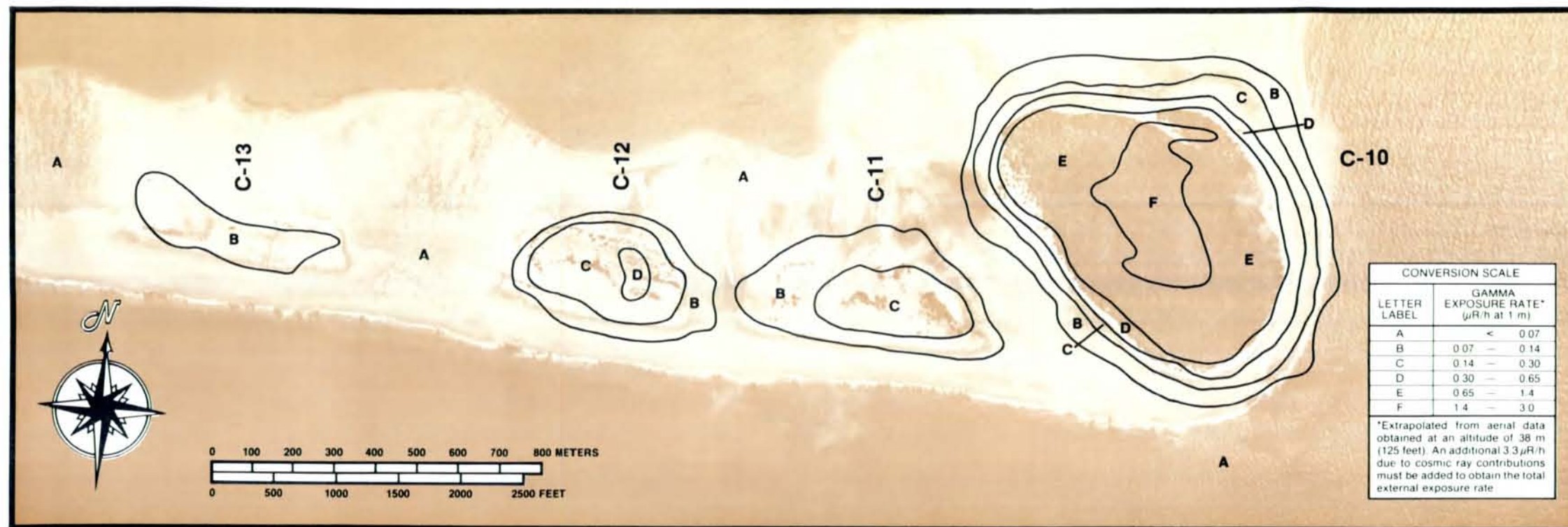


Figure D-90. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS C-10 TO C-13 AT AILINGINAE ATOLL. (Photograph Frame Number 26)

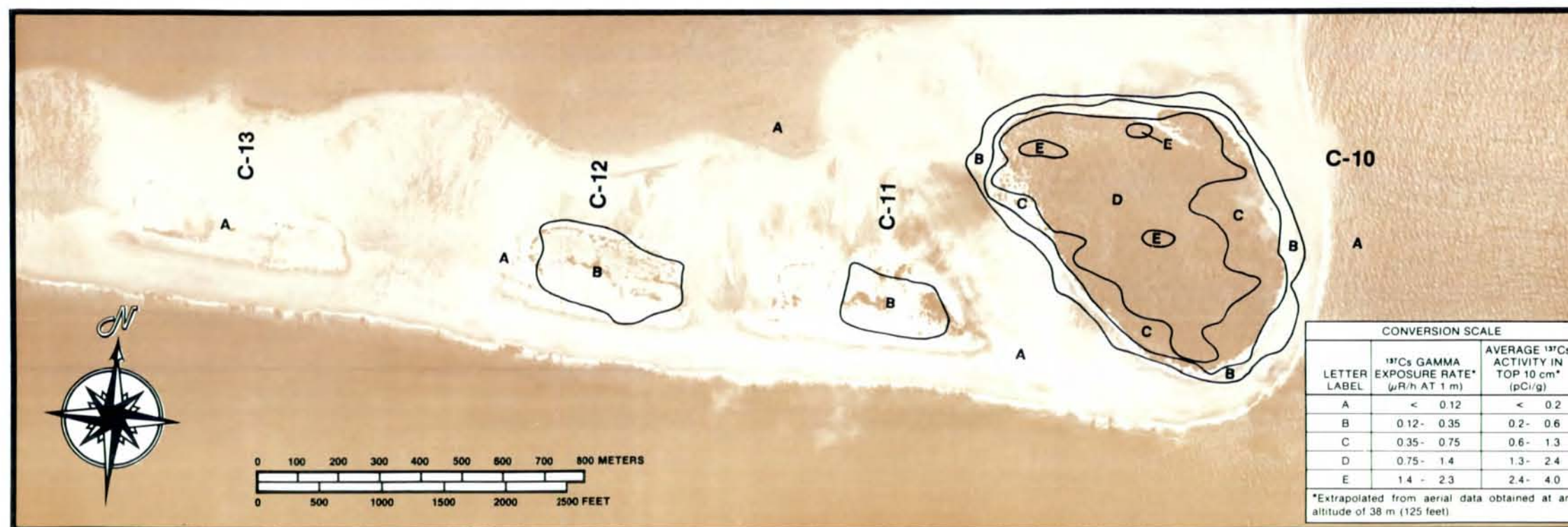


Figure D-91. CESIUM 137 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS C-10 TO C-13 AT AILINGINAE ATOLL. (Photograph Frame Number 26)



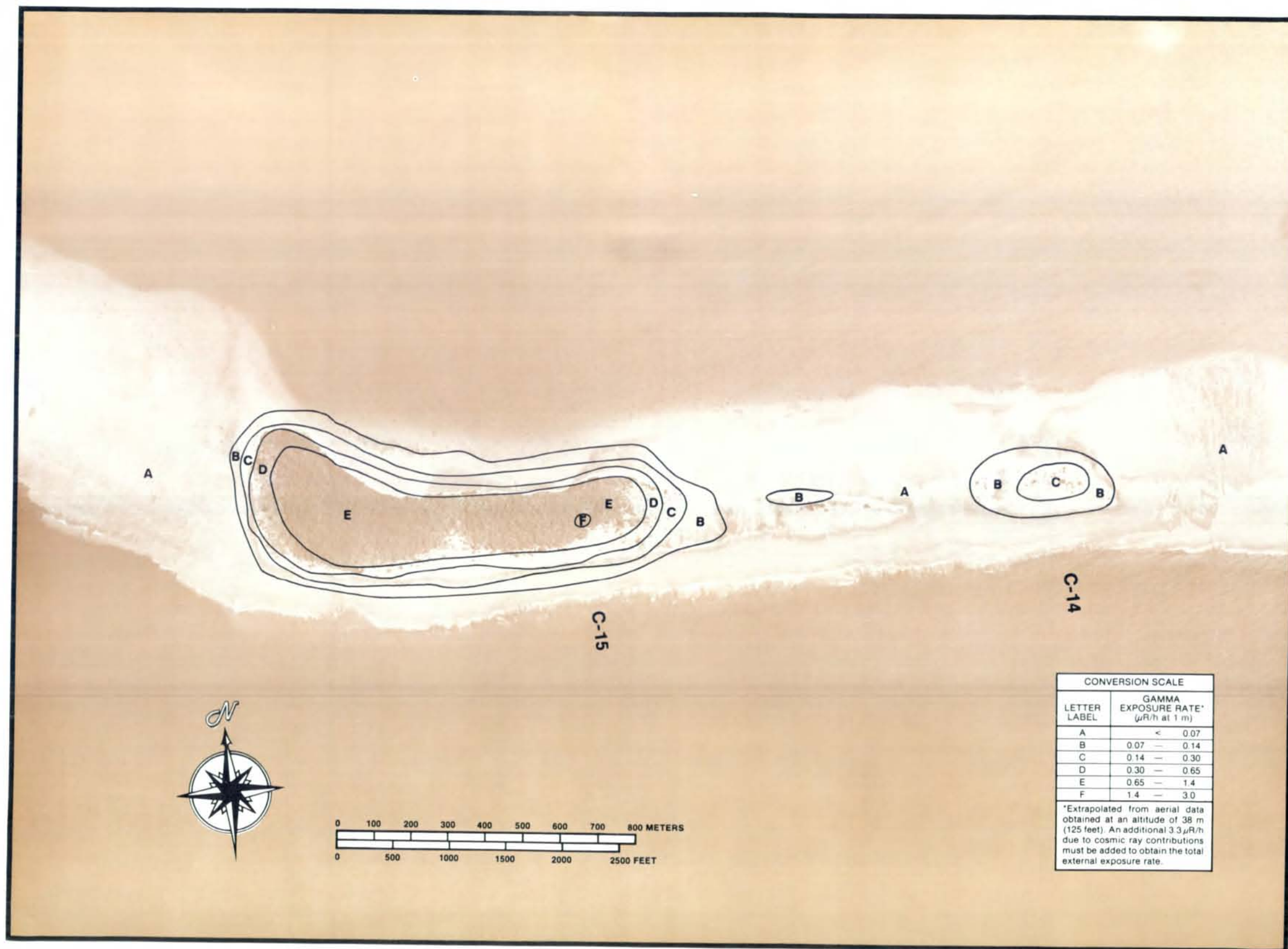


Figure D-92. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS C-14 TO C-15 AT AILINGINAE ATOLL. (Photograph Frame Number 27)



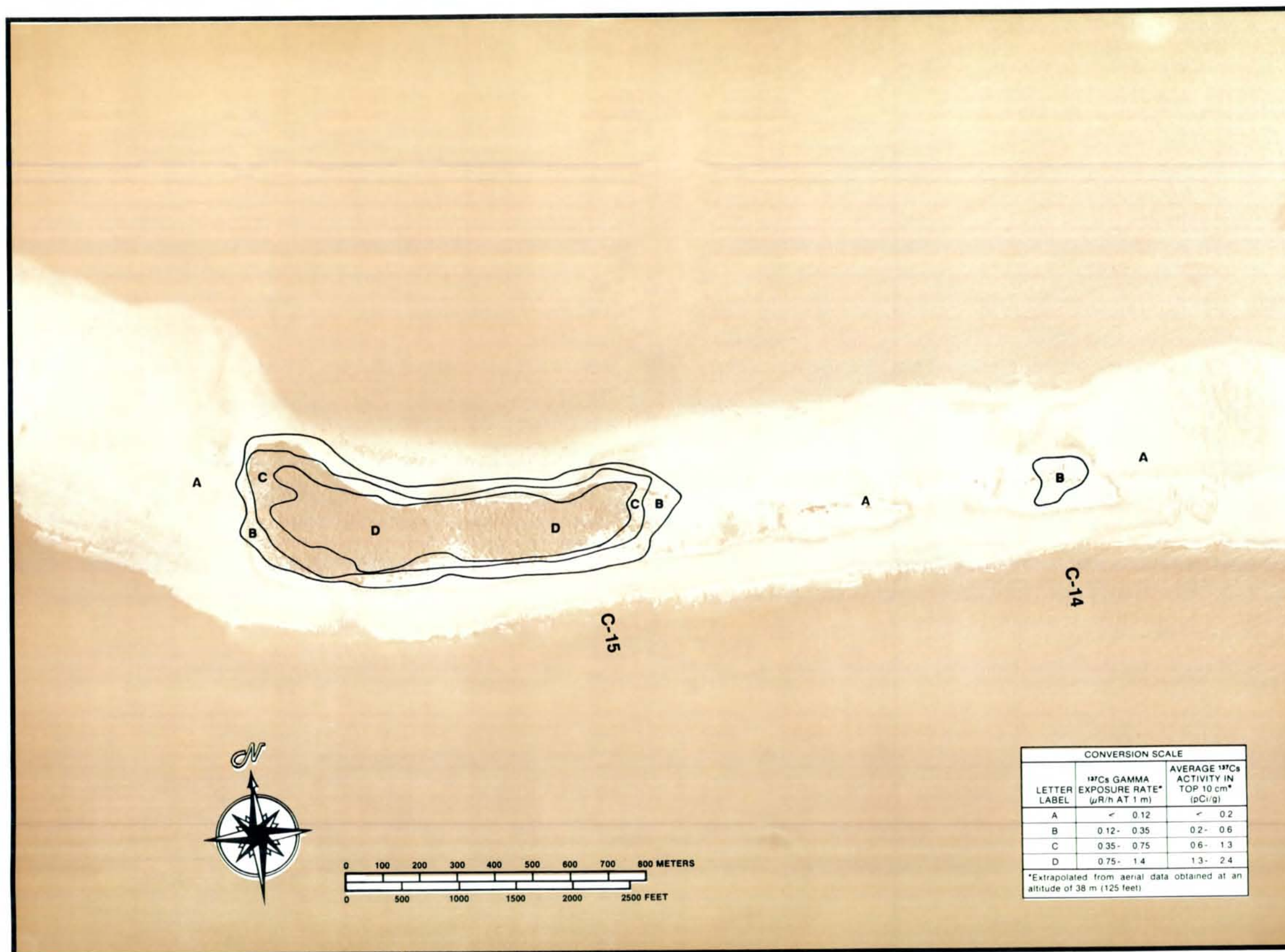


Figure D-93. CESIUM 137 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS C-14 TO C-15 AT AILINGINAE ATOLL. (Photograph Frame Number 27)



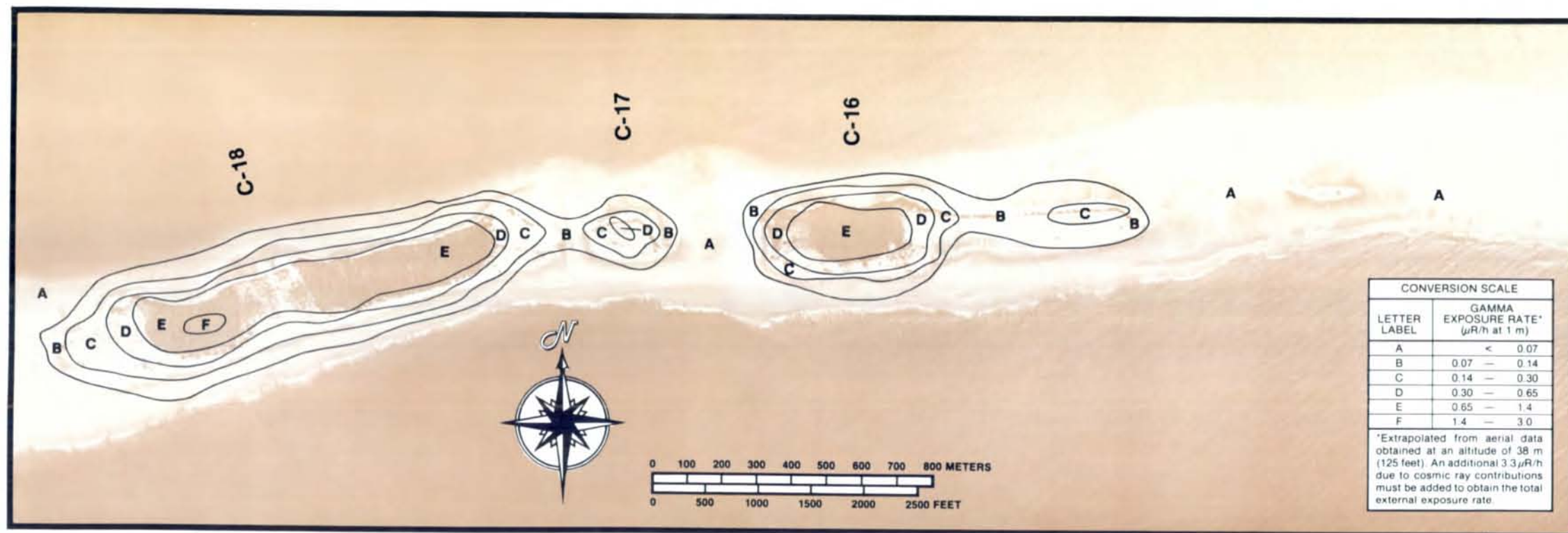


Figure D-94. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS C-16 TO C-18 AT AILINGINAE ATOLL. (Photograph Frame Number 29)

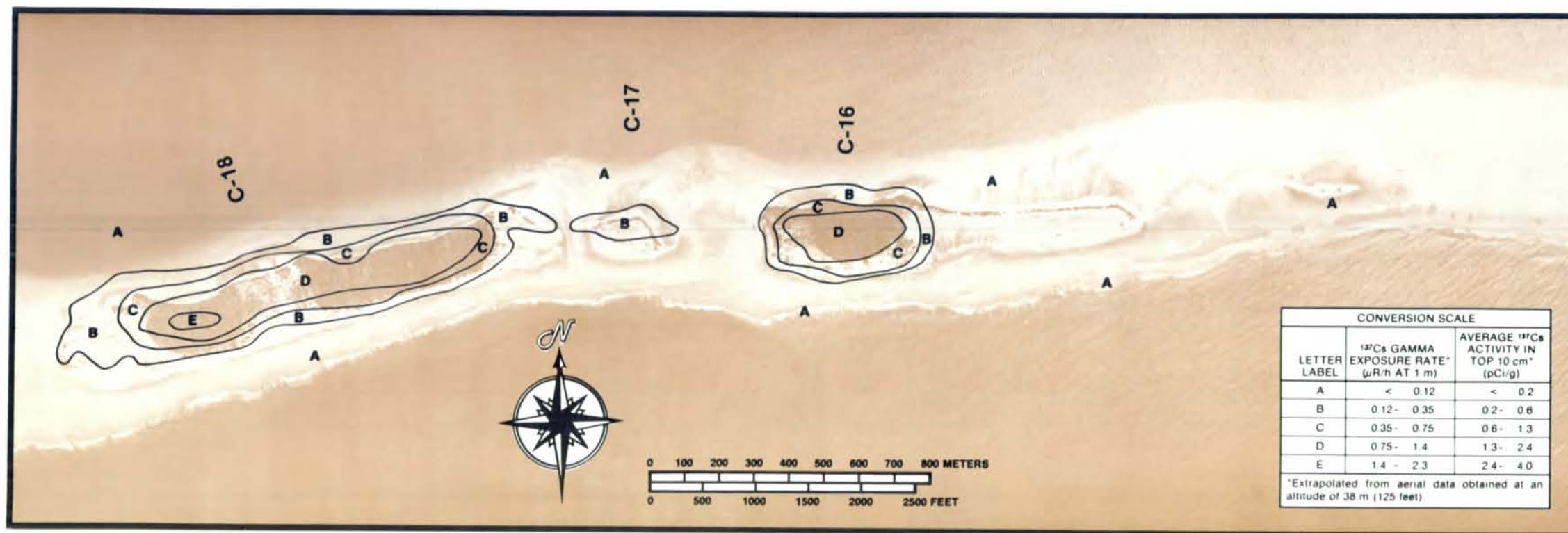


Figure D-95. CESIUM 137 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS C-16 TO C-18 AT AILINGINAE ATOLL. (Photograph Frame Number 29)



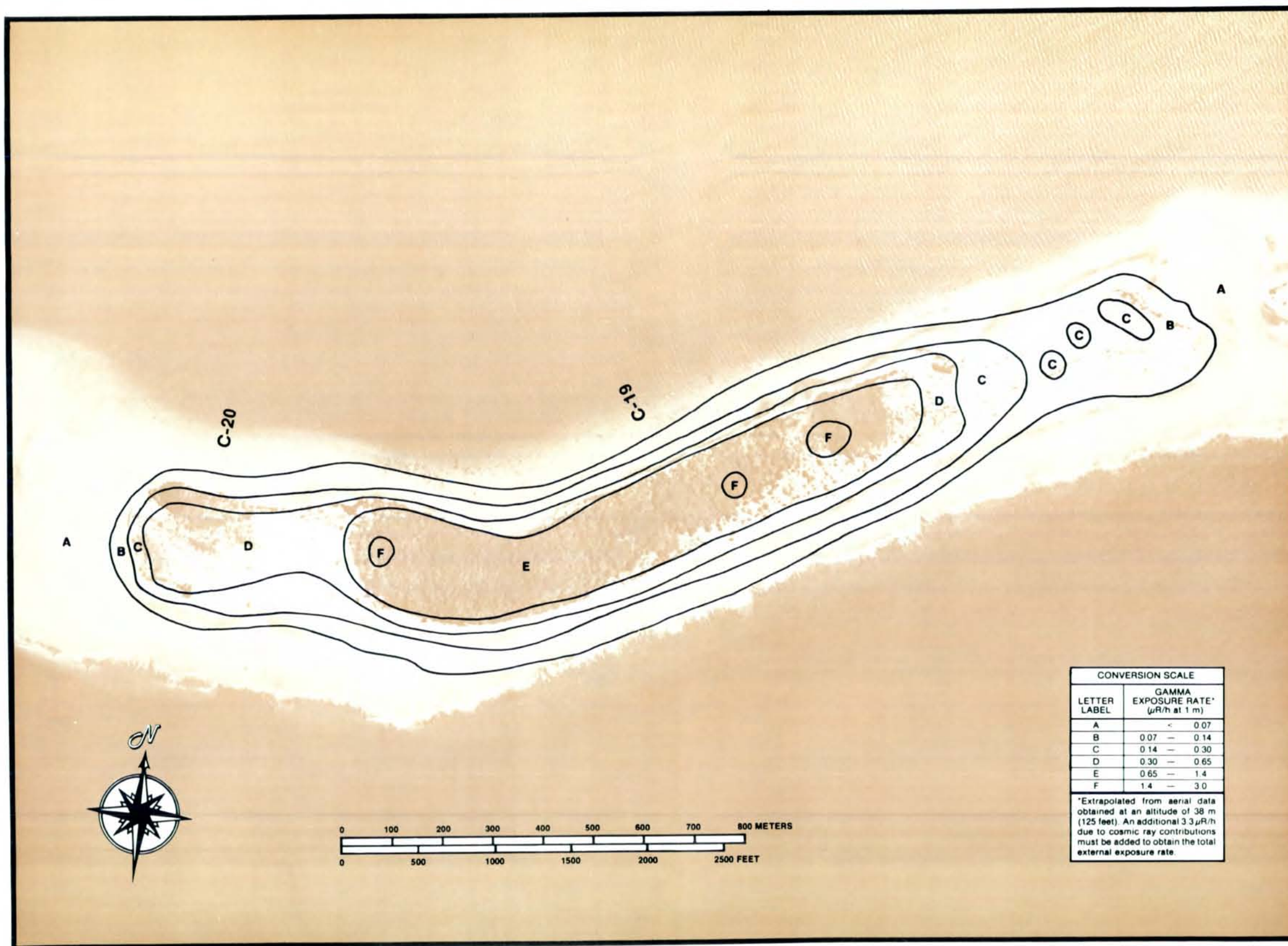


Figure D-96. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS C-19 TO C-20 AT AILINGINAE ATOLL. (Photograph Frame Number 30)



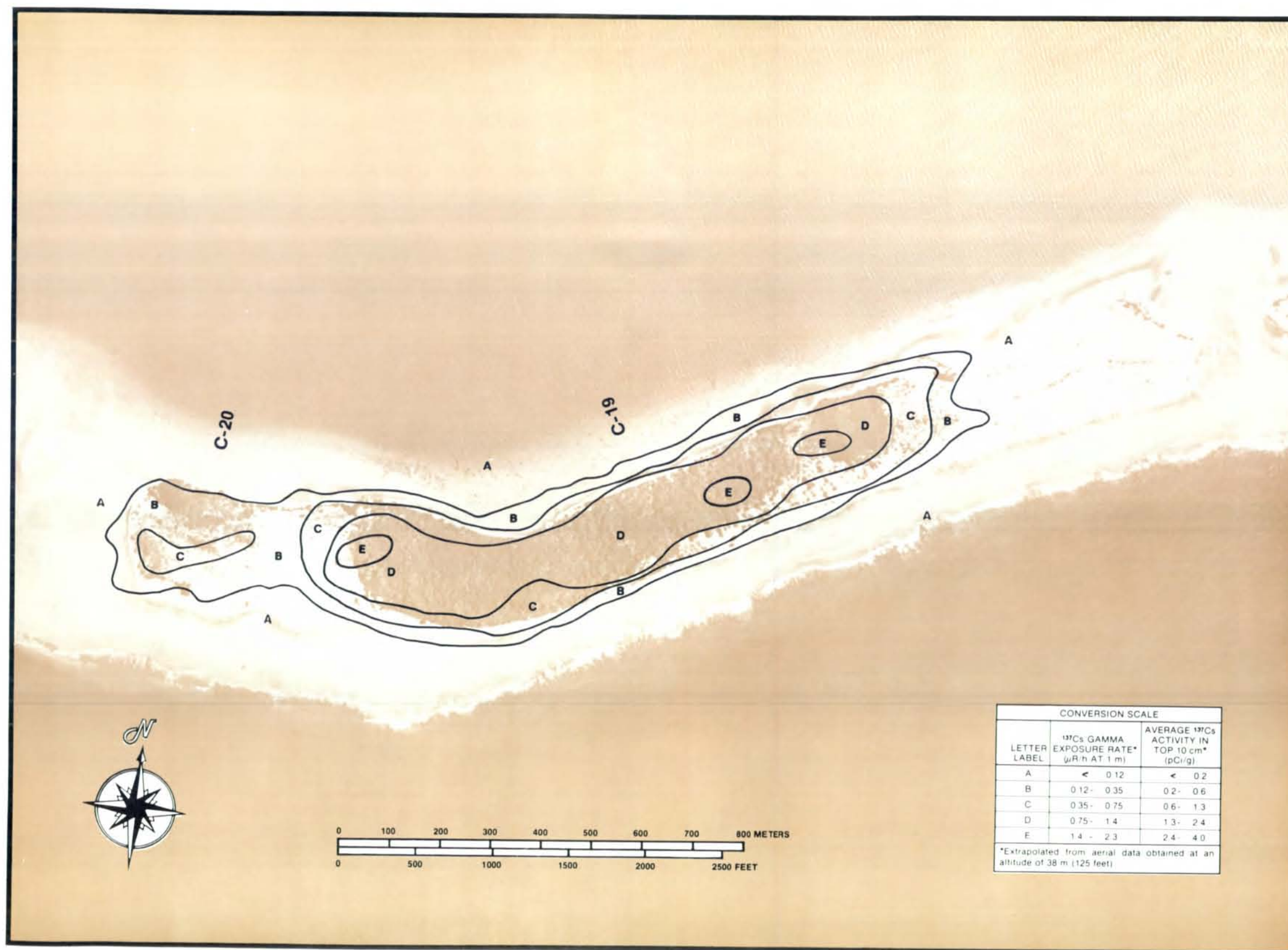


Figure D-97. CESIUM 137 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS C-19 TO C-20 AT AILINGINAE ATOLL. (Photograph Frame Number 30)



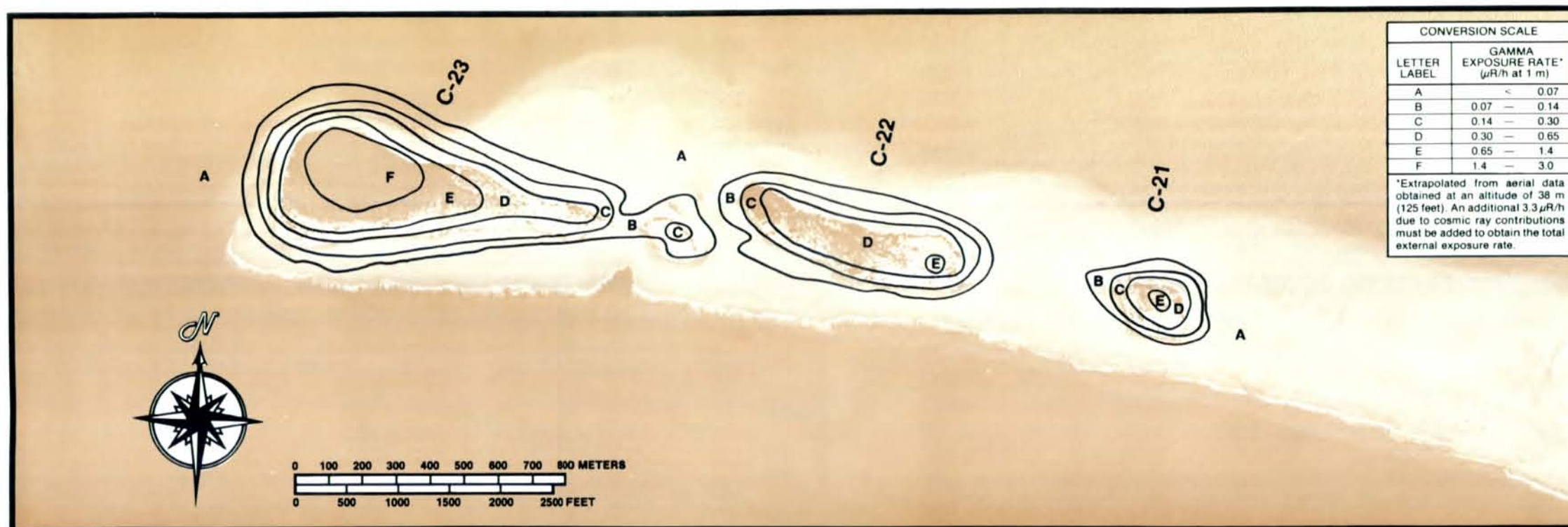


Figure D-98. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS C-21 TO C-23 AT AILINGINAE ATOLL. (Photograph Frame Number 31)

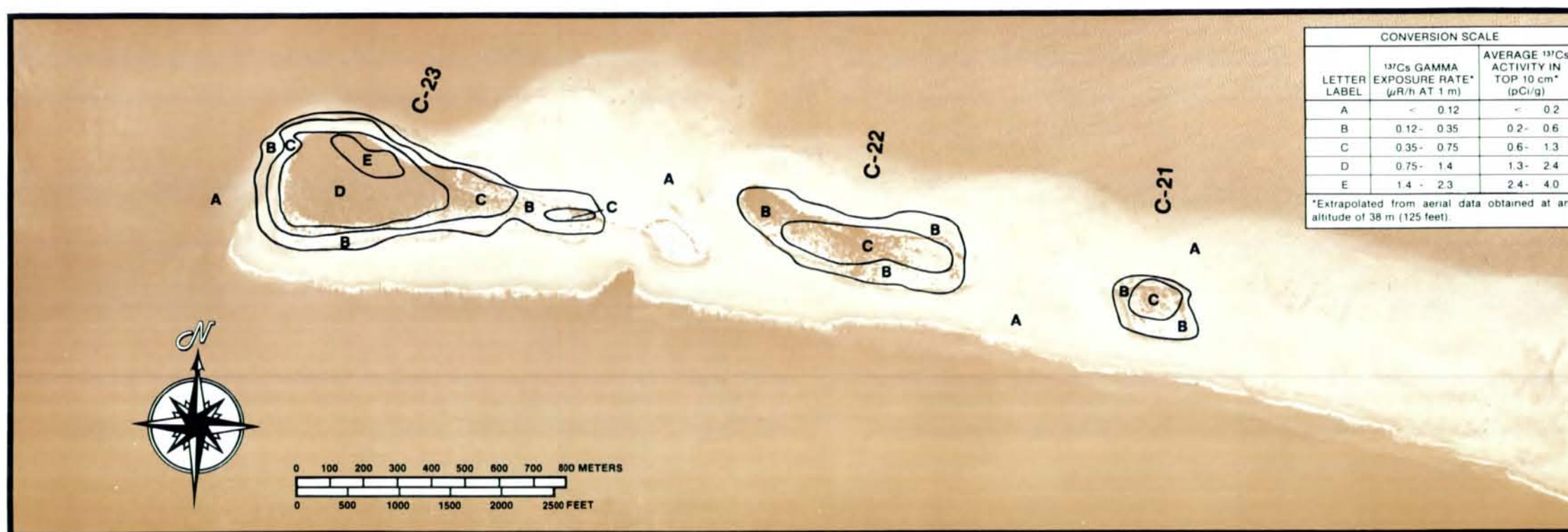


Figure D-99. CESIUM 137 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS C-21 TO C-23 AT AILINGINAE ATOLL. (Photograph Frame Number 31)



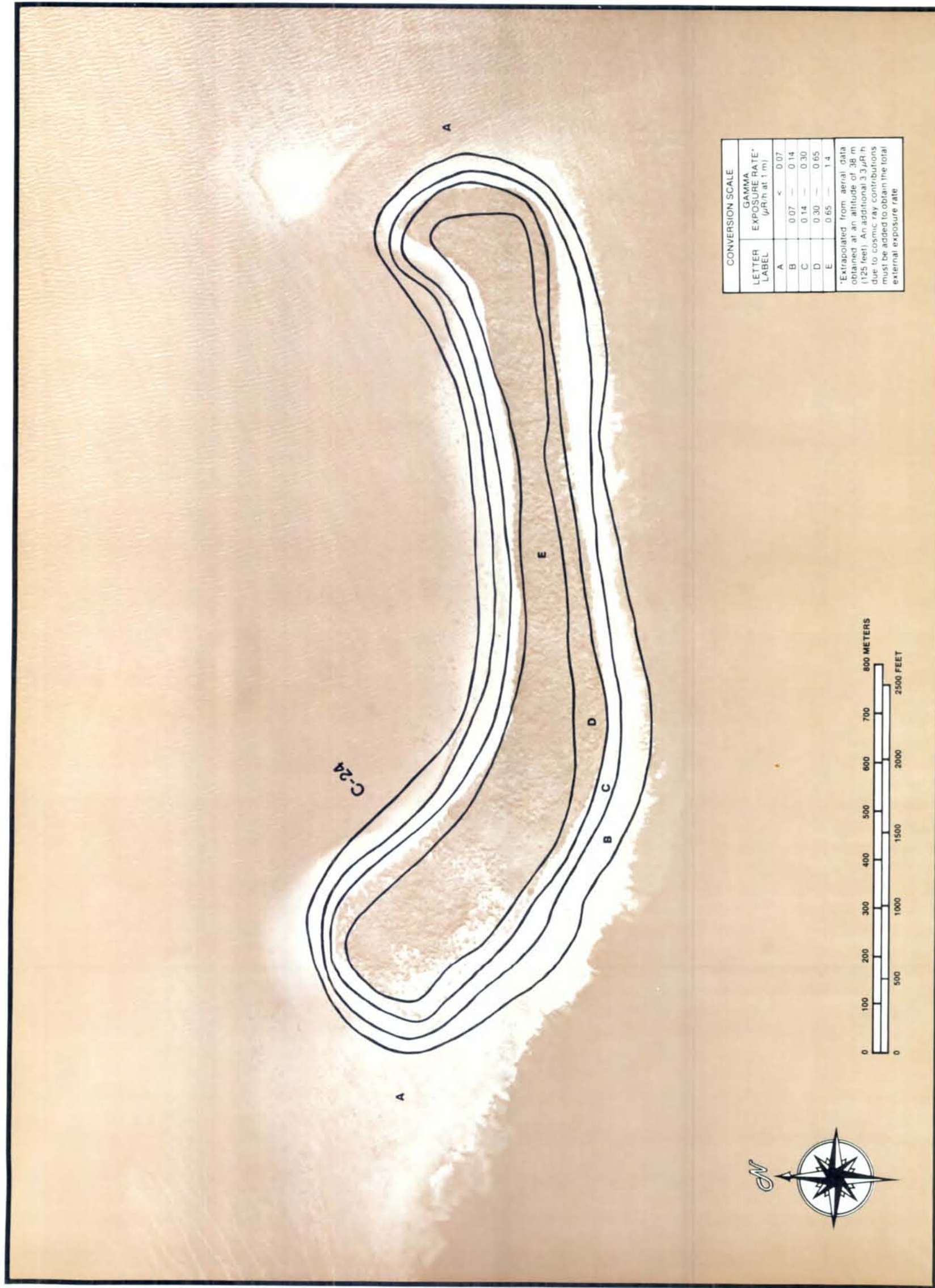


Figure D-100. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLAND C-24 AT AILINGINAE ATOLL. (Photograph Frame Number 32)



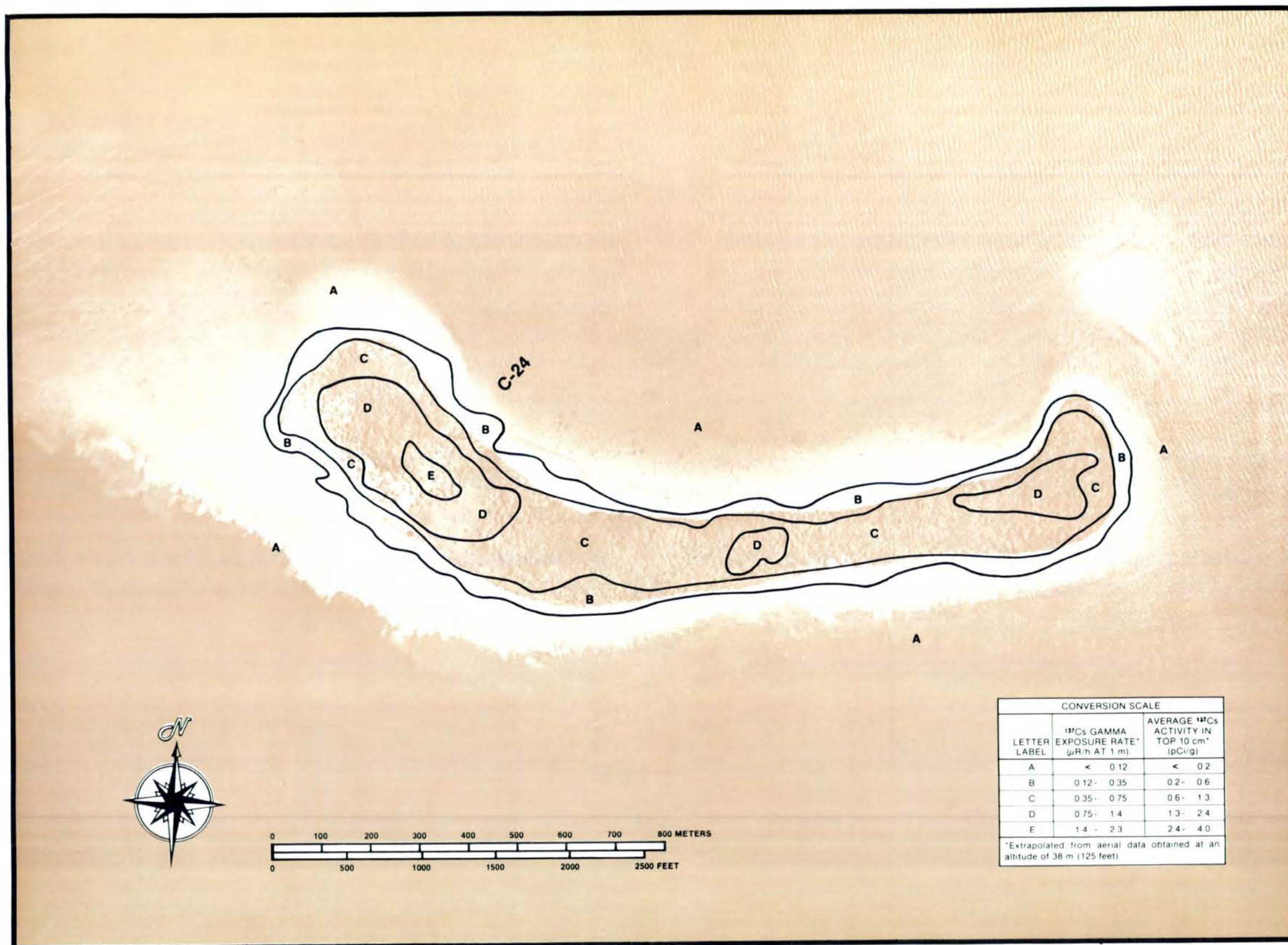


Figure D-101. CESIUM 137 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLAND C-24 AT AILINGINAE ATOLL. (Photograph Frame Number 32)



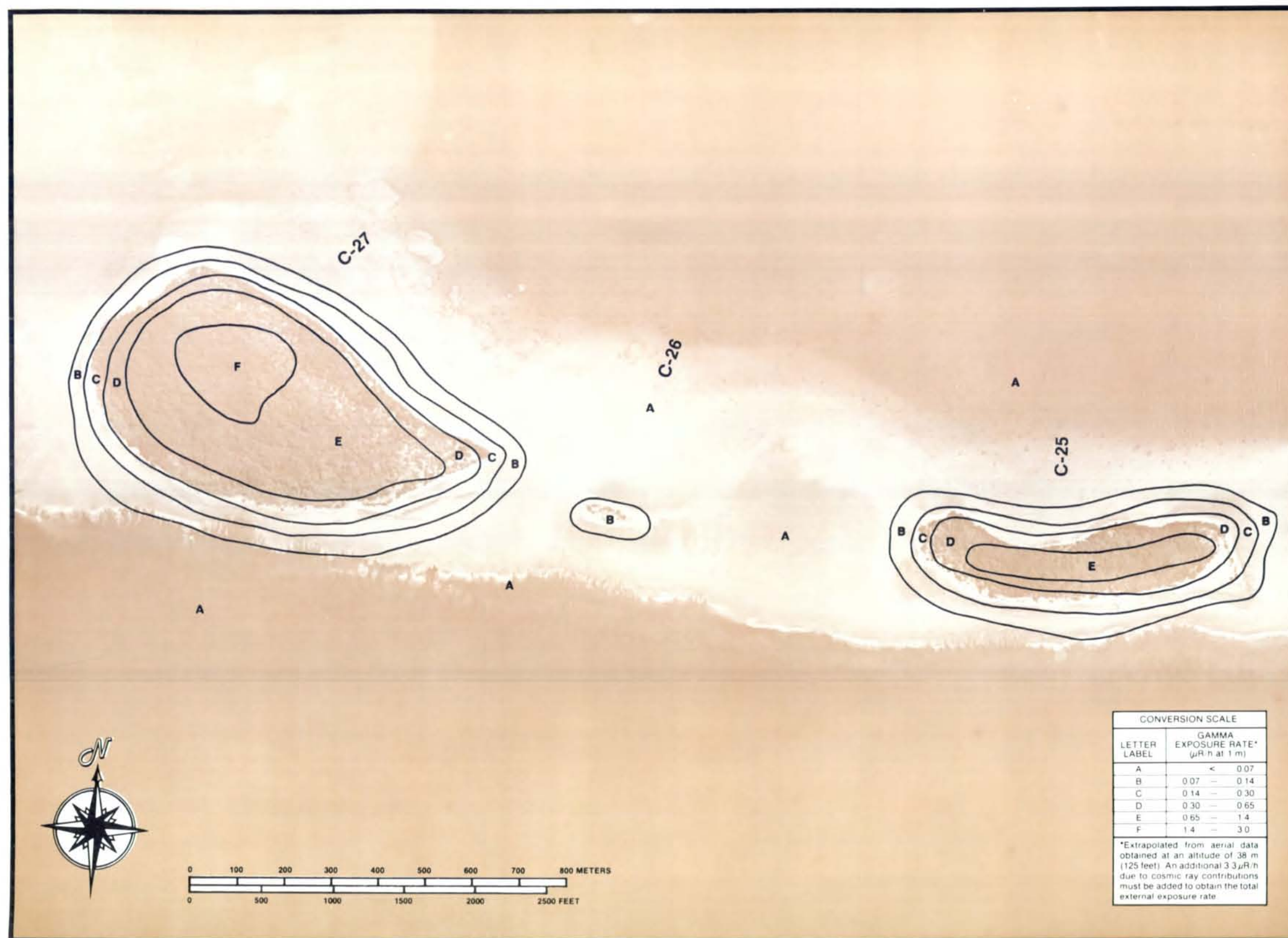


Figure D-102. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS C-25 TO C-27 AT AILINGINAE ATOLL. (Photograph Frame Number 33)



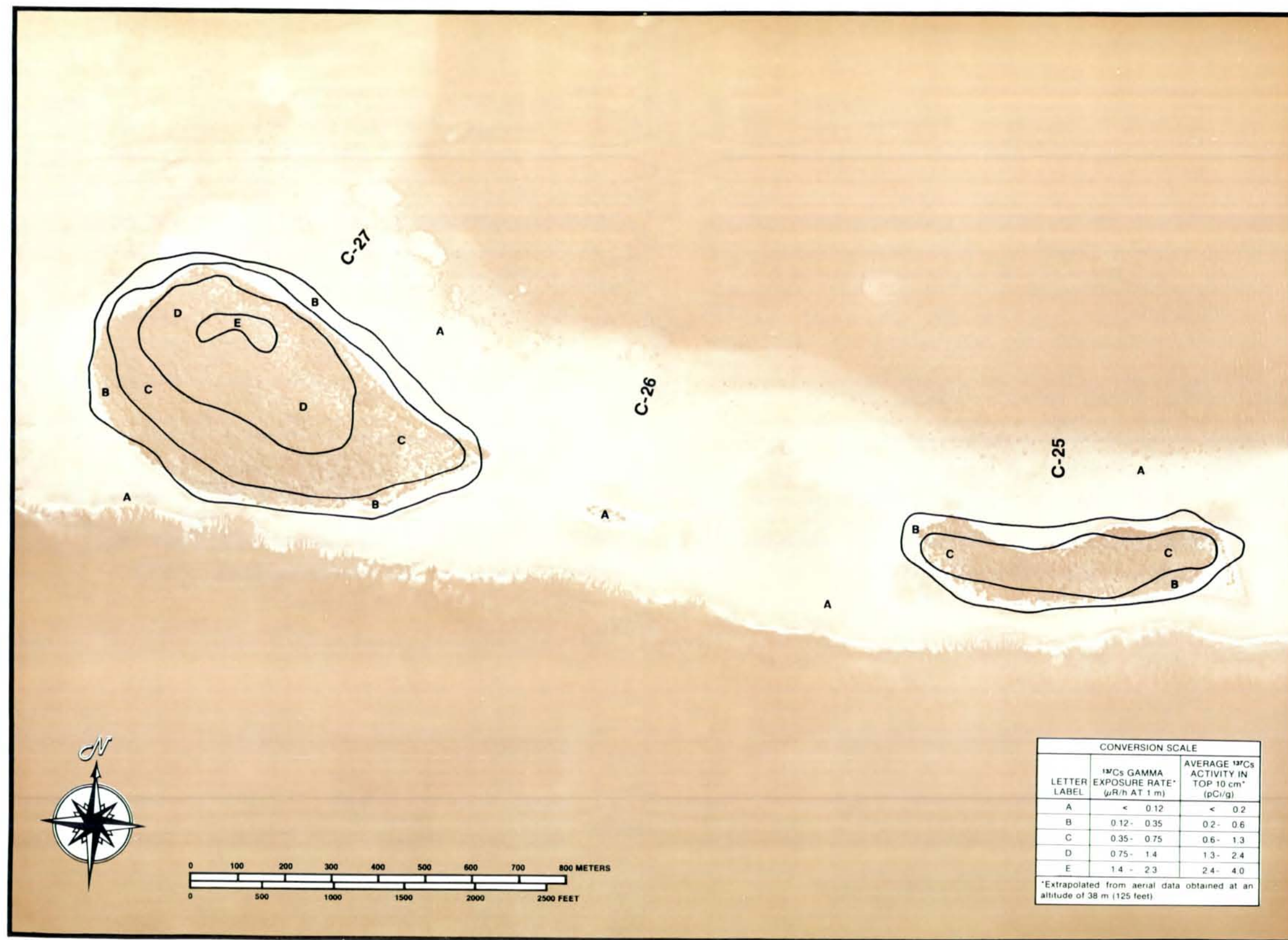


Figure D-103. CESIUM 137 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS C-25 TO C-27 AT AILINGINAE ATOLL. (Photograph Frame Number 33)



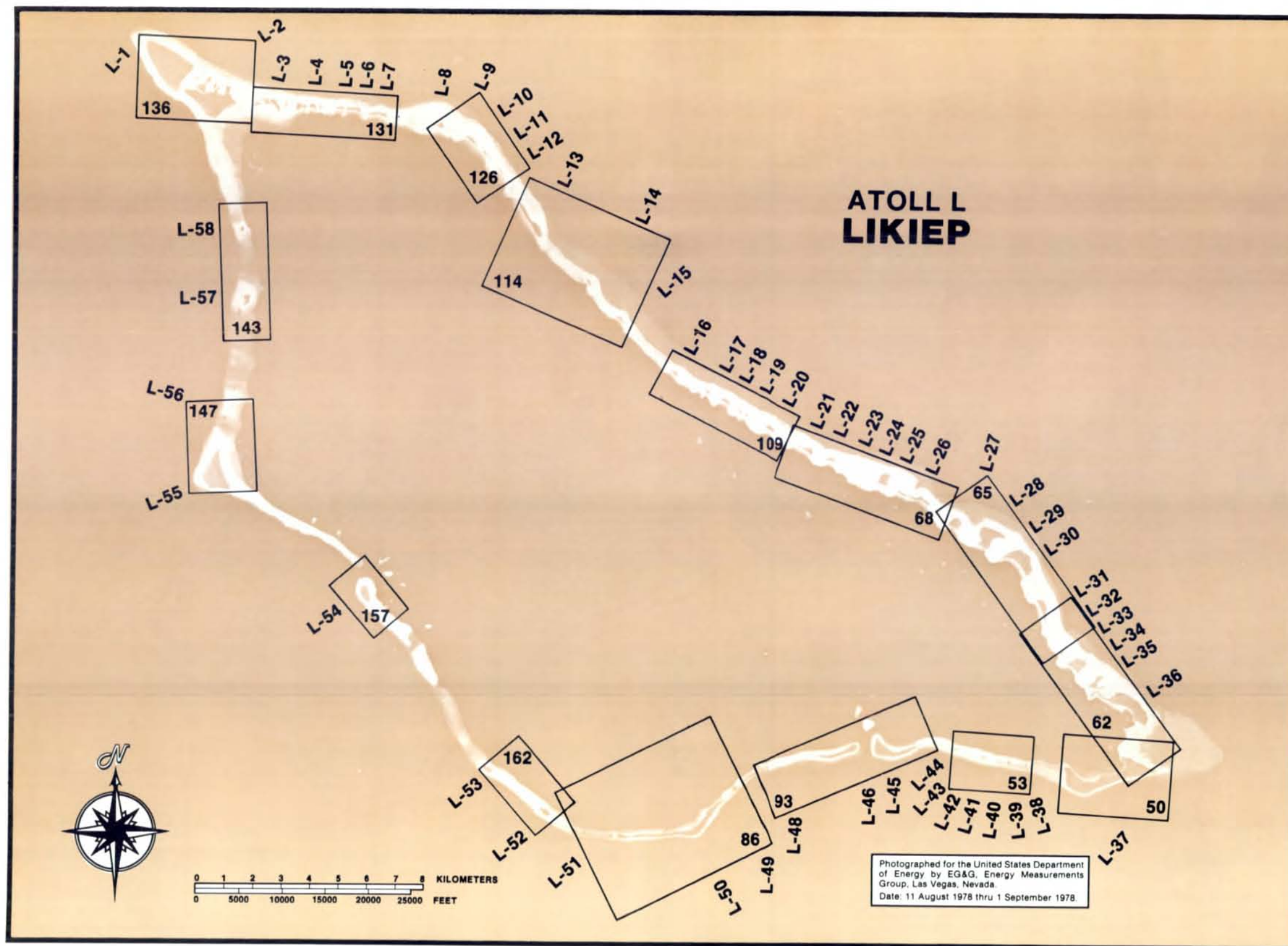


Figure D-104. BASE MAP KEY FOR LIKIEP ATOLL. The photomosaic shows the area covered by each base map photograph and the photograph frame number used to identify each survey area.



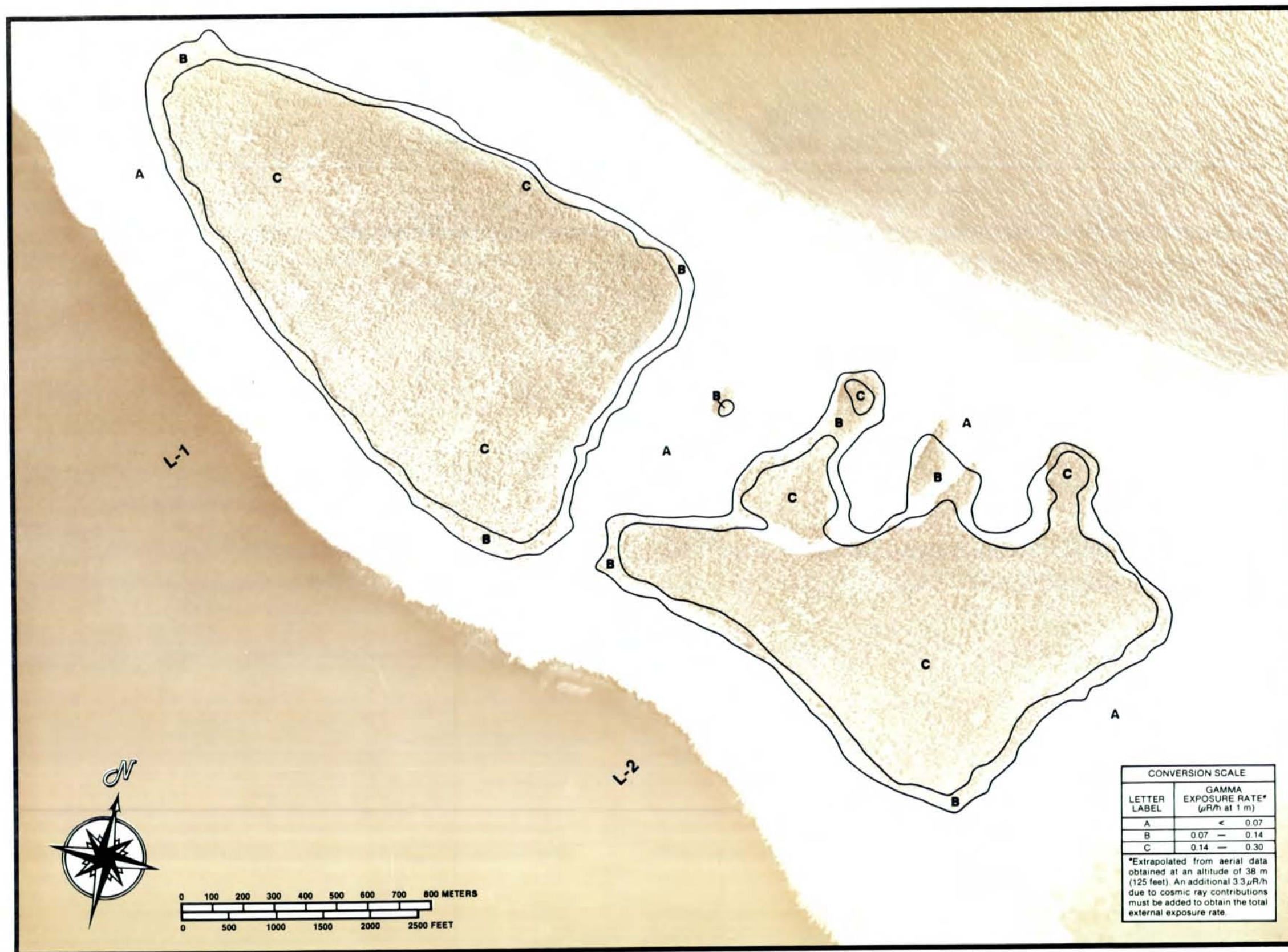


Figure D-105. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS L-1 TO L-2 AT LIKIEP ATOLL. (Photograph Frame Number 136)



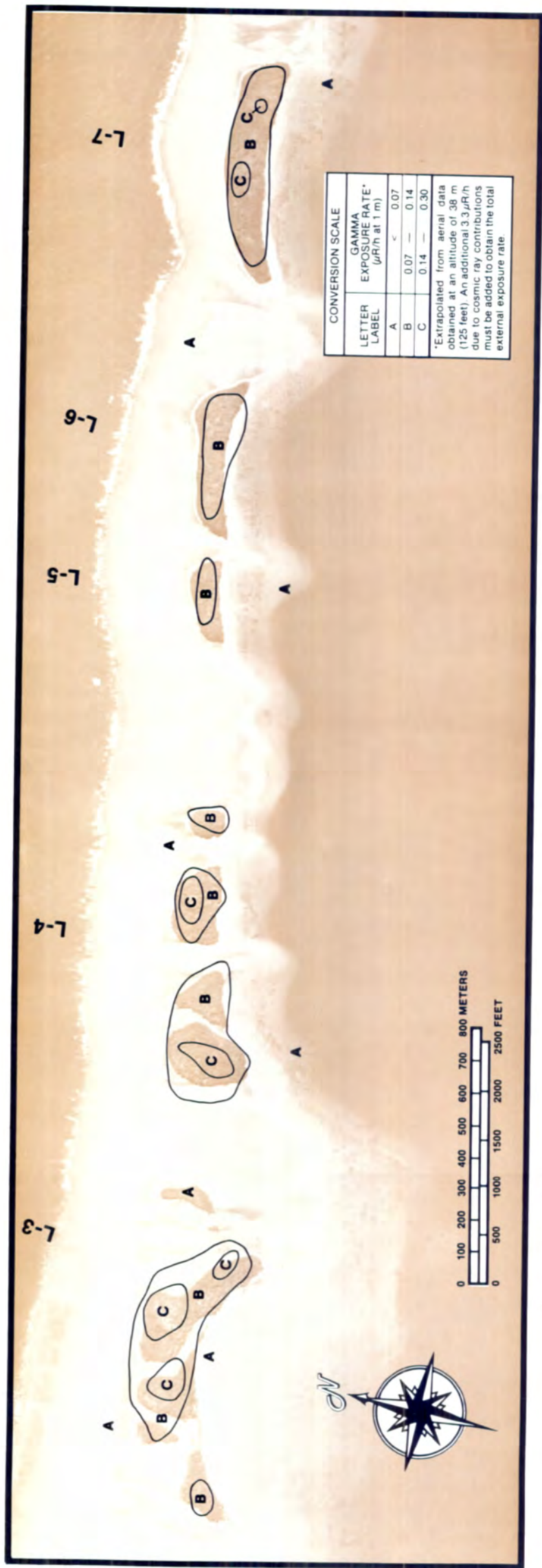


Figure D-106. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS L-3 TO L-7 AT LIKIEP ATOLL. (Photograph Frame Number 131)



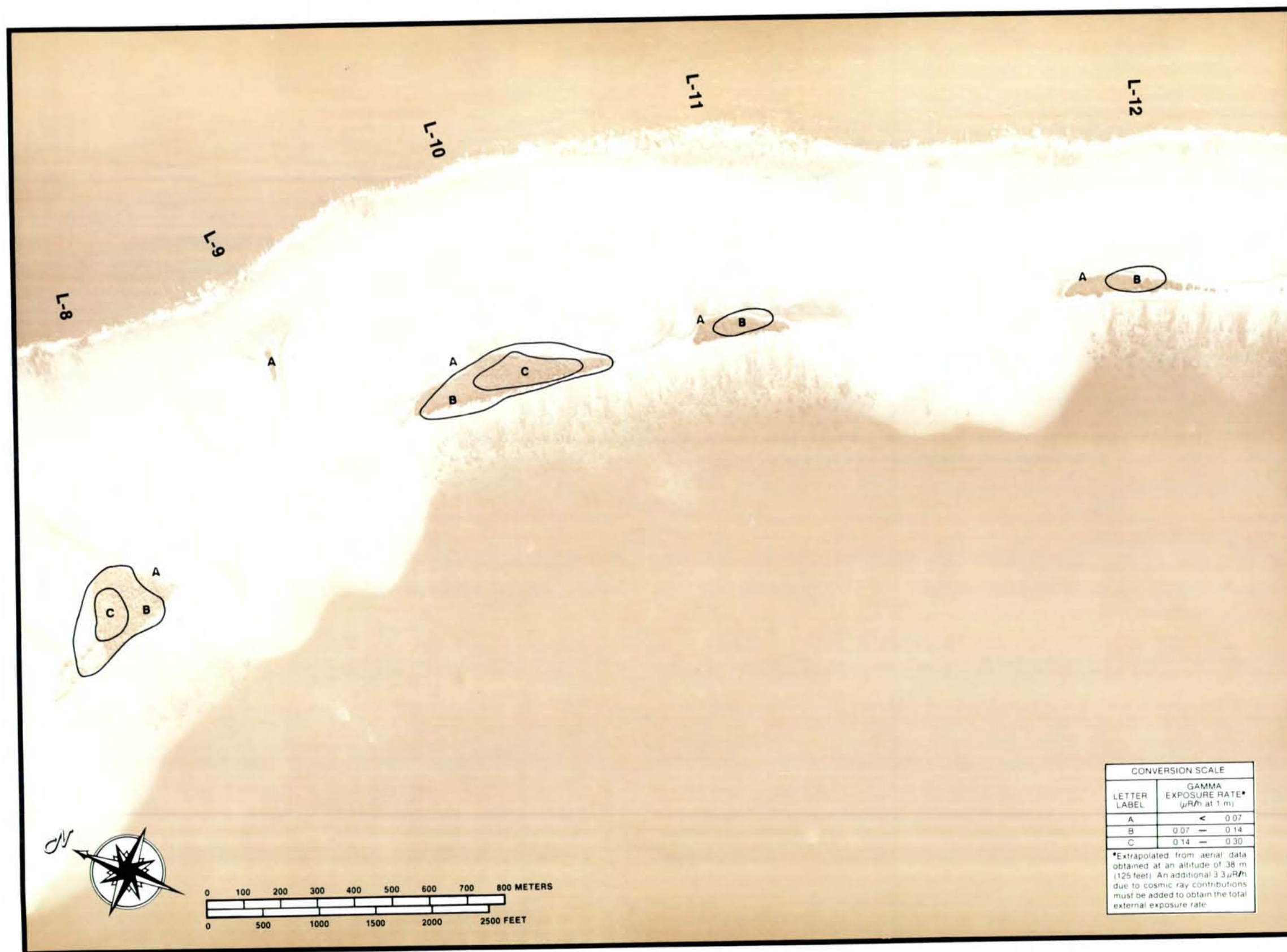


Figure D-107. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS L-8 TO L-12 AT LIKIEP ATOLL (Photograph Frame Number 126)





Figure D-108. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS L-13 TO L-15 AT LIKIEP ATOLL. (Photograph Frame Number 114)



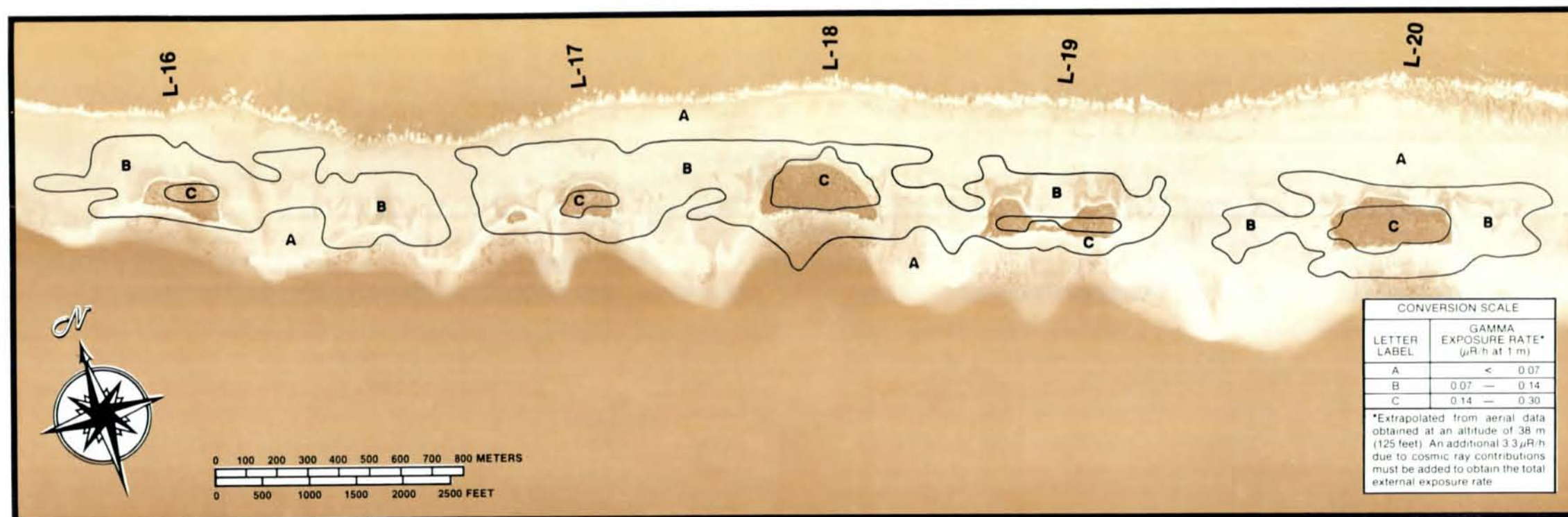


Figure D-109. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS L-16 TO L-20 AT LIKIEPATOLL. (Photograph Frame Number 109)

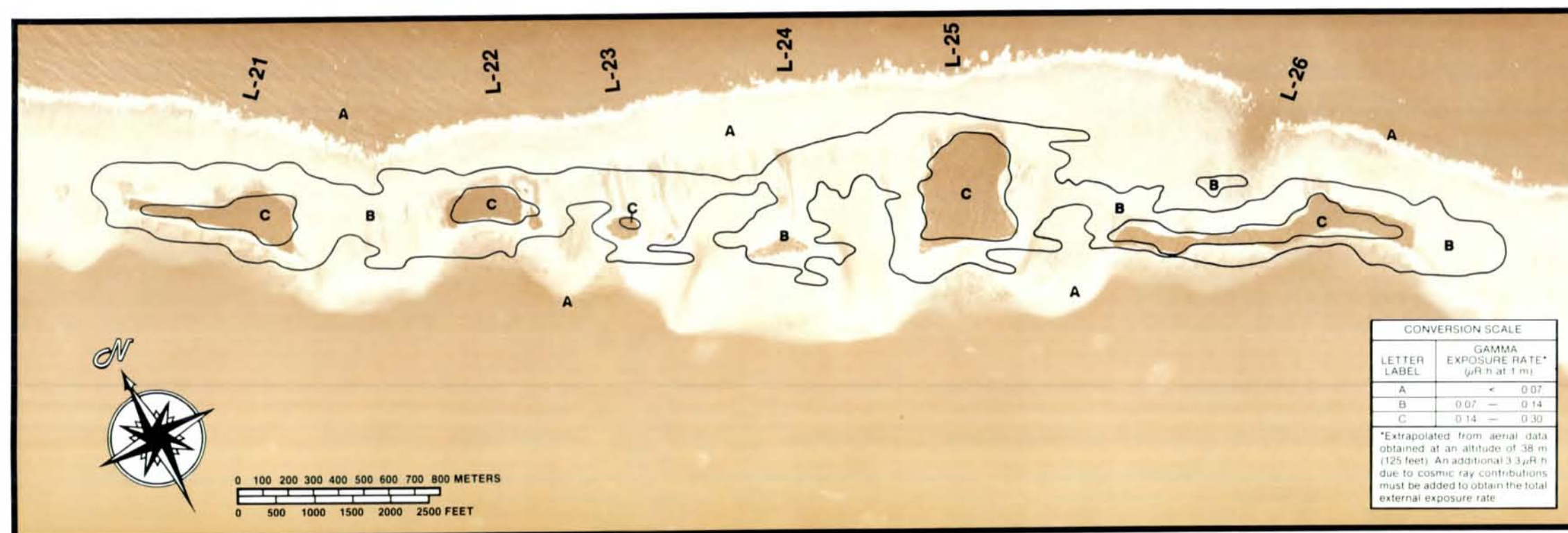


Figure D-110. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS L-21 TO L-26 AT LIKIEPATOLL. (Photograph Frame Number 68)



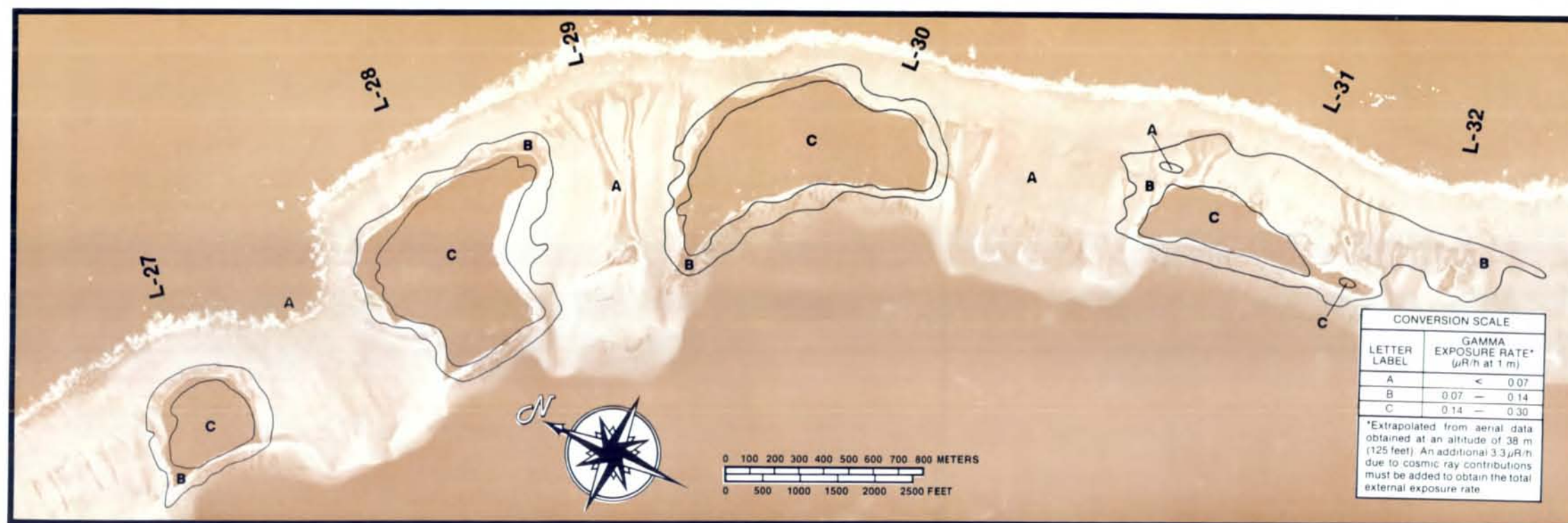


Figure D-111. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS L-27 TO L-32 AT LIKIEP ATOLL. (Photograph Frame Number 65)

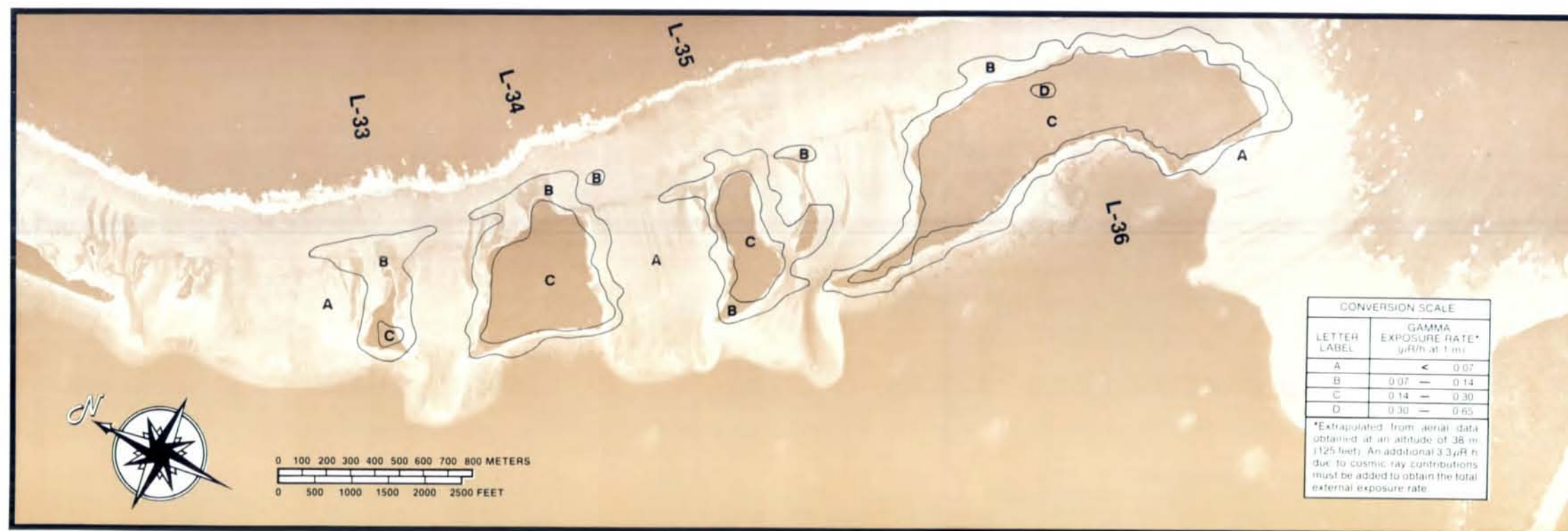


Figure D-112. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS L-33 TO L-36 AT LIKIEP ATOLL. (Photograph Frame Number 62)





Figure D-113. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLAND L-37 AT LIKIEP ATOLL. (Photograph Frame Number 50)

| CONVERSION SCALE |                                          |
|------------------|------------------------------------------|
| LETTER LABEL     | GAMMA EXPOSURE RATE* ( $\mu R/h$ at 1 m) |
| A                | 0.07 - 0.07                              |
| B                | 0.14 - 0.14                              |
| C                | 0.14 - 0.30                              |

\*Extrapolated from aerial data obtained at an altitude of 38 m (125 feet). An additional  $3 \mu R/h$  due to cosmic ray contributions must be added to obtain the total external exposure rate.



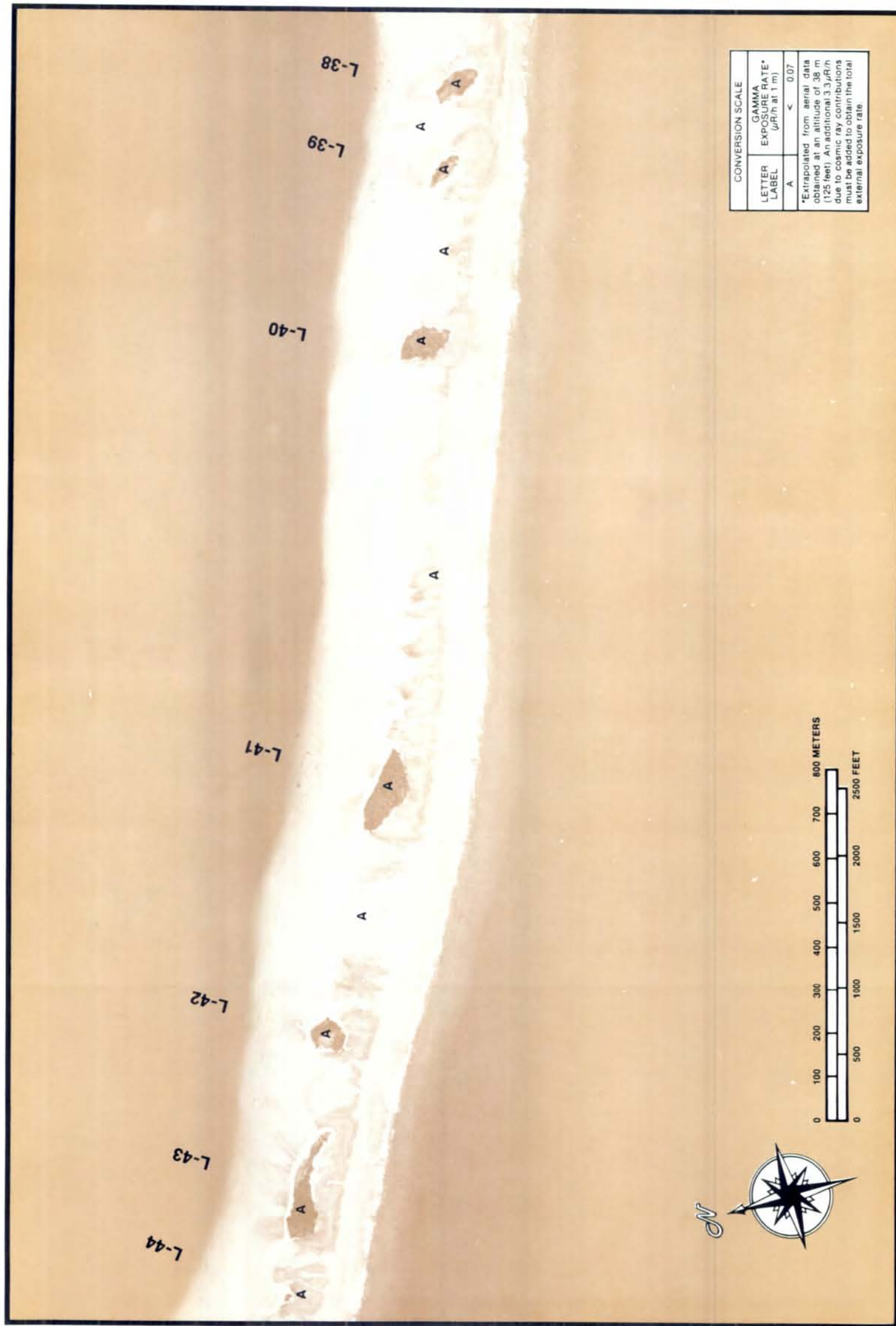


Figure D-114. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS L-38 TO L-44 AT LIKIEPATOLL. (Photograph Frame Number 53)



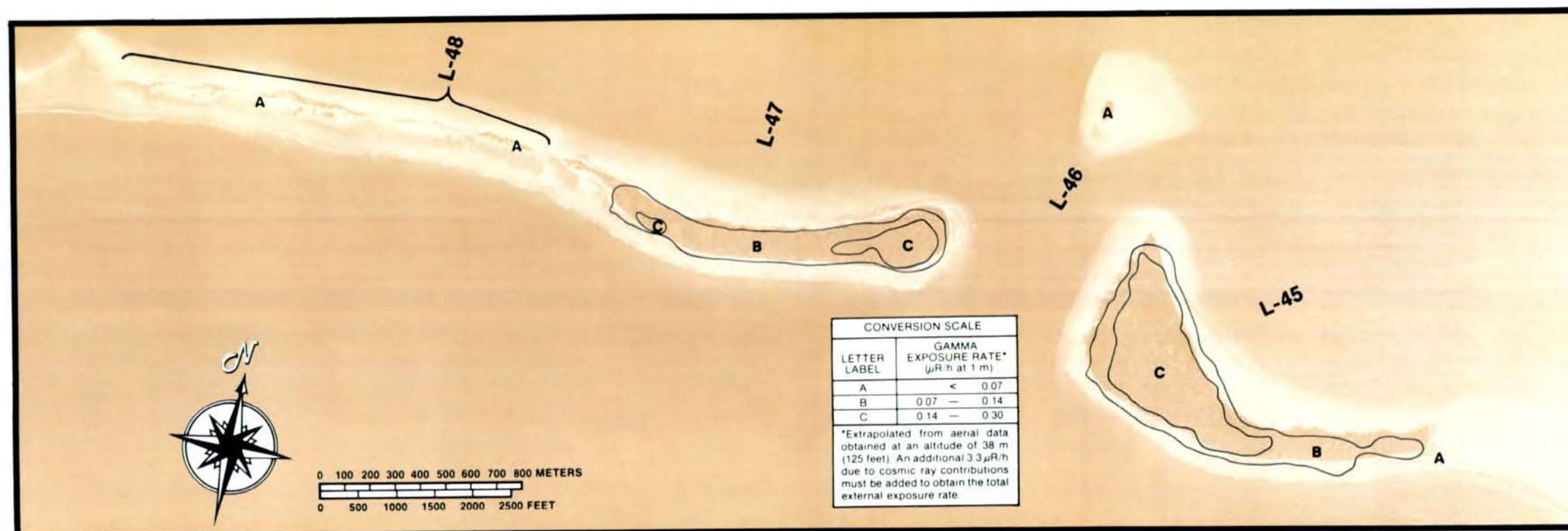


Figure D-115. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS L-45 TO L-48 AT LIKIEP ATOLL. (Photograph Frame Number 93)



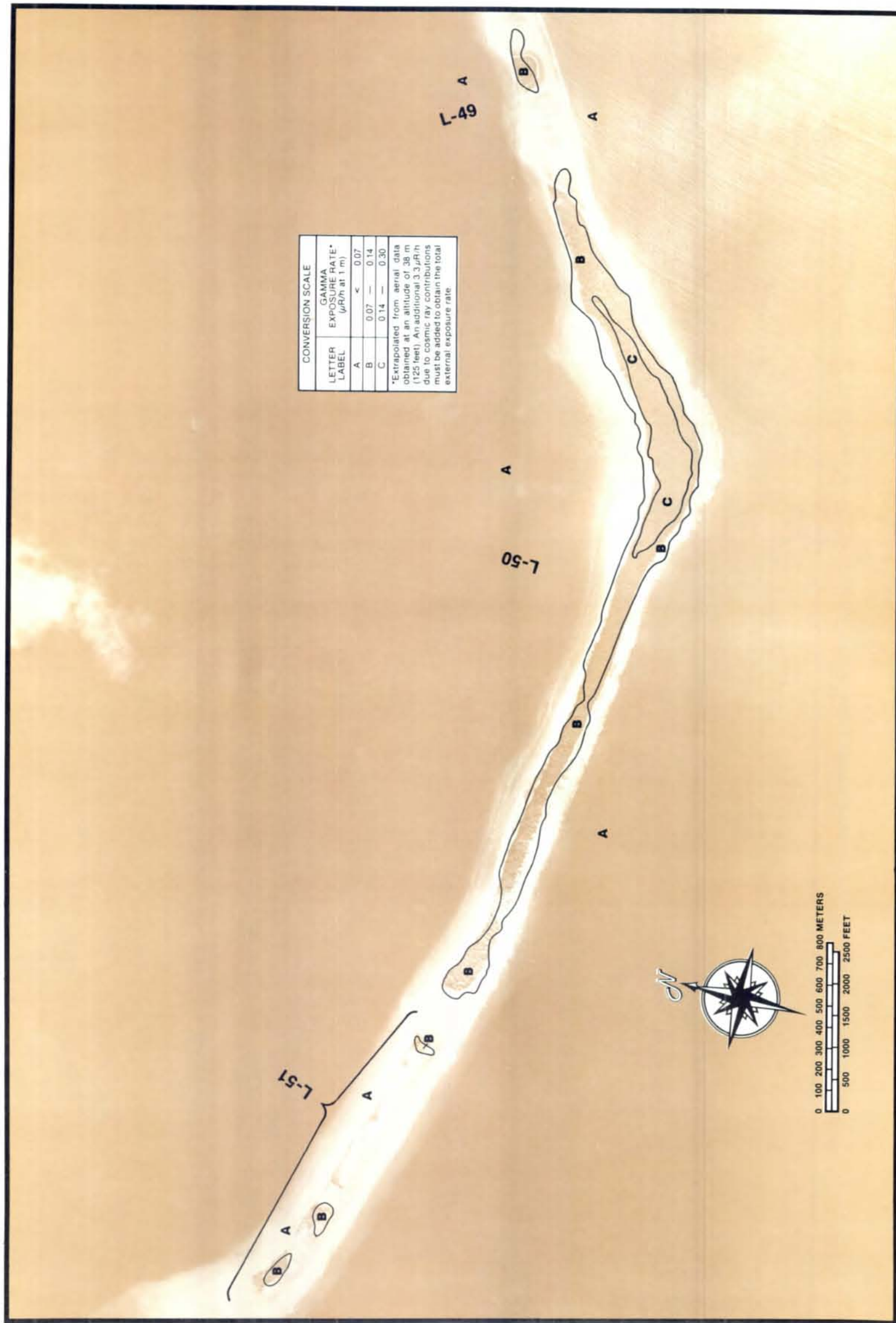


Figure D-116. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS L-49 TOL-51 AT LIKIEPATOLL. (Photograph Frame Number 86)



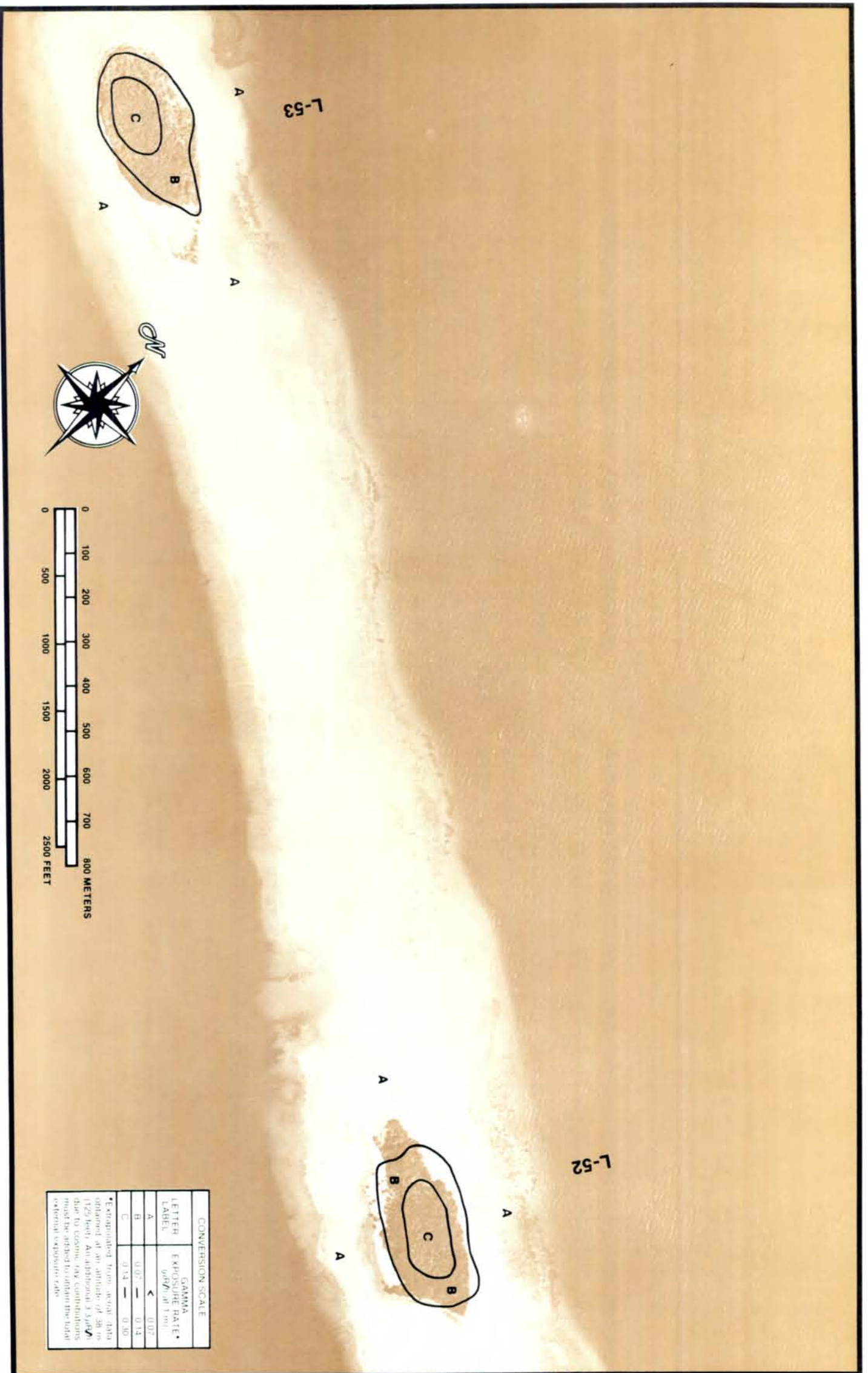


Figure D-117. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS L-52 TO L-53 AT LIKIEP ATOLL. (Photograph Frame Number 162)



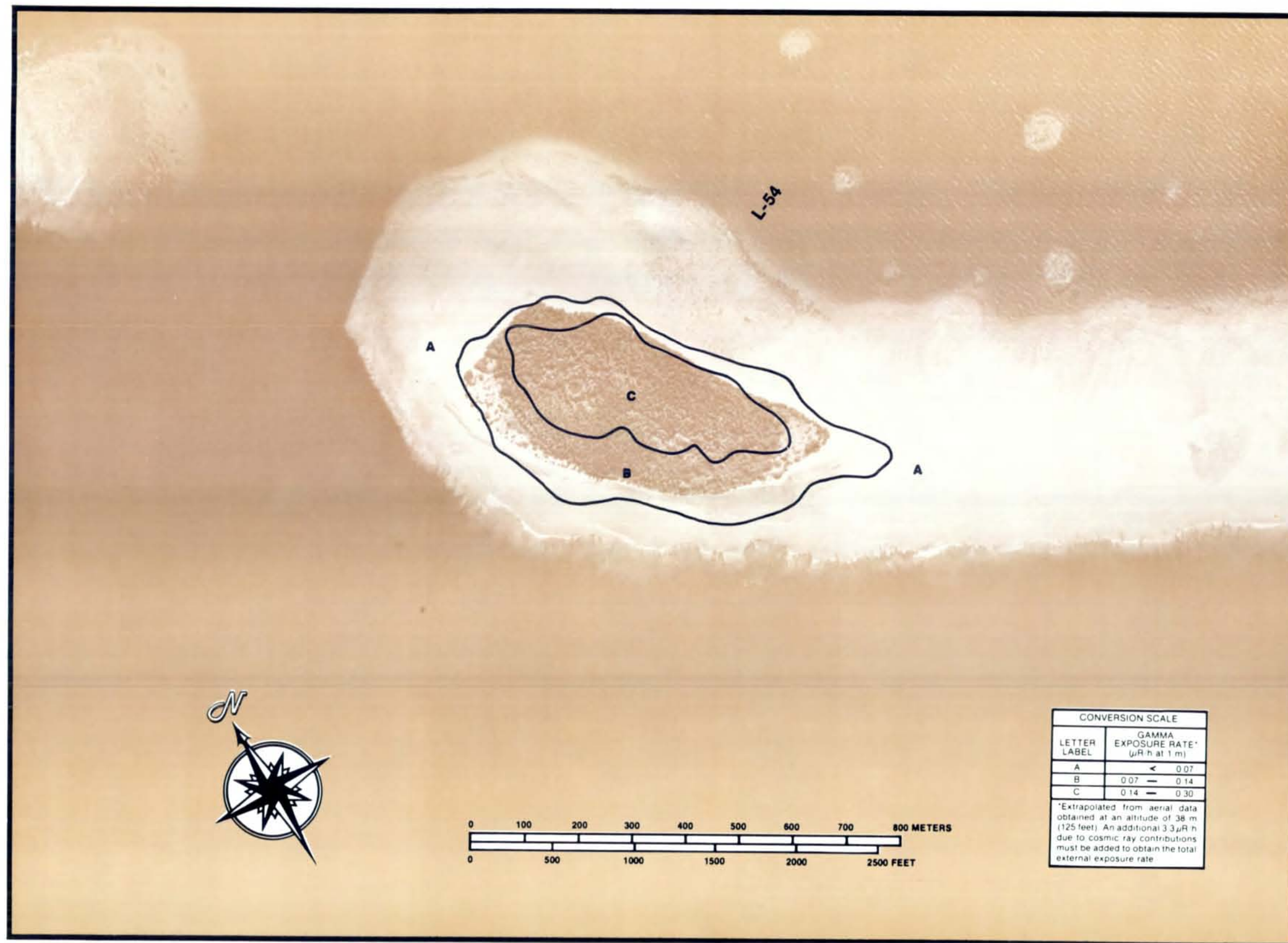


Figure D-118. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLAND L-54 AT LIKIEP ATOLL. (Photograph Frame Number 157)



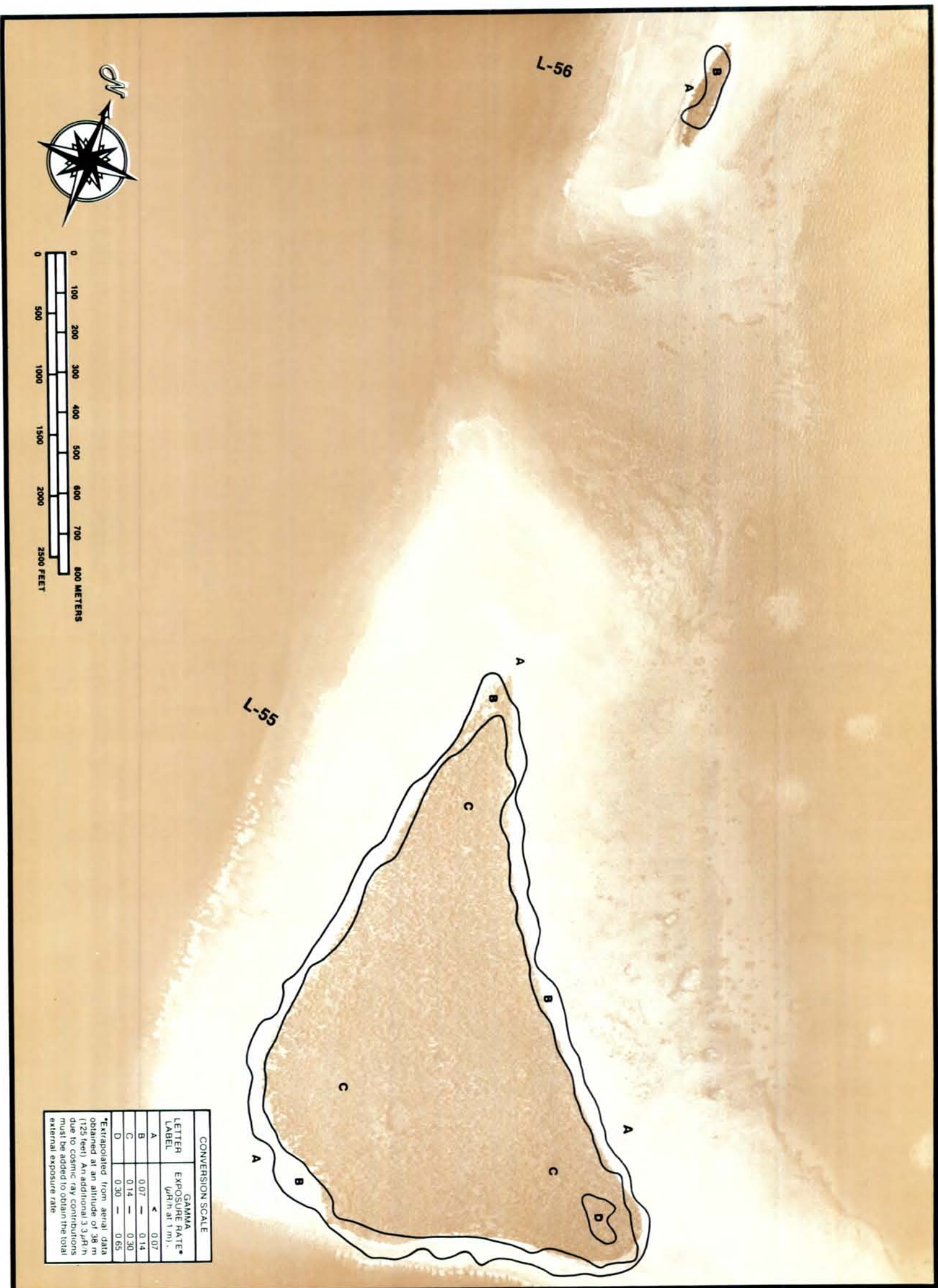


Figure D-119. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS L-55 TOL-56 AT LIKIEP ATOLL. (Photograph Frame Number 147)



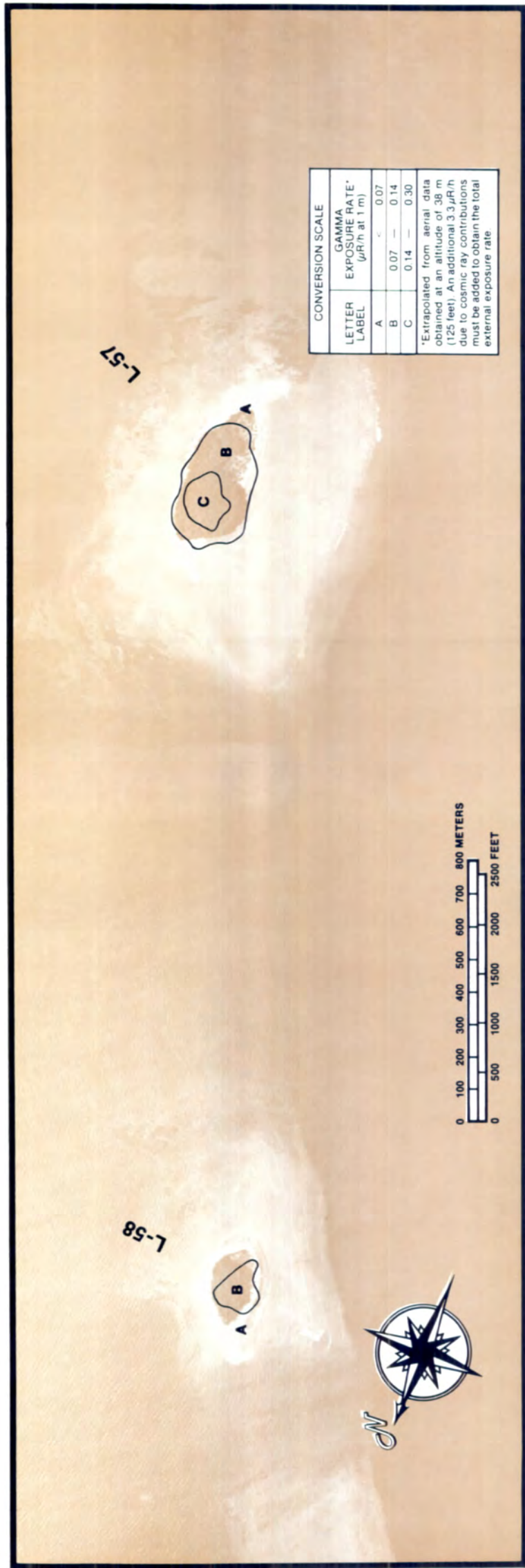


Figure D-120. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS L-57 TO L-58 AT LIKIEPATOLL. (Photograph Frame Number 143)



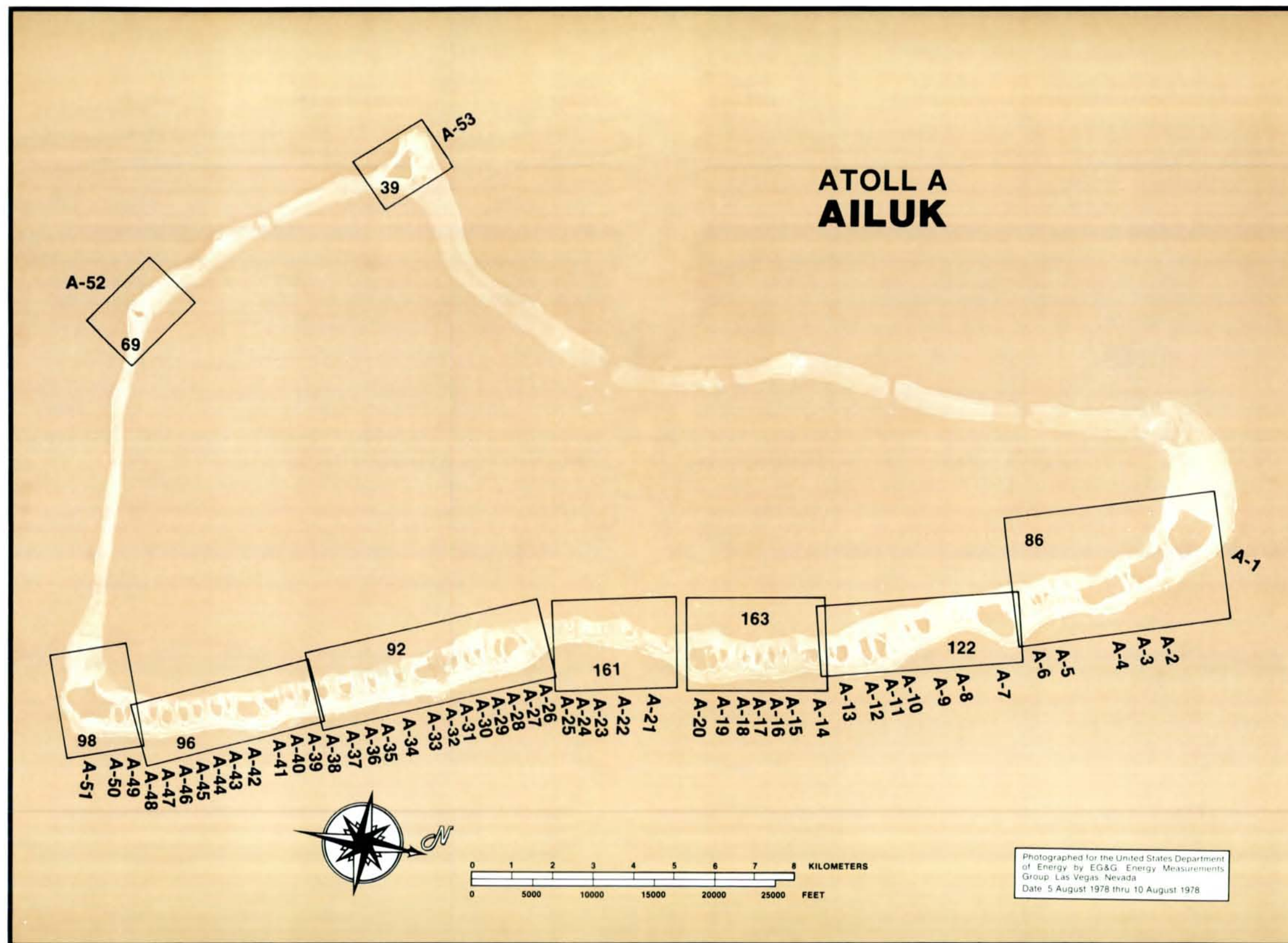


Figure D-121. BASE MAP KEY FOR AILUK ATOLL. The photomosaic shows the area covered by each base map photograph and the photograph frame number used to identify each survey area.



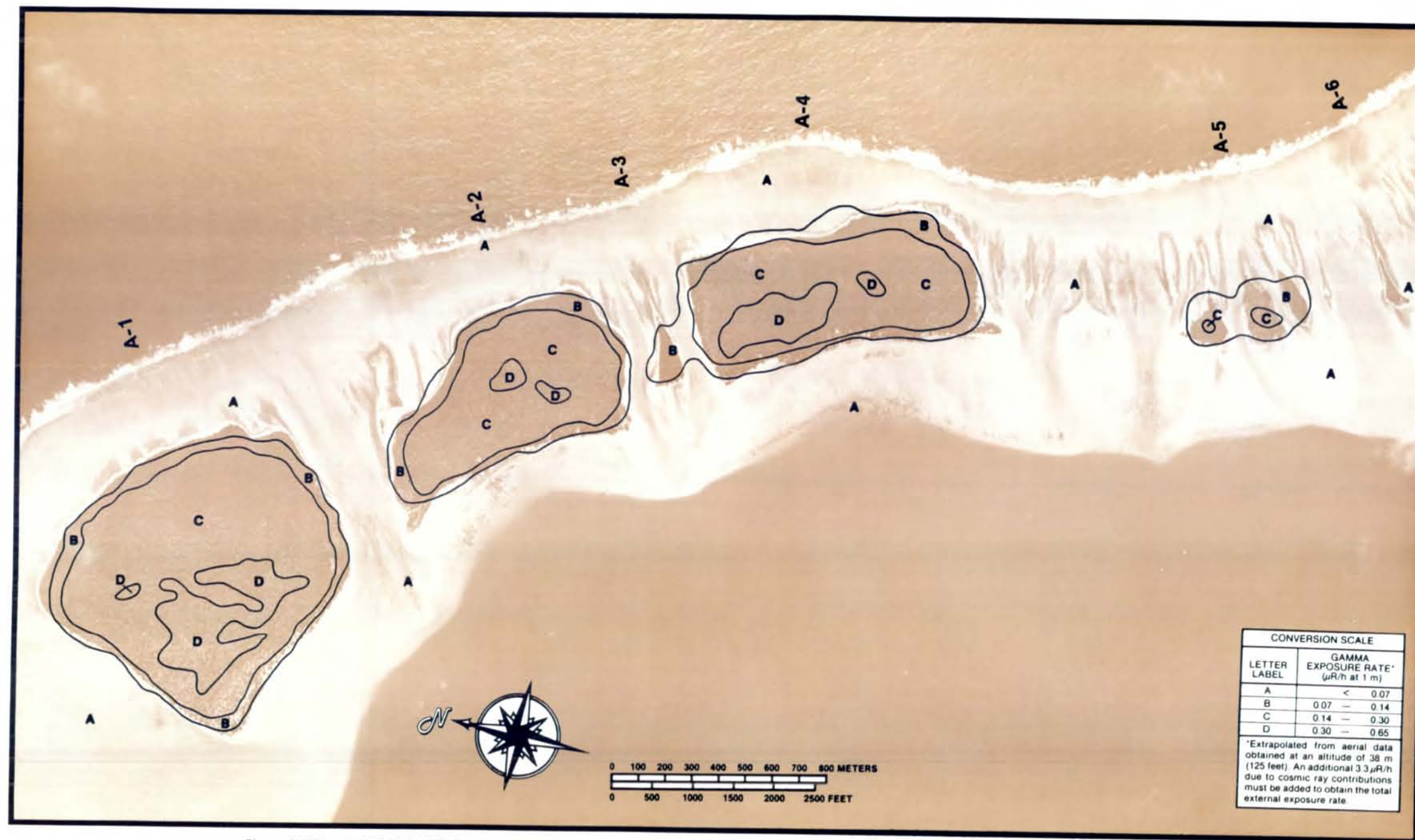


Figure D-122. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS A-1 TO A-6 AT AILUK ATOLL. (Photograph Frame Number 86)





Figure D-123. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS A-7 TO A-13 AT AILUK ATOLL (Photograph Frame Number 122)



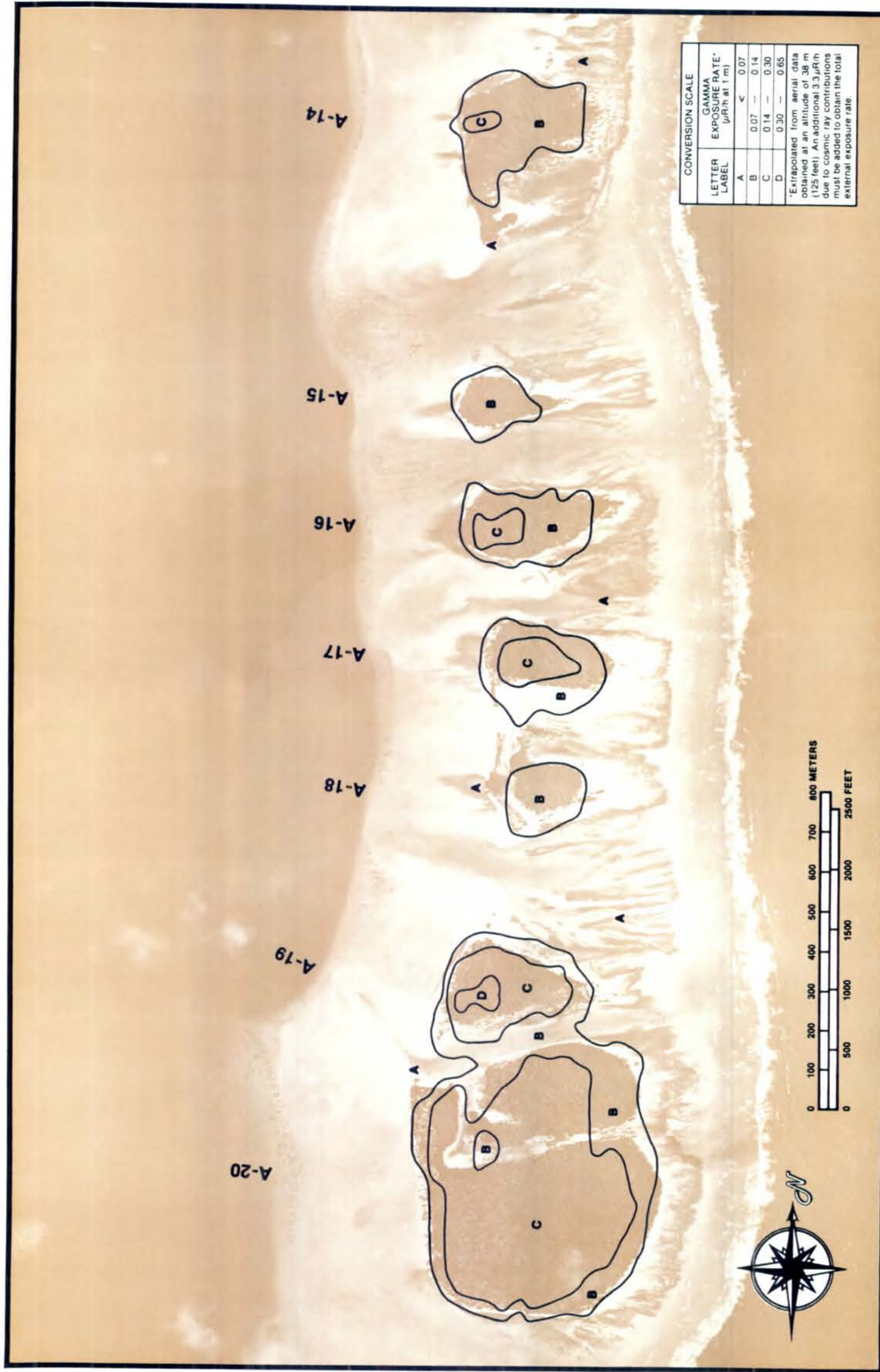


Figure D-124. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS A-14 TO A-20 AT AILUK ATOLL. (Photograph Frame Number 163)



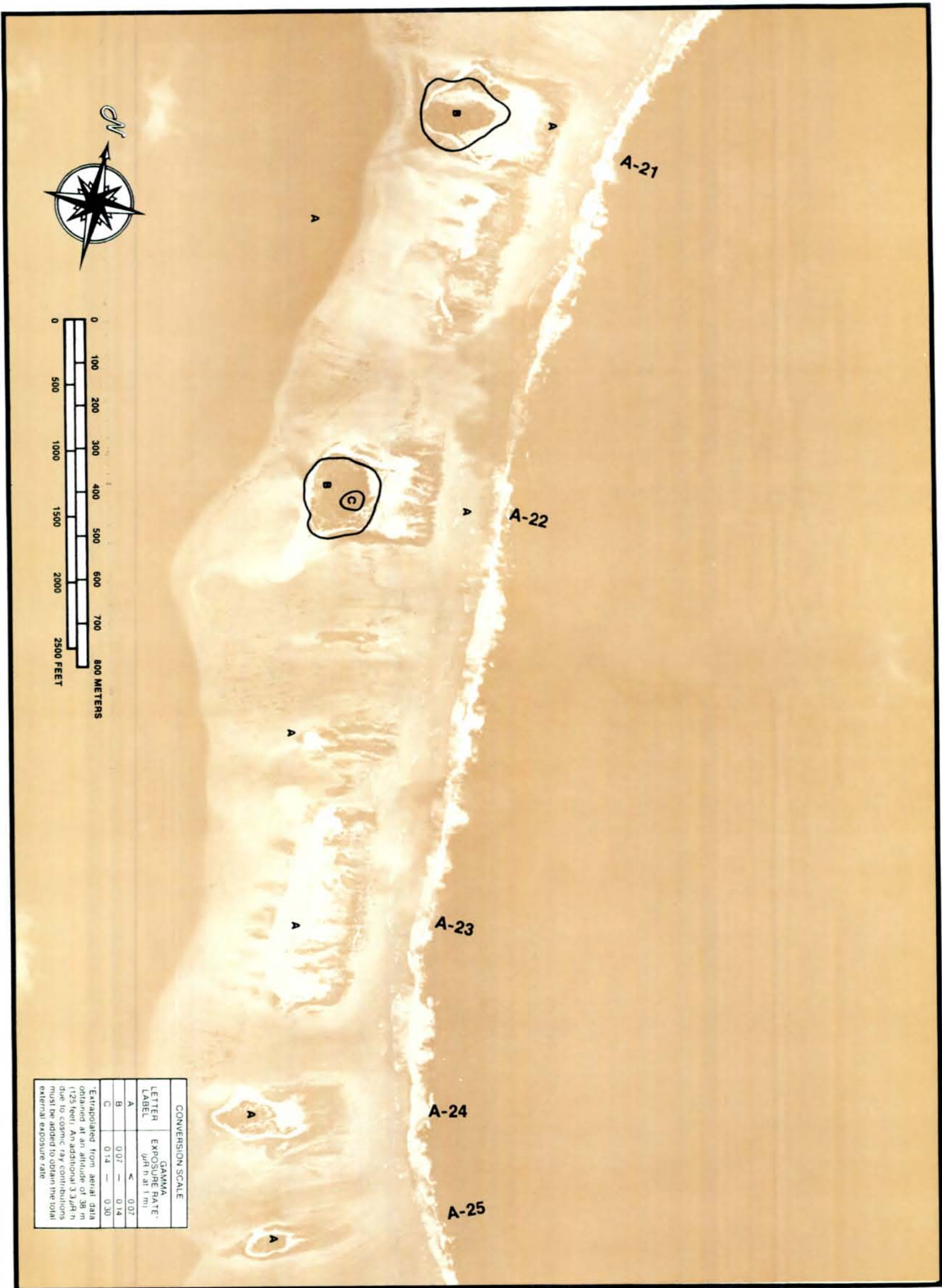


Figure D-125. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS A-21 TO A-25 AT AILUK ATOLL. (Photograph Frame Number 161)



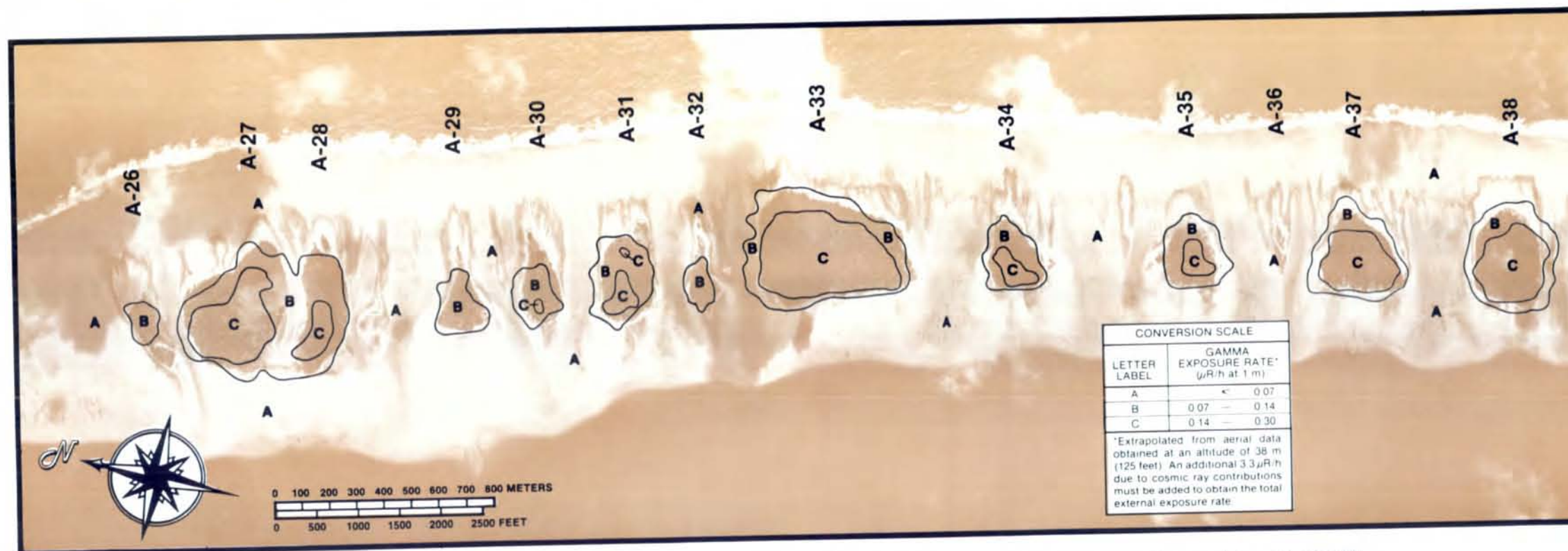


Figure D-126. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS A-26 TO A-38 AT AILUK ATOLL. (Photograph Frame Number 92)

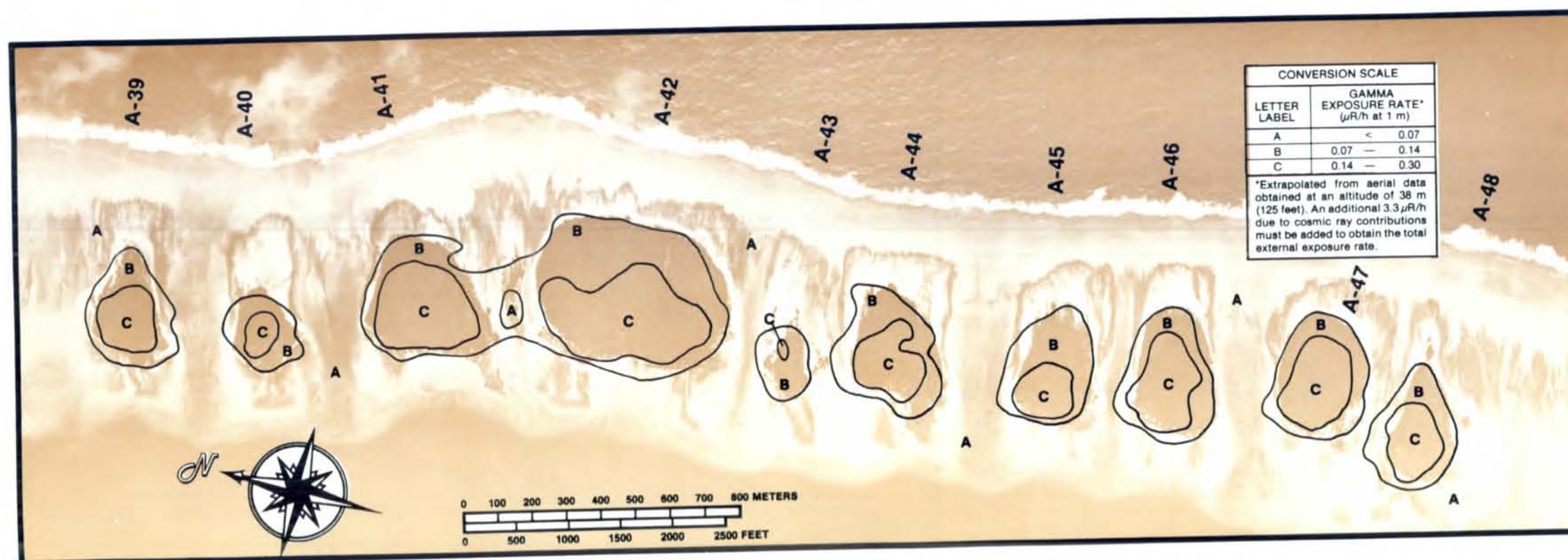


Figure D-127. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS A-39 TO A-48 AT AILUK ATOLL. (Photograph Frame Number 96)



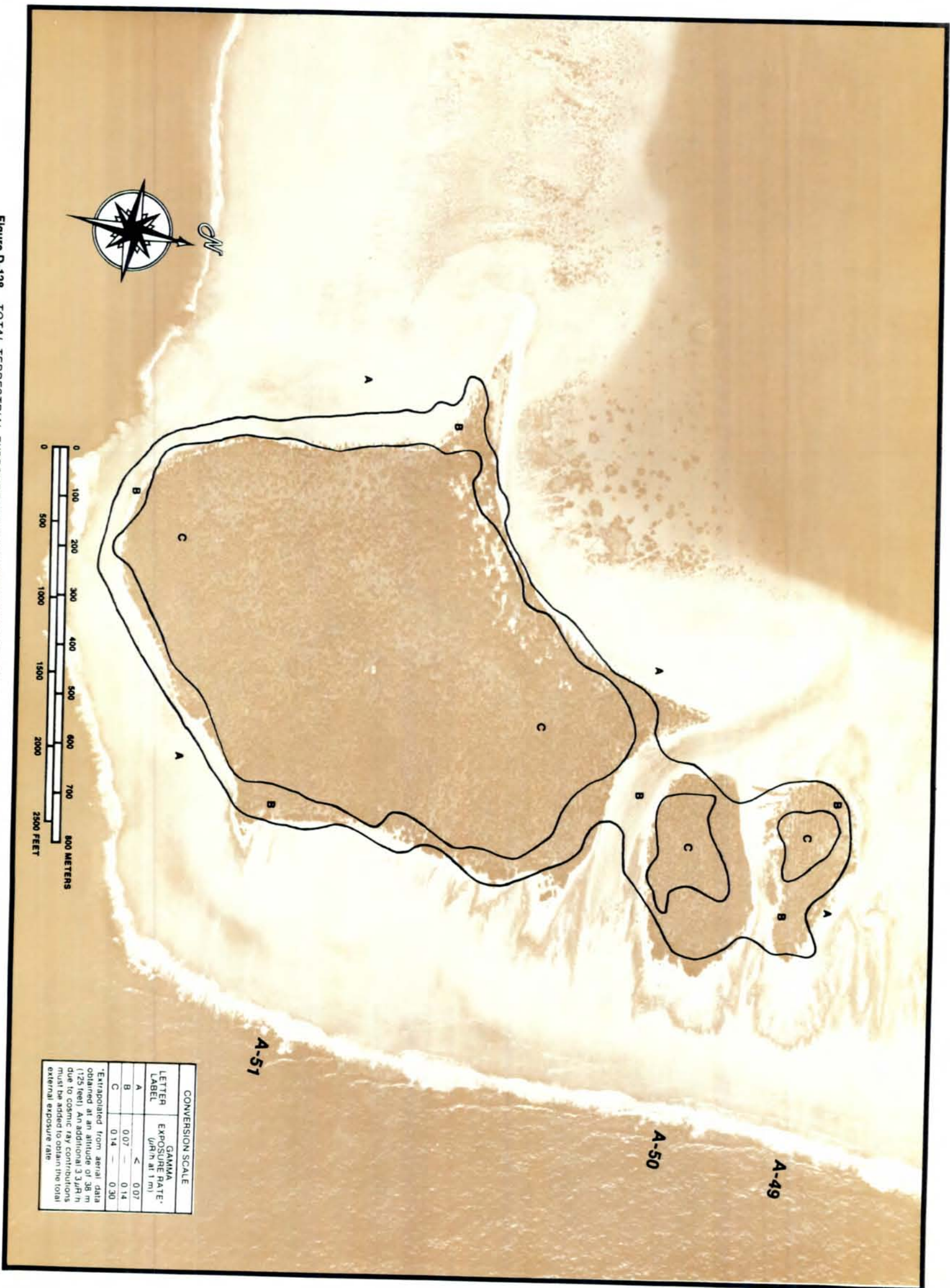


Figure D-128. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS A-49 TO A-51 AT ALUK ATOLL. (Photograph Frame Number 98)



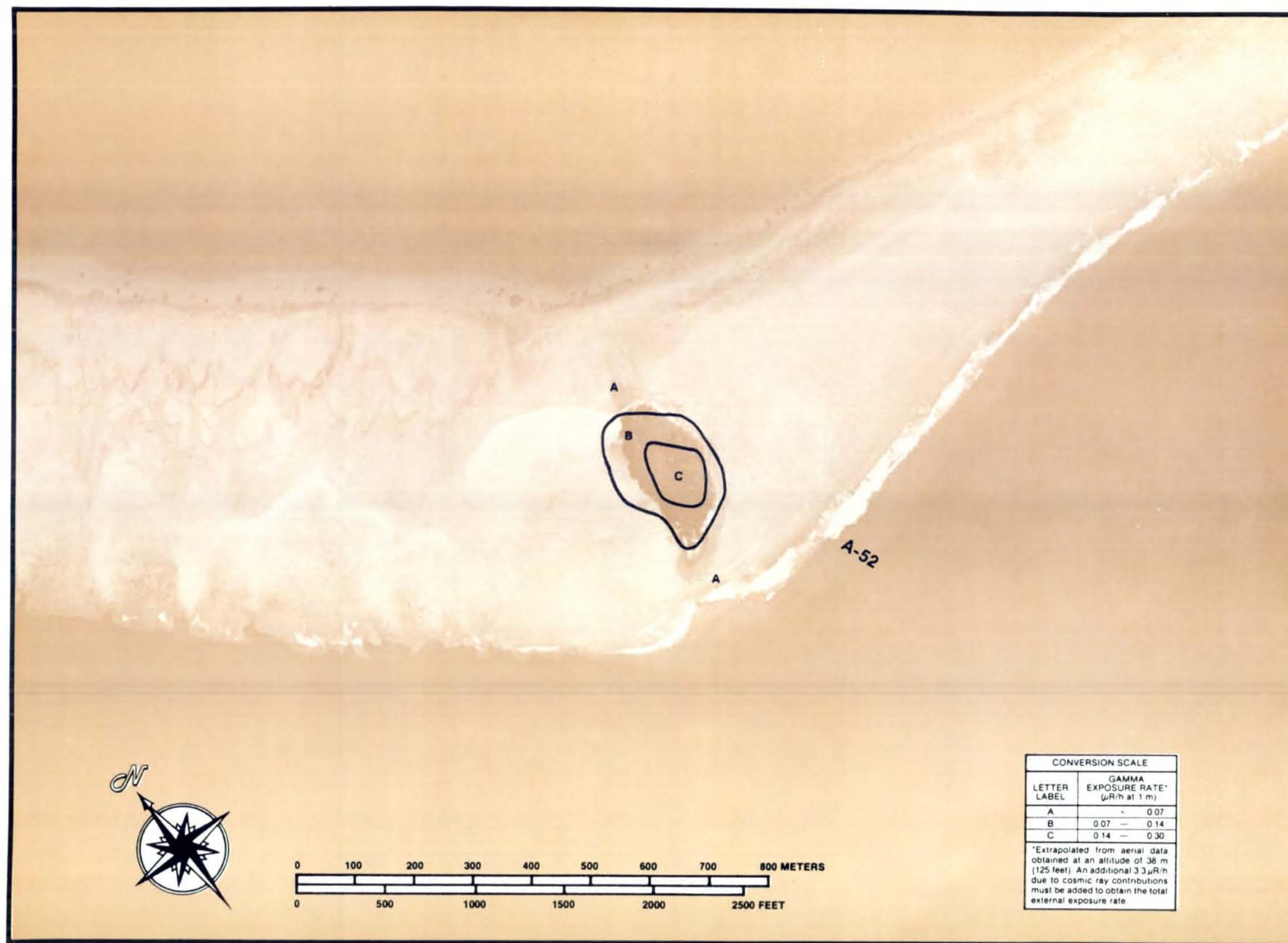


Figure D-129. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLAND A-52 AT AILUK ATOLL. (Photograph Frame Number 69)



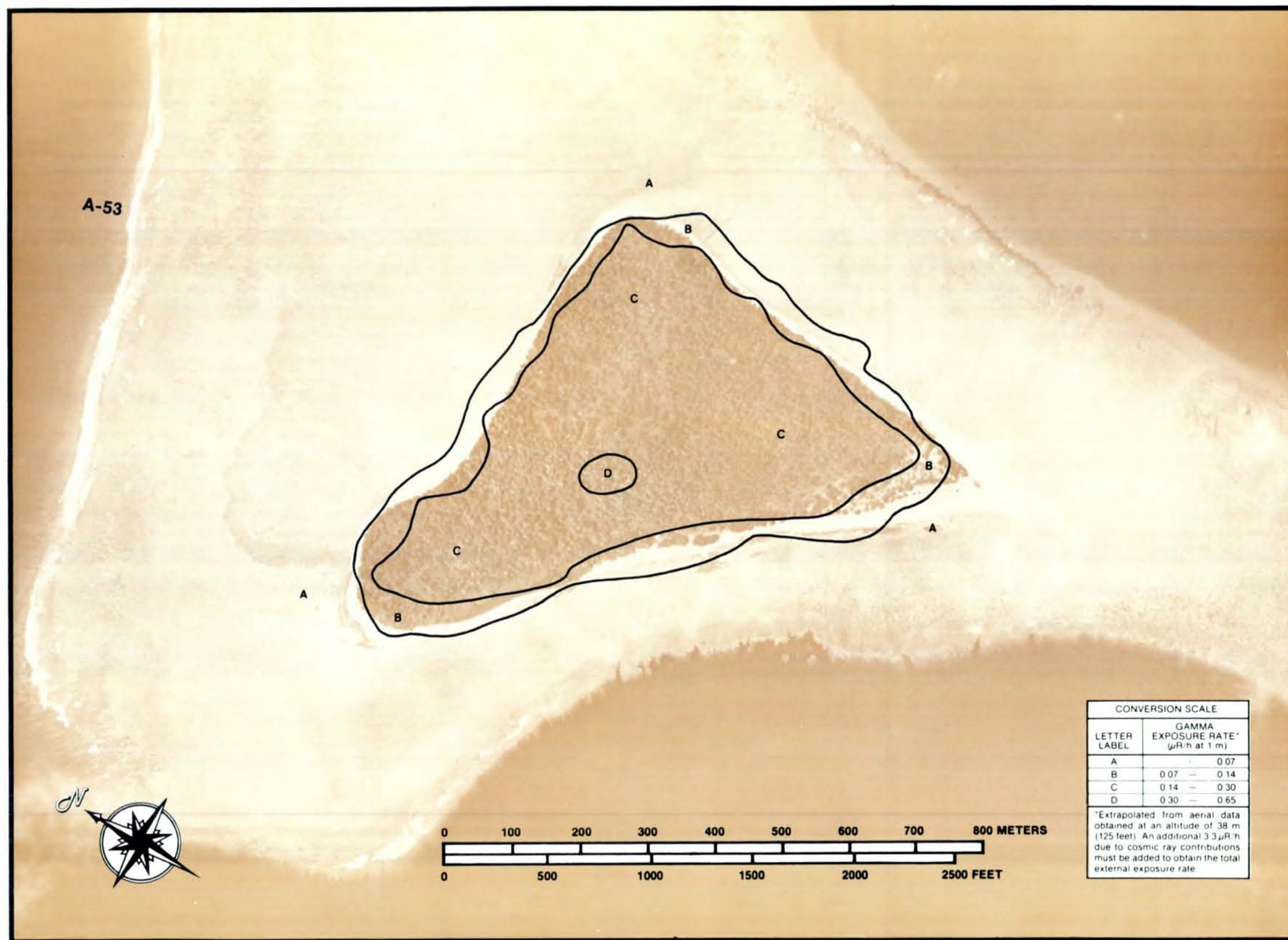


Figure D-130. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLAND A-53 AT AILUK ATOLL. (Photograph Frame Number 39)



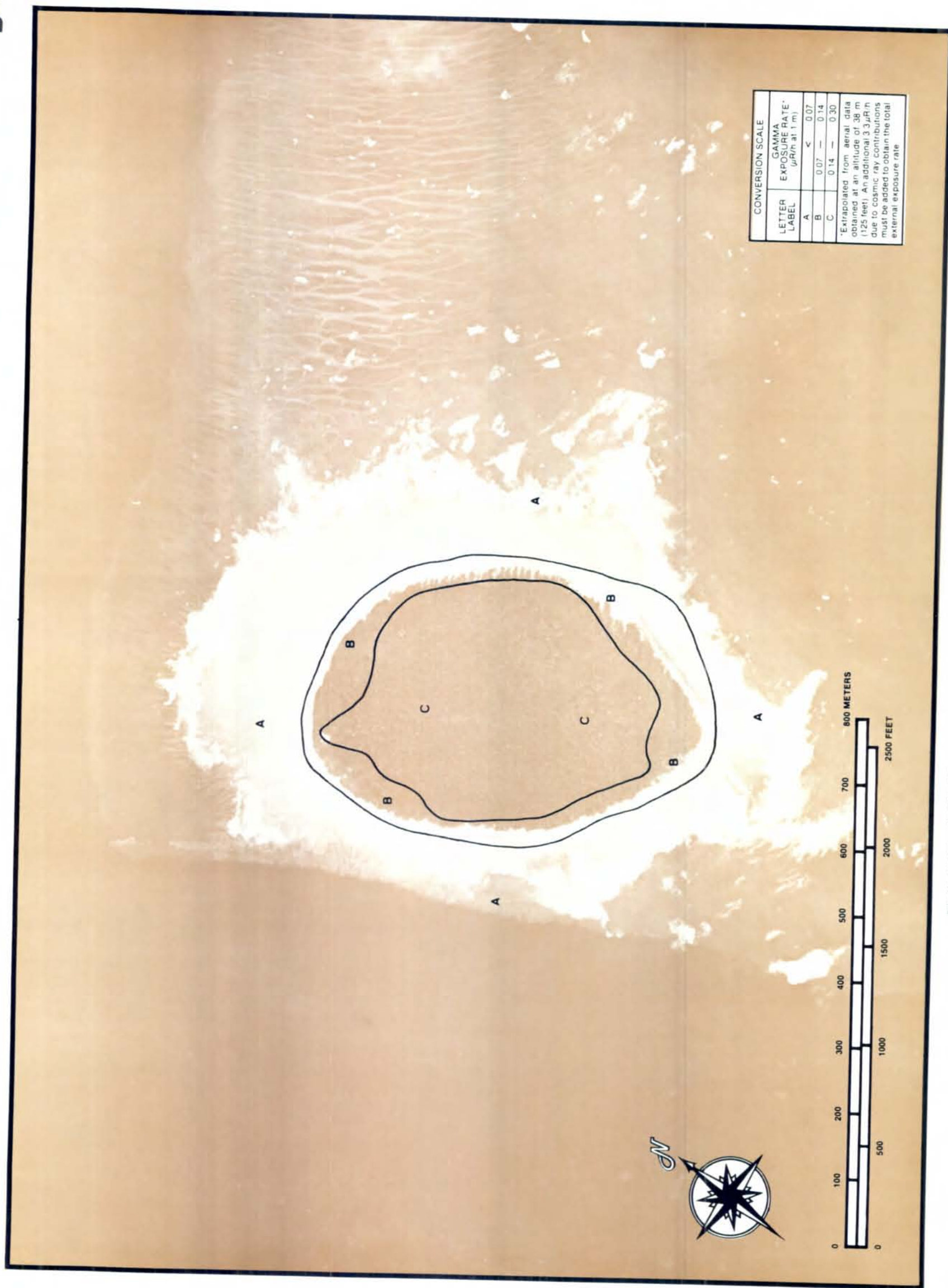


Figure D-131. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR JEMO ISLAND.



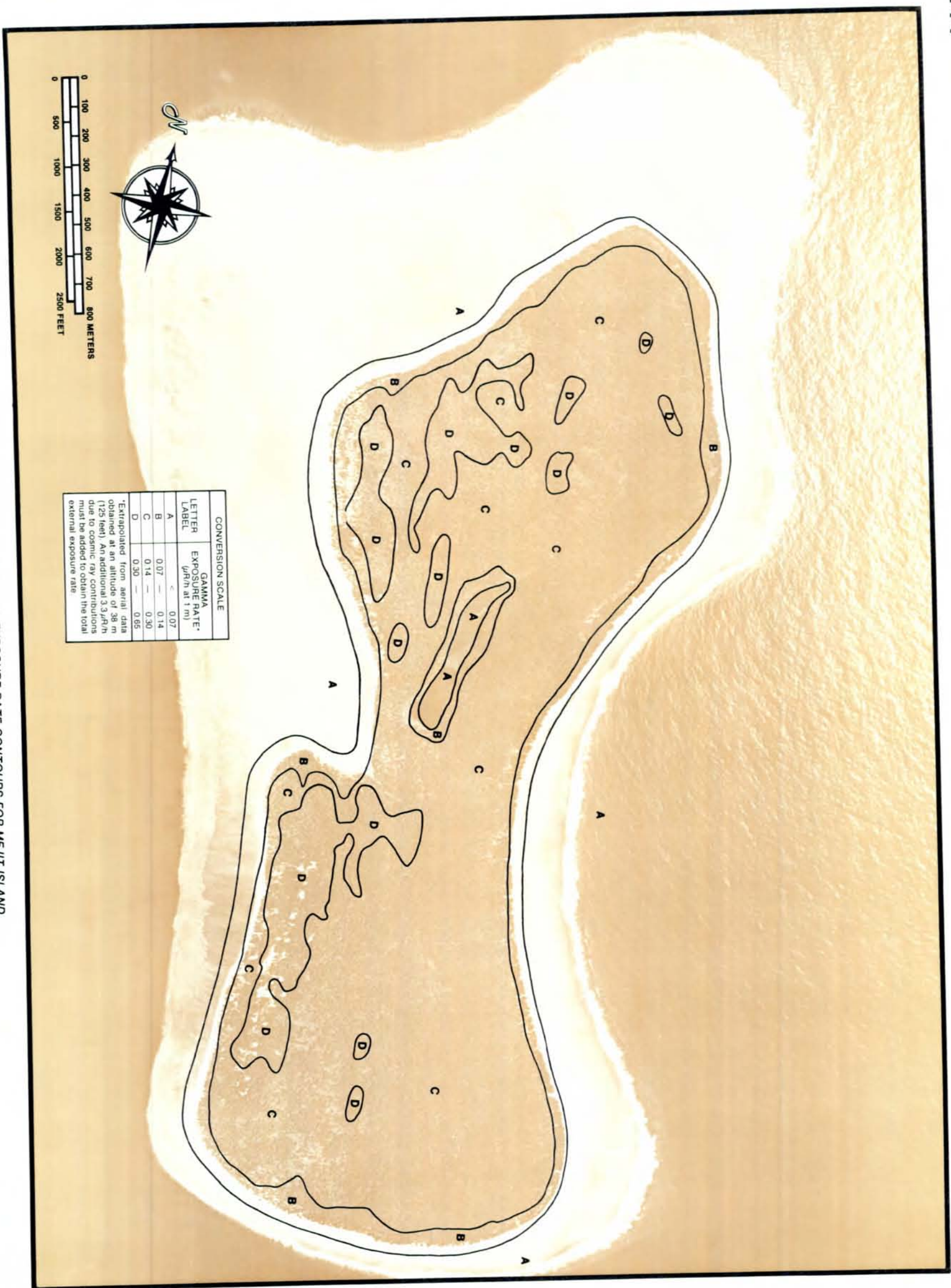


Figure D-132. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR MEJIT ISLAND.



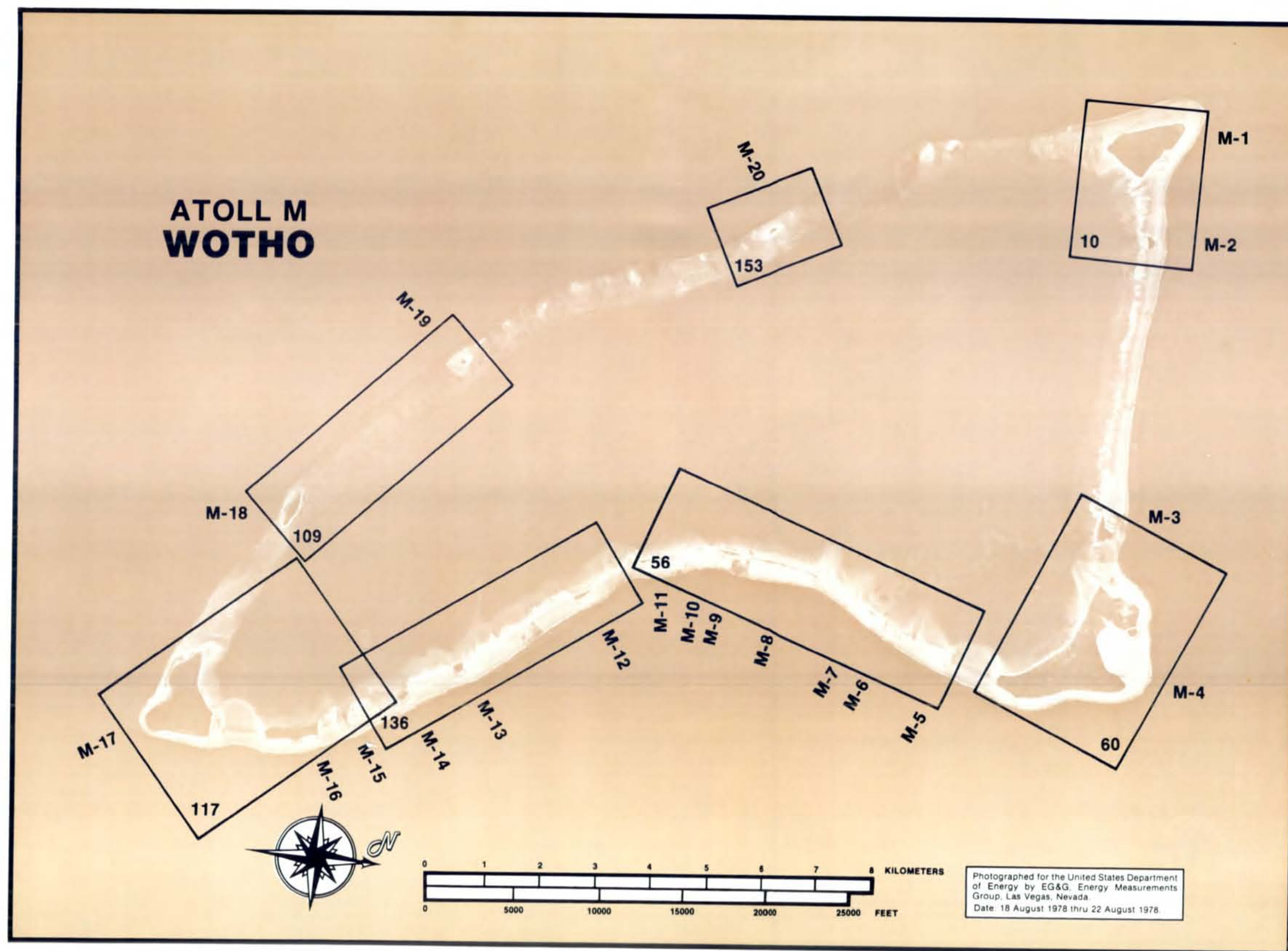


Figure D-133. BASE MAP KEY FOR WOTHO ATOLL. The photomosaic shows the area covered by each base map photograph and the photograph frame number used to identify each survey area.



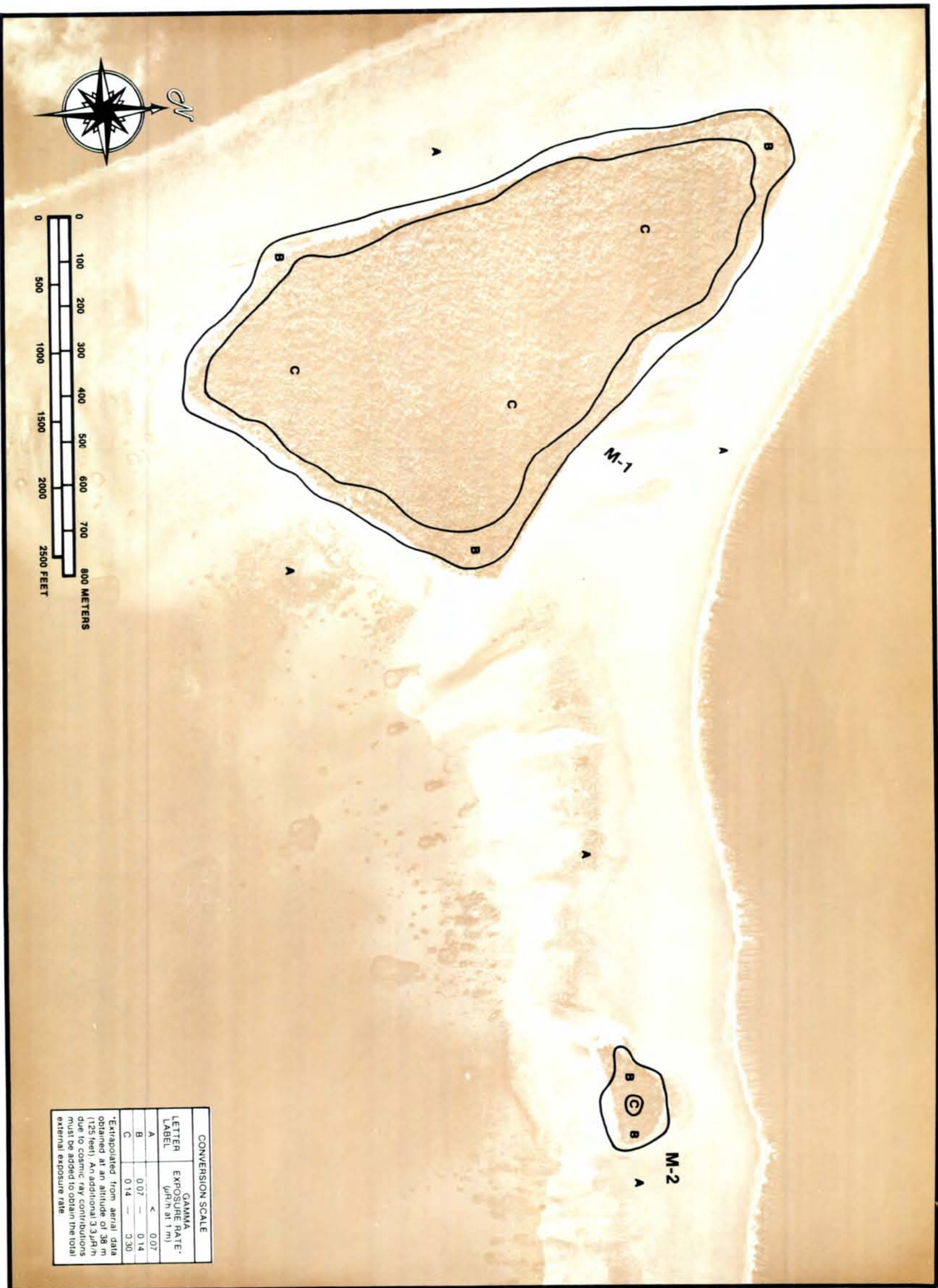


Figure D-134. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS M-1 TO M-2 AT WOTHO ATOLL. (Photograph Frame Number 10)



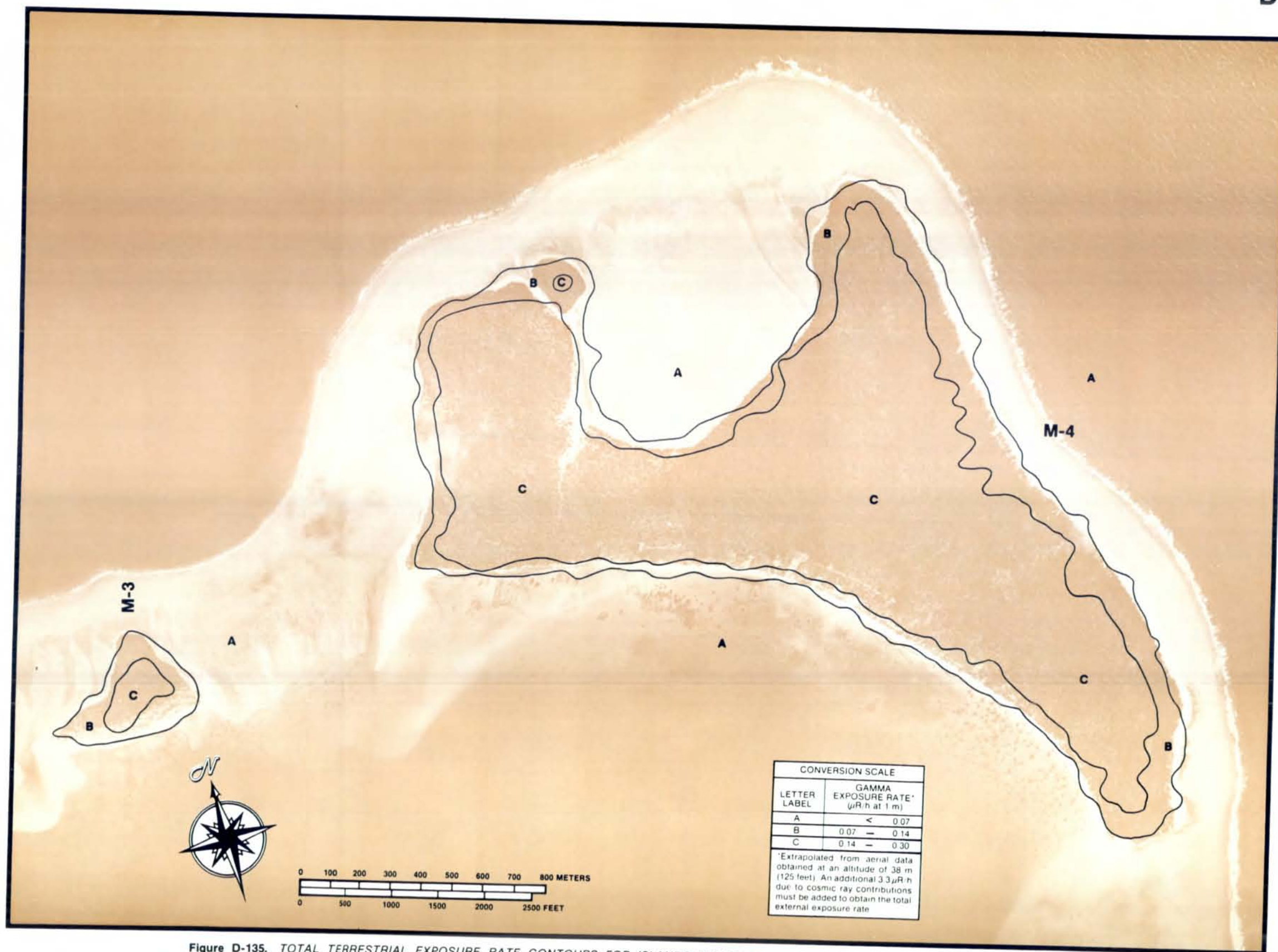


Figure D-135. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS M-3 TO M-4 AT WOTHO ATOLL. (Photograph Frame Number 60)





Figure D-136. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS M-5 TO M-11 AT WOTHO ATOLL. (Photograph Frame Number 56)

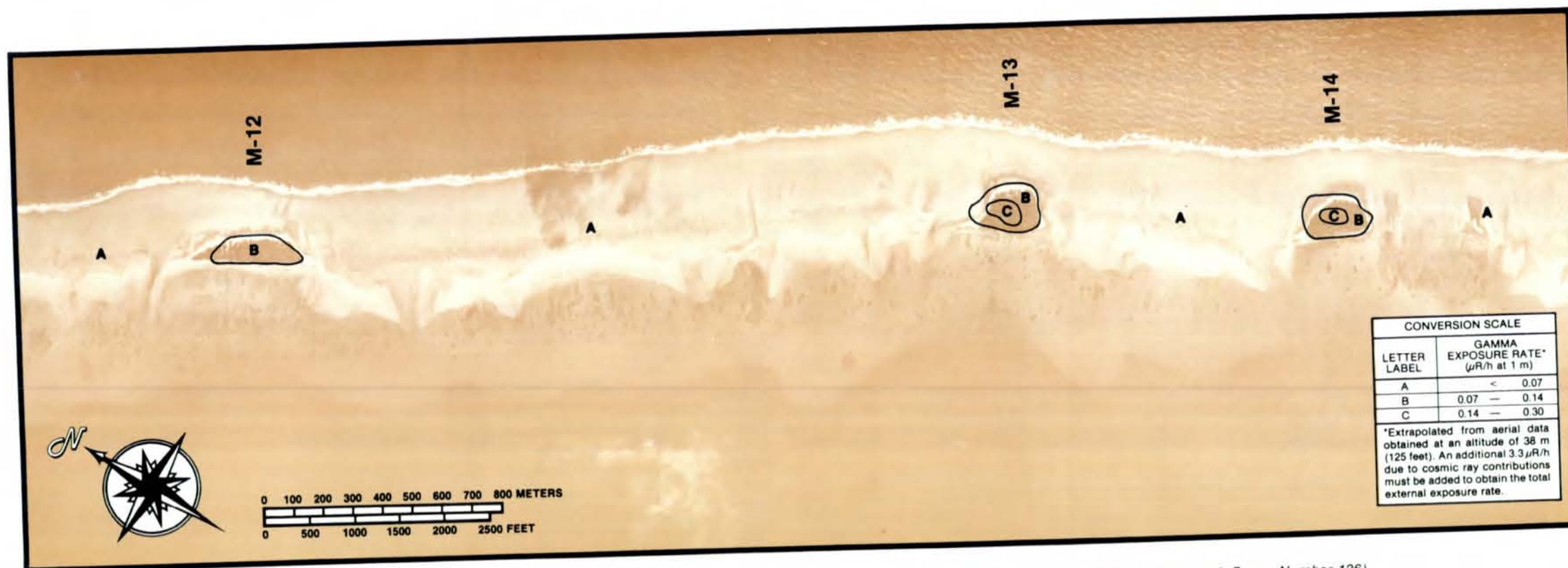


Figure D-137. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS M-12 TO M-14 AT WOTHO ATOLL. (Photograph Frame Number 136)



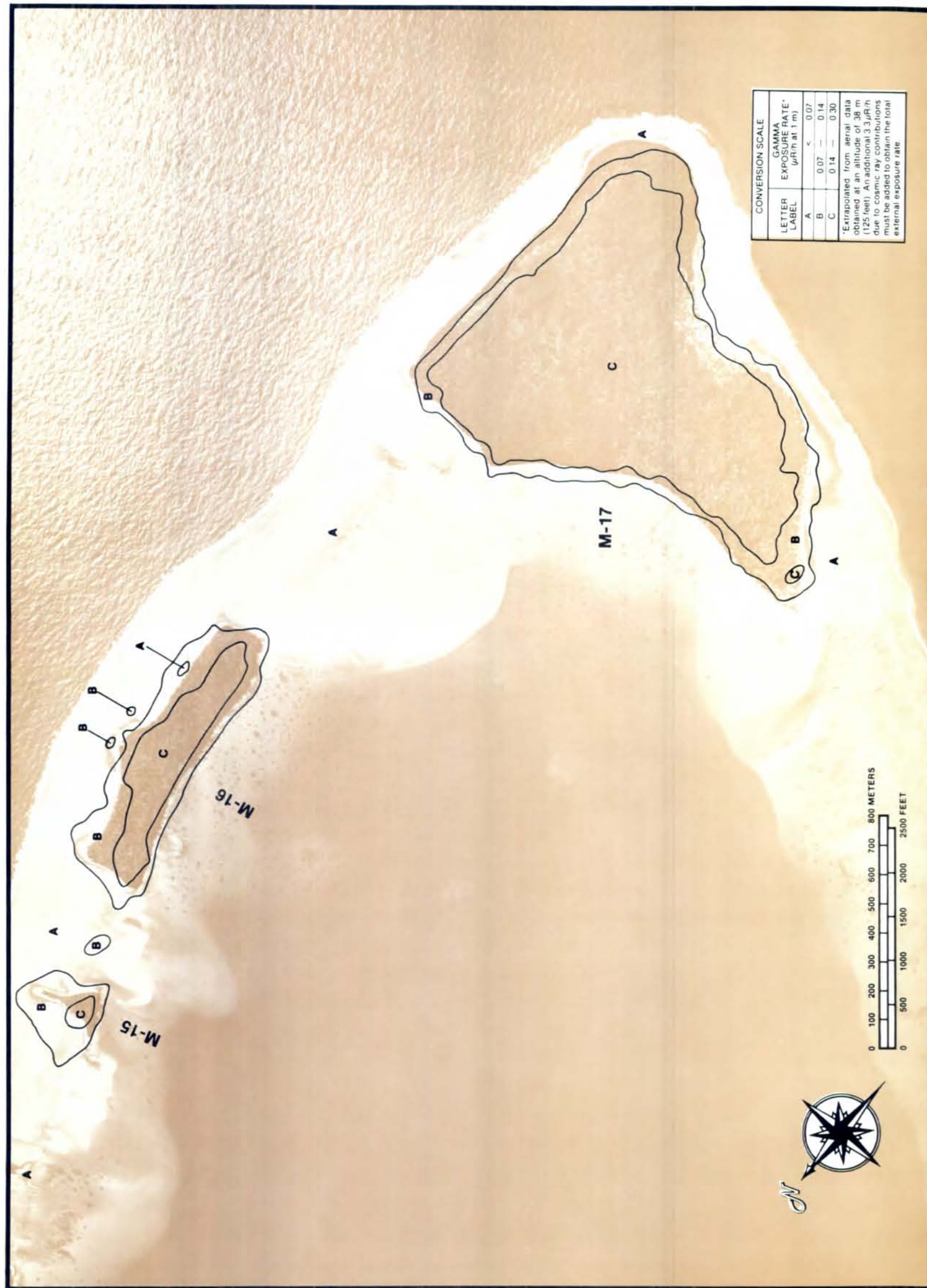


Figure D-138. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS M-15 TO M-17 AT WOTHO ATOLL. (Photograph Frame Number 117)



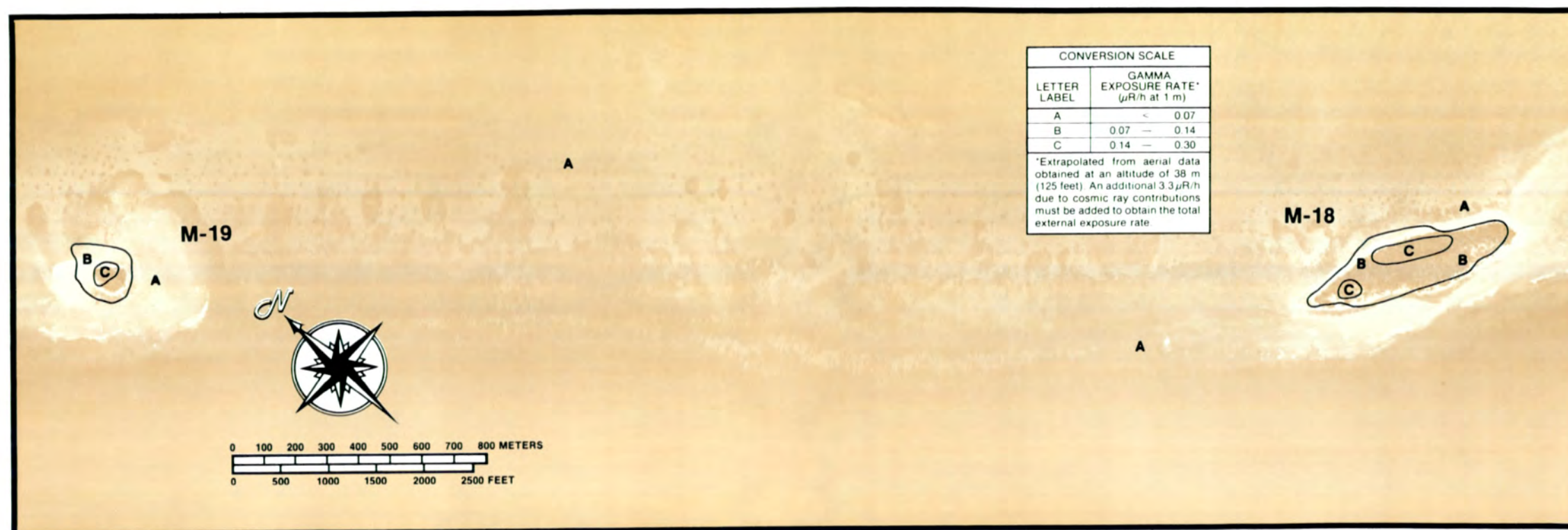


Figure D-139. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS M-18 TO M-19 AT WOTHO ATOLL. (Photograph Frame Number 109)



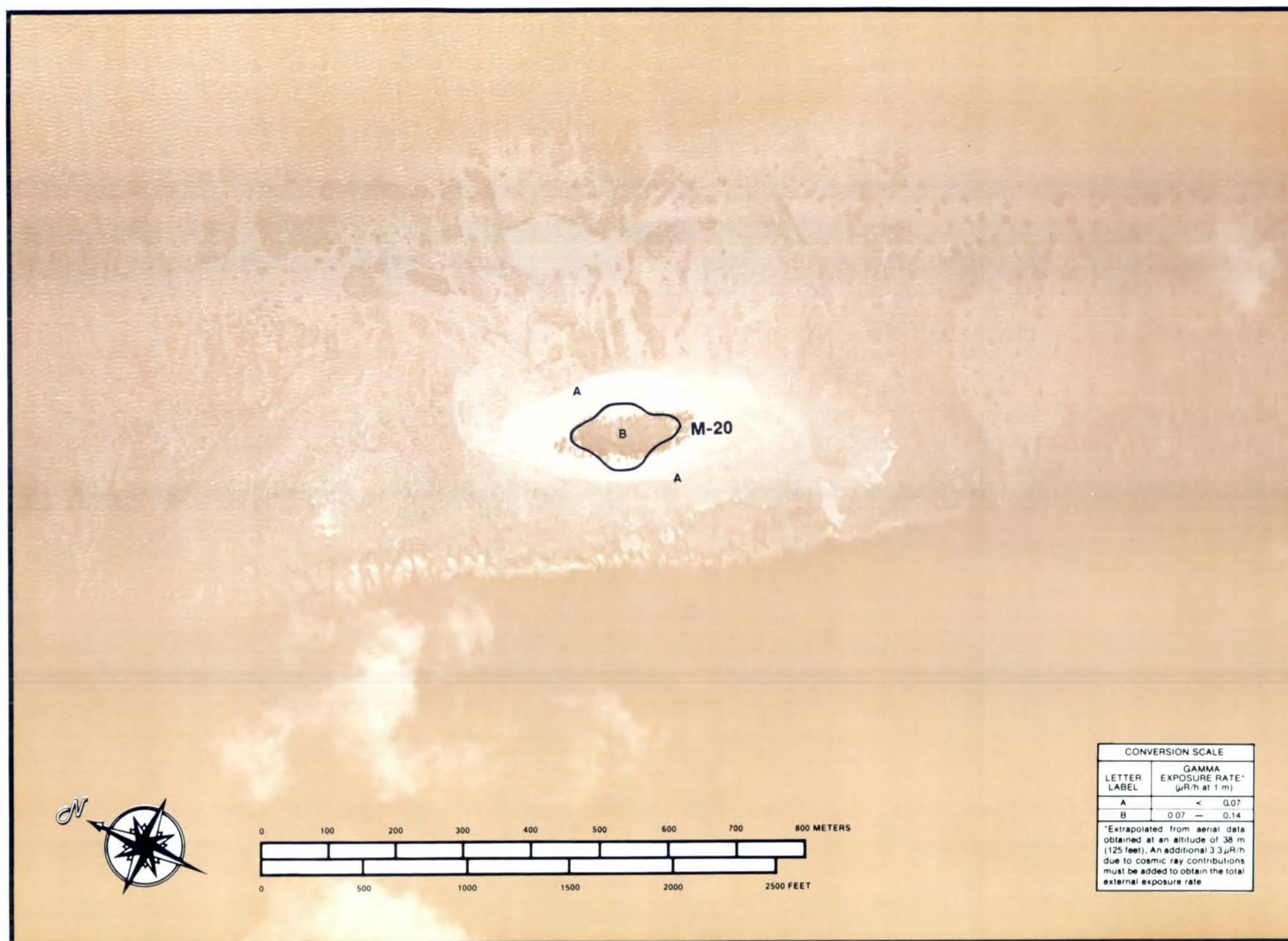


Figure D-140. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLAND M-20 AT WOTHO ATOLL. (Photograph Frame Number 153)



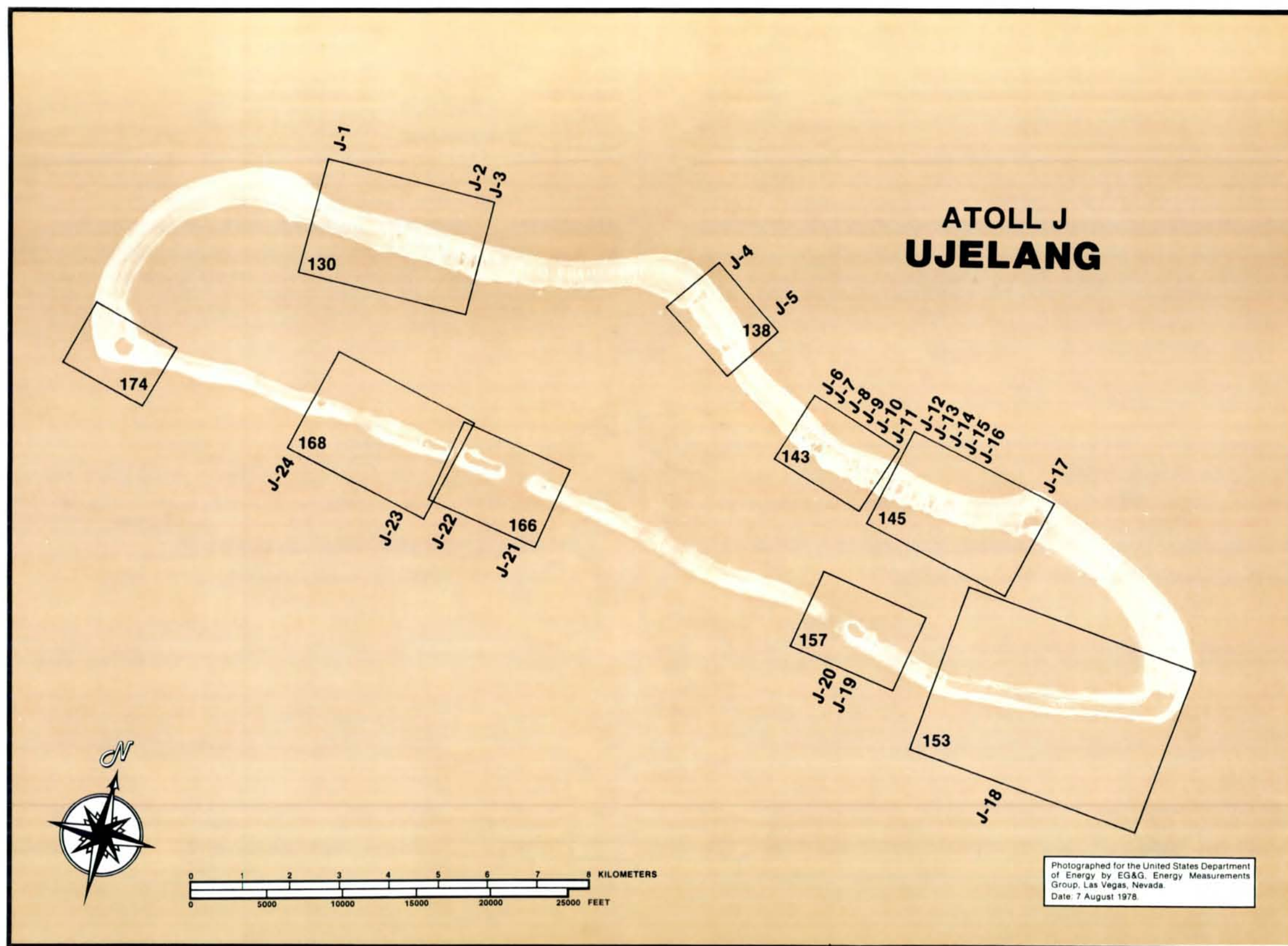


Figure D-141. BASE MAP KEY FOR UJELANG ATOLL. The photomosaic shows the area covered by each base map photograph and the photograph frame number used to identify each survey area.



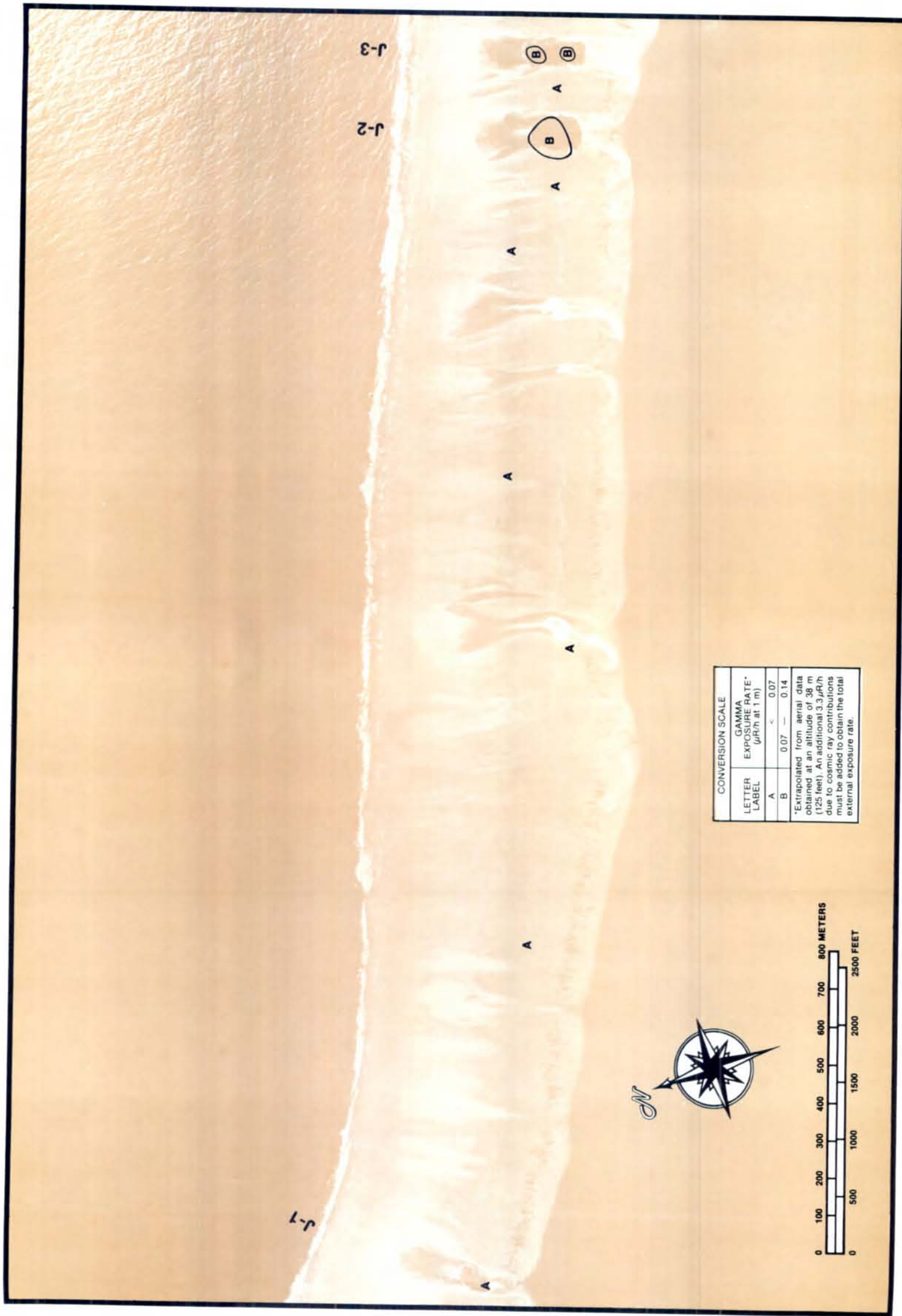


Figure D-142. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS J-1 TO J-3 AT UJELANG ATOLL. (Photograph Frame Number 130)



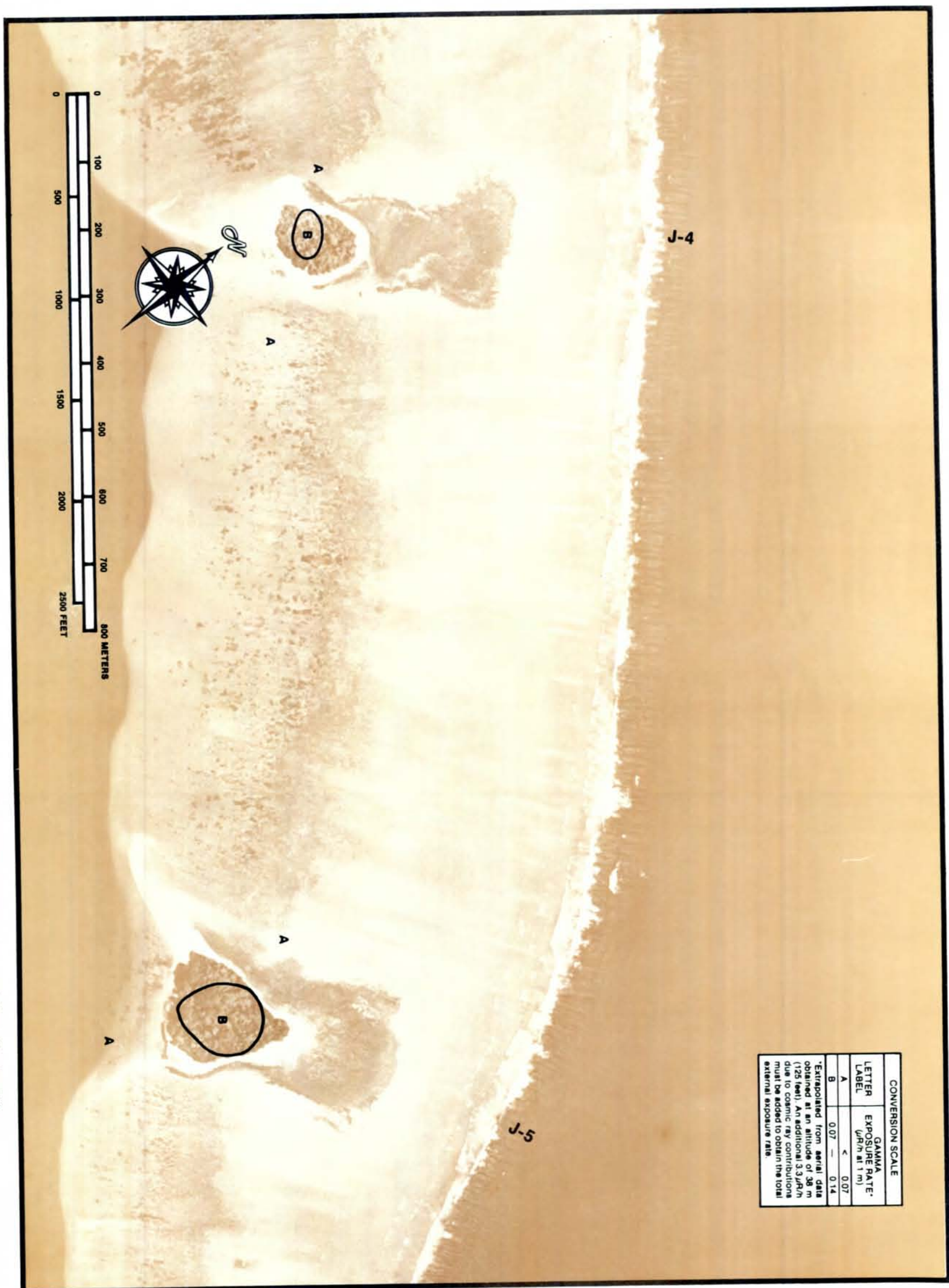


Figure D-143. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS J-4 TO J-5 AT UJELANG ATOLL. (Photograph Frame Number 138)



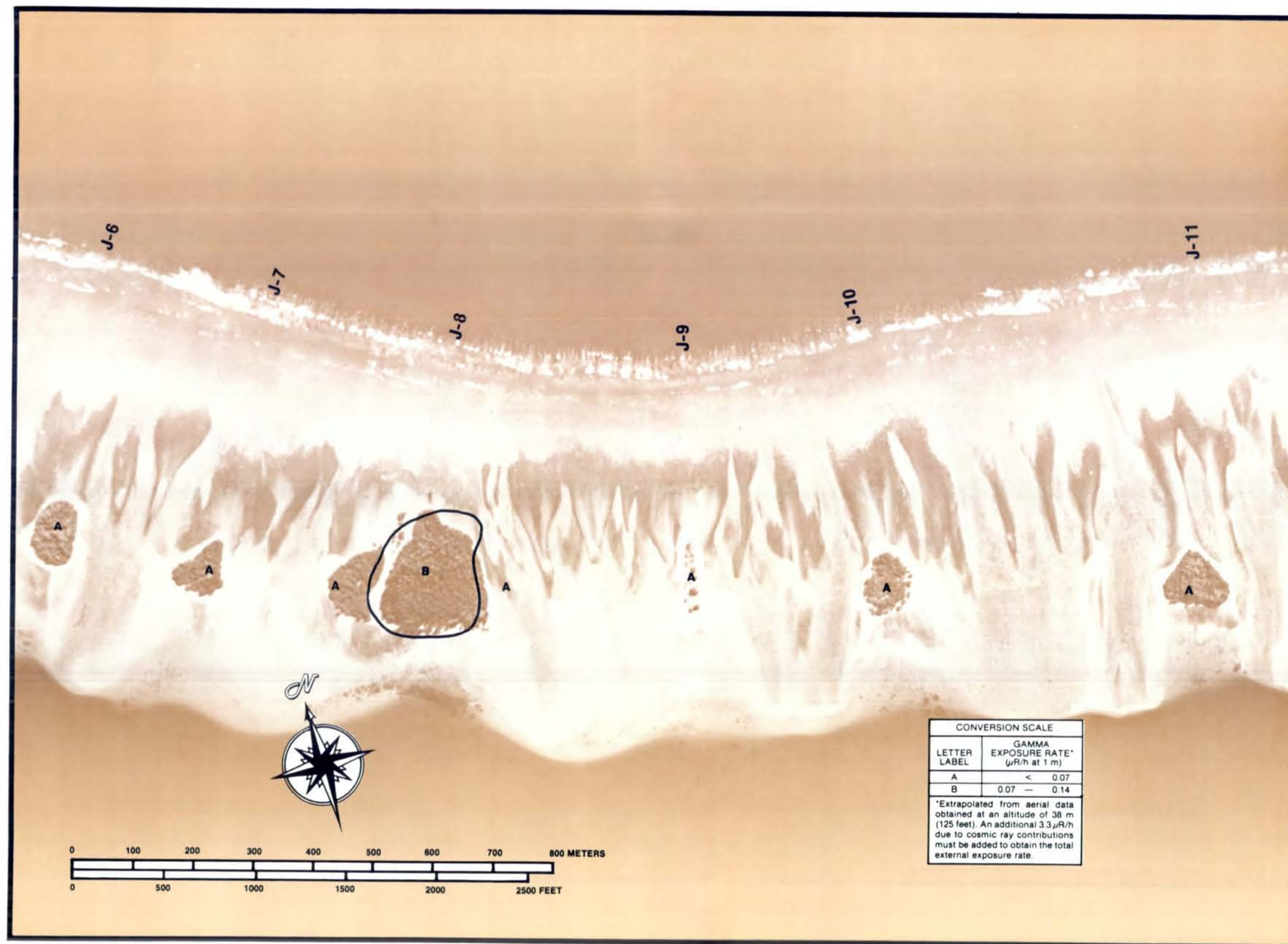


Figure D-144. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS J-6 TO J-11 AT UJELANG ATOLL. (Photograph Frame Number 143)



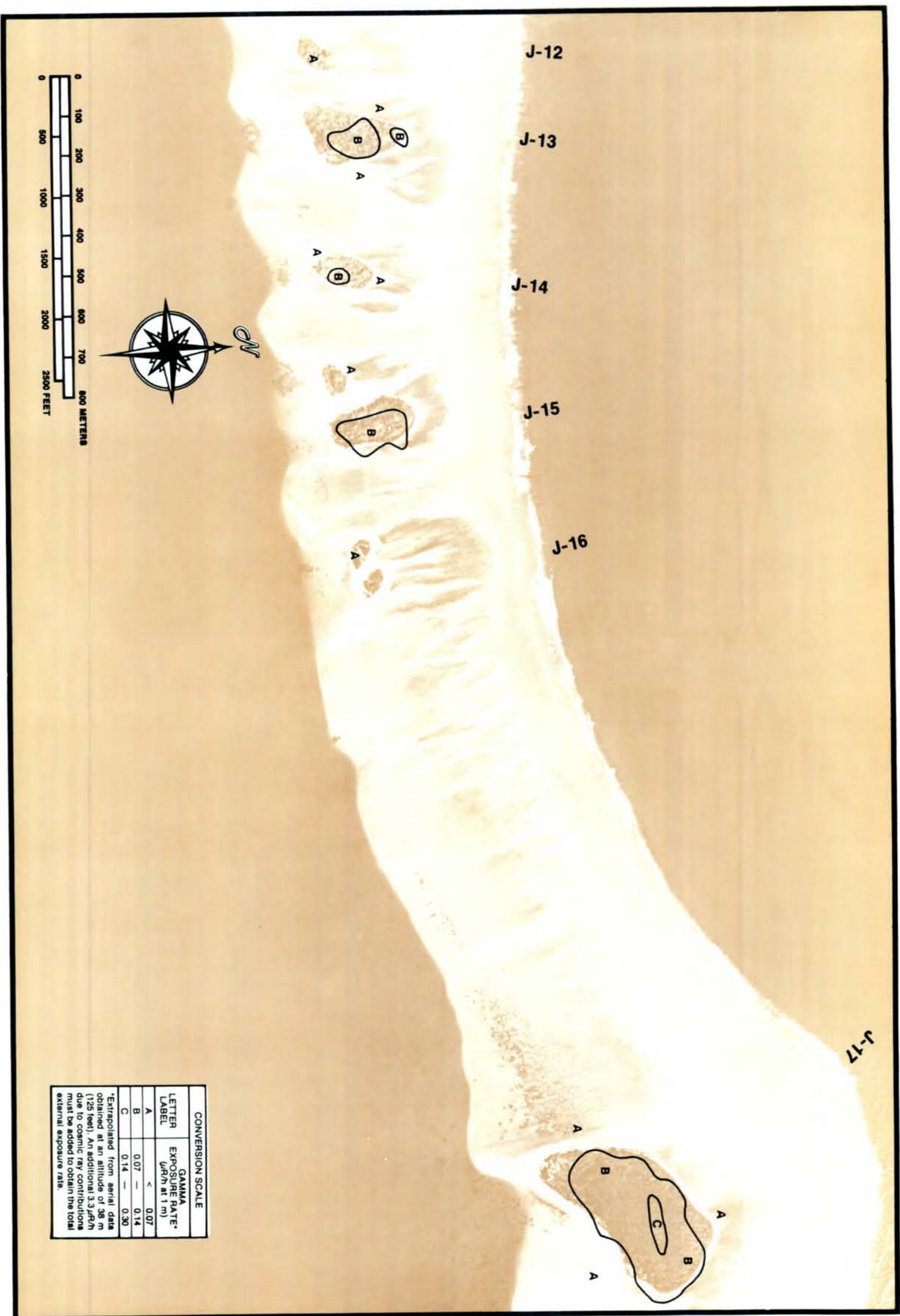


Figure D-145. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS J-12 TO J-17 AT UELUNG ATOLL. (Photograph Frame Number 145)



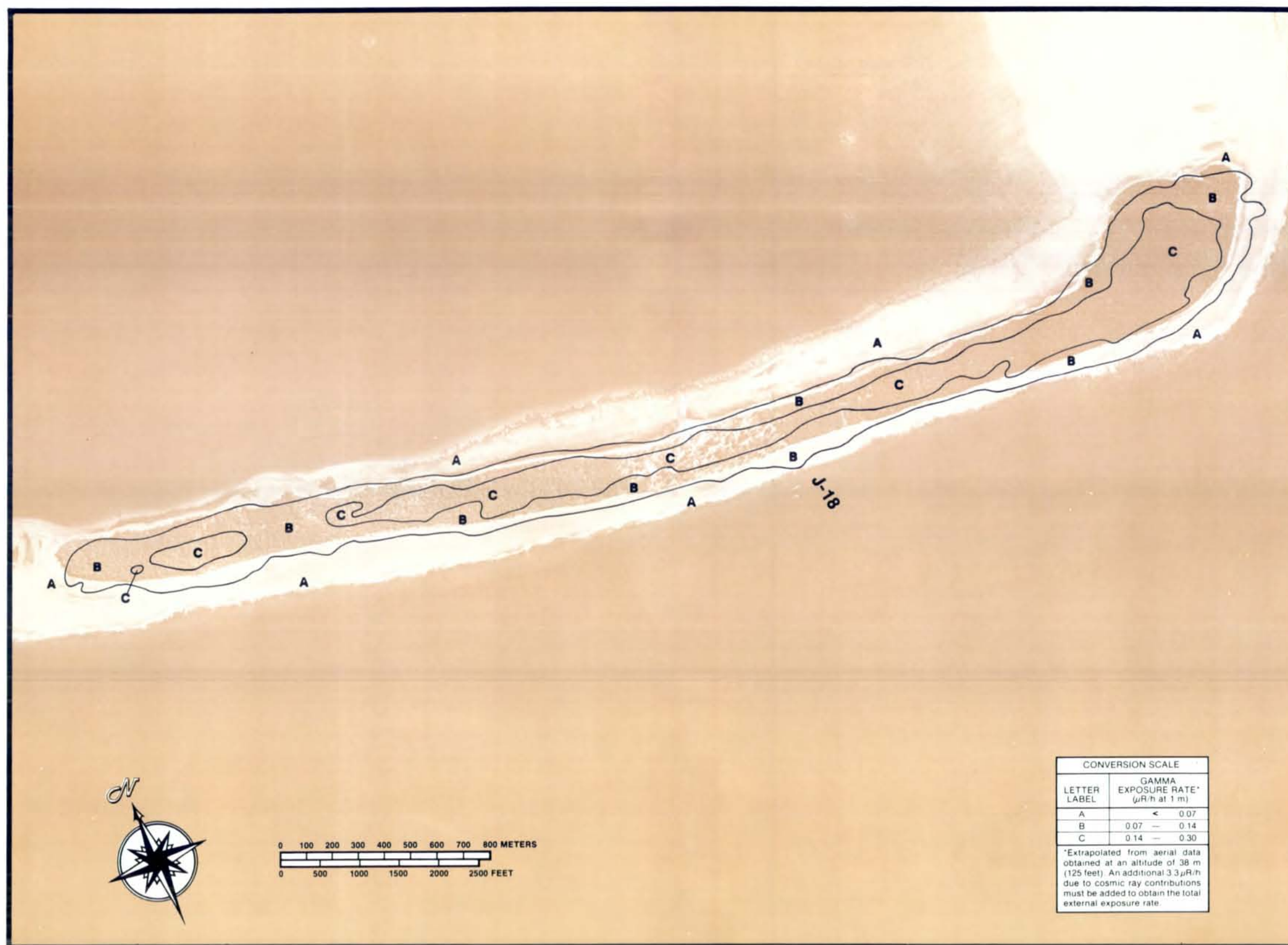


Figure D-146. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLAND J-18 AT UJELANG ATOLL. (Photograph Frame Number 153)



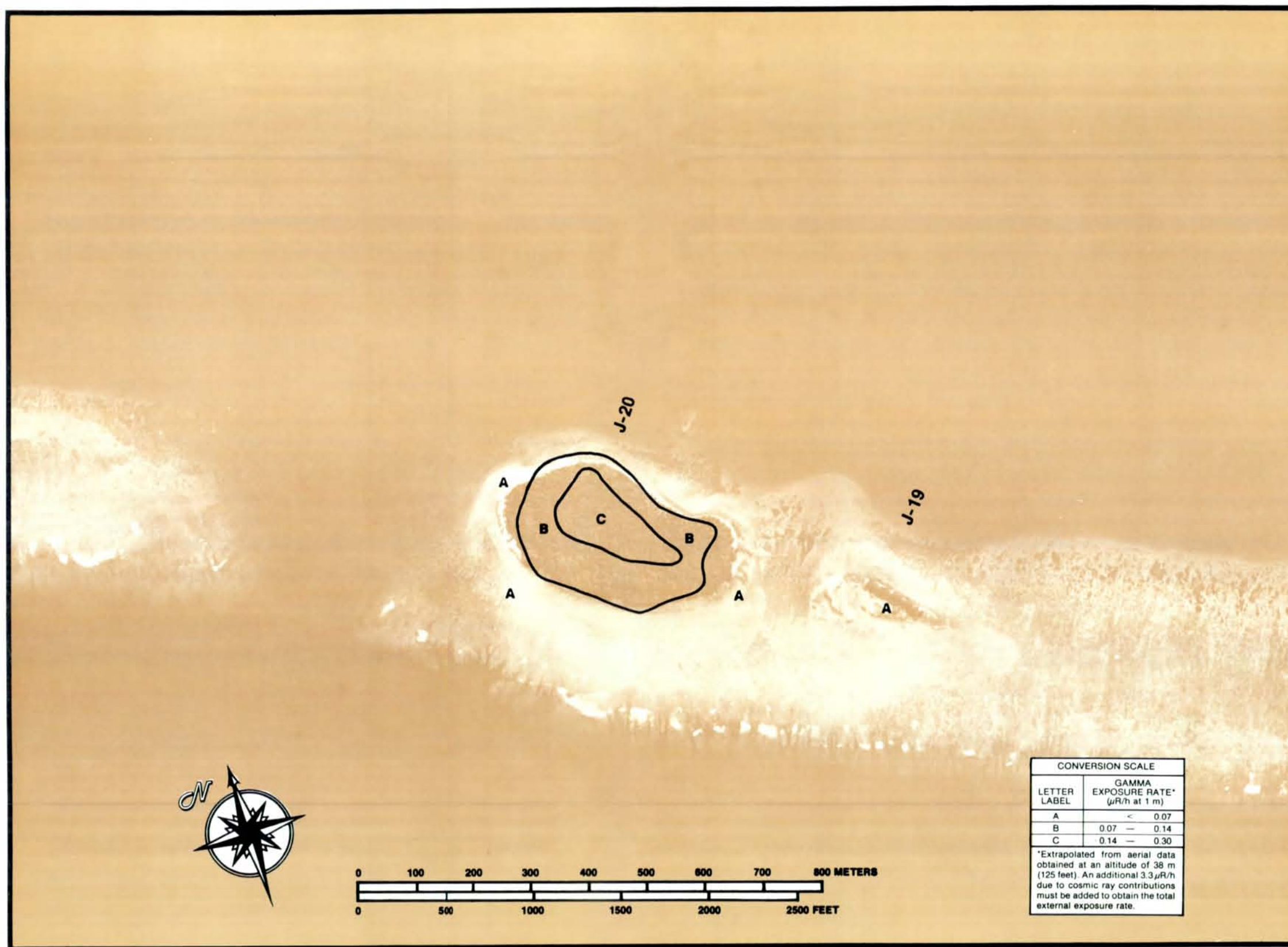


Figure D-147. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS J-19 TO J-20 AT UJELANG ATOLL. (Photograph Frame Number 157)



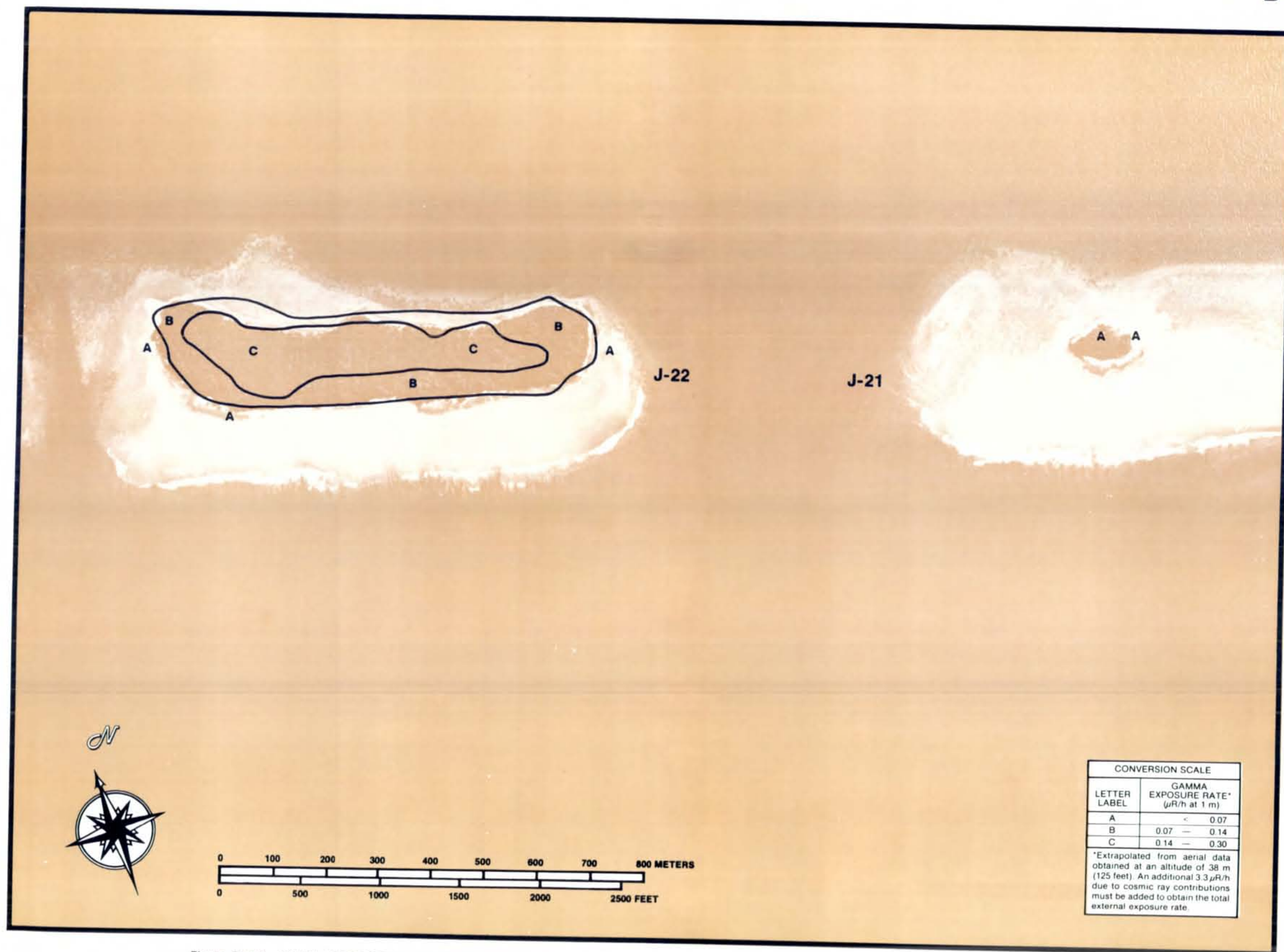
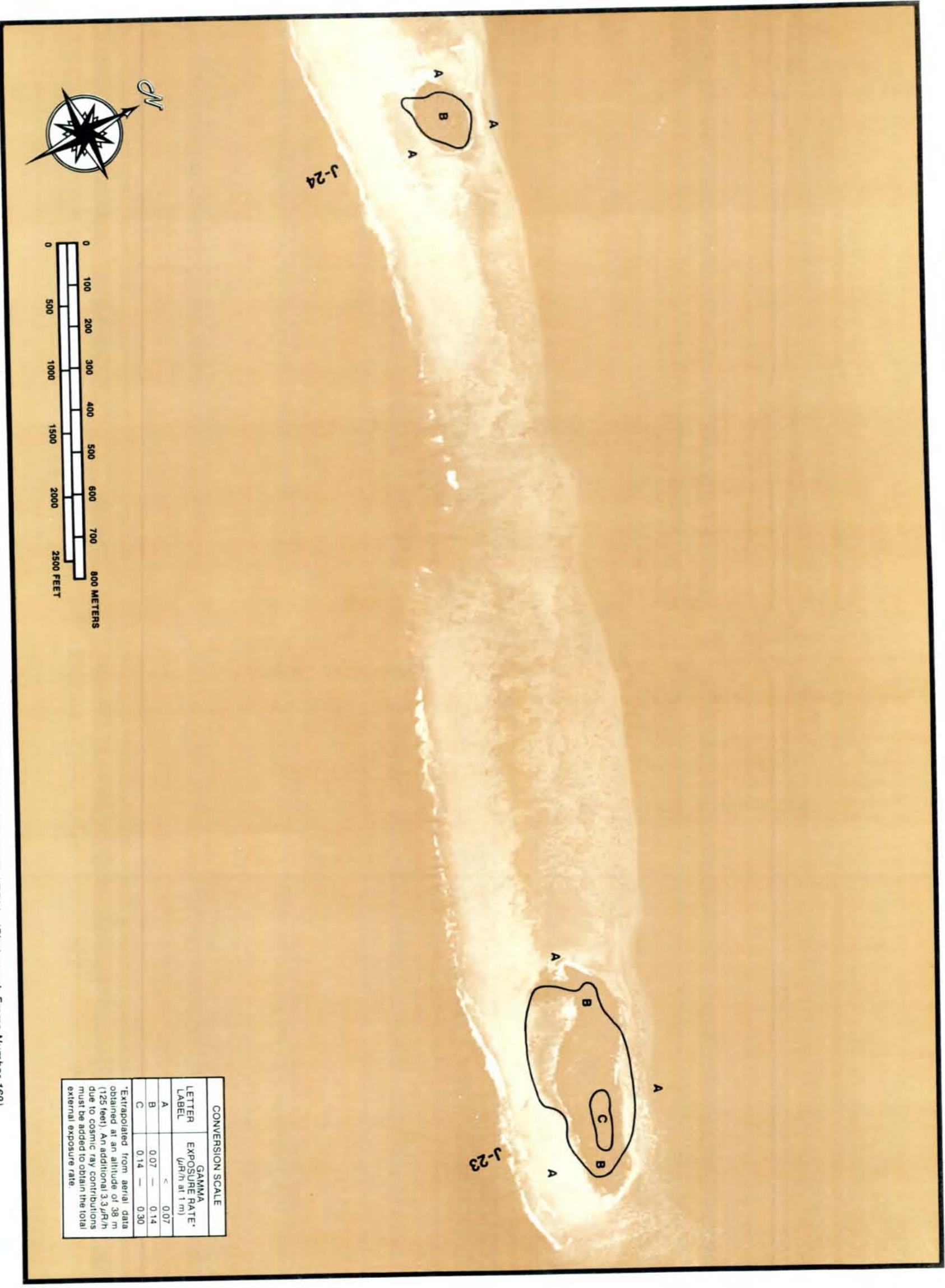


Figure D-148. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS J-21 TO J-22 AT UJELANG ATOLL. (Photograph Frame Number 166)





| CONVERSION SCALE |                                          |
|------------------|------------------------------------------|
| LETTER LABEL     | GAMMA EXPOSURE RATE* ( $\mu$ R/h at 1 m) |
| A                | < 0.07                                   |
| B                | 0.07 - 0.14                              |
| C                | 0.14 - 0.30                              |

\*Extrapolated from aerial data obtained at an altitude of 38 m (125 feet). An additional 3.3  $\mu$ R/h due to cosmic ray contributions must be added to obtain the total external exposure rate.

Figure D-149. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS J-23 TO J-24 AT UJELANG ATOLL. (Photograph Frame Number 168)



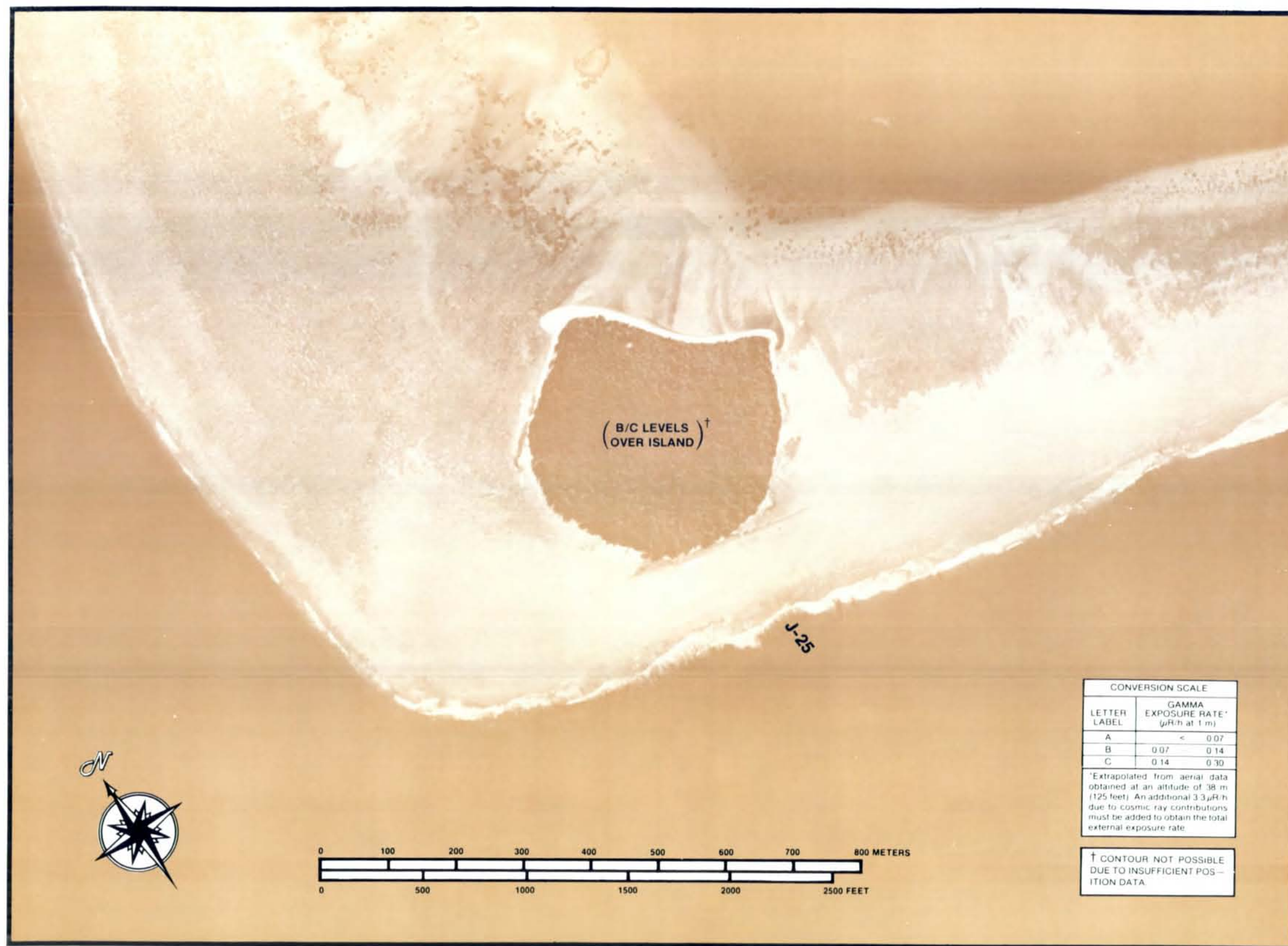


Figure D-150. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLAND J-25 AT UJELANG ATOLL. (Photograph Frame Number 174)



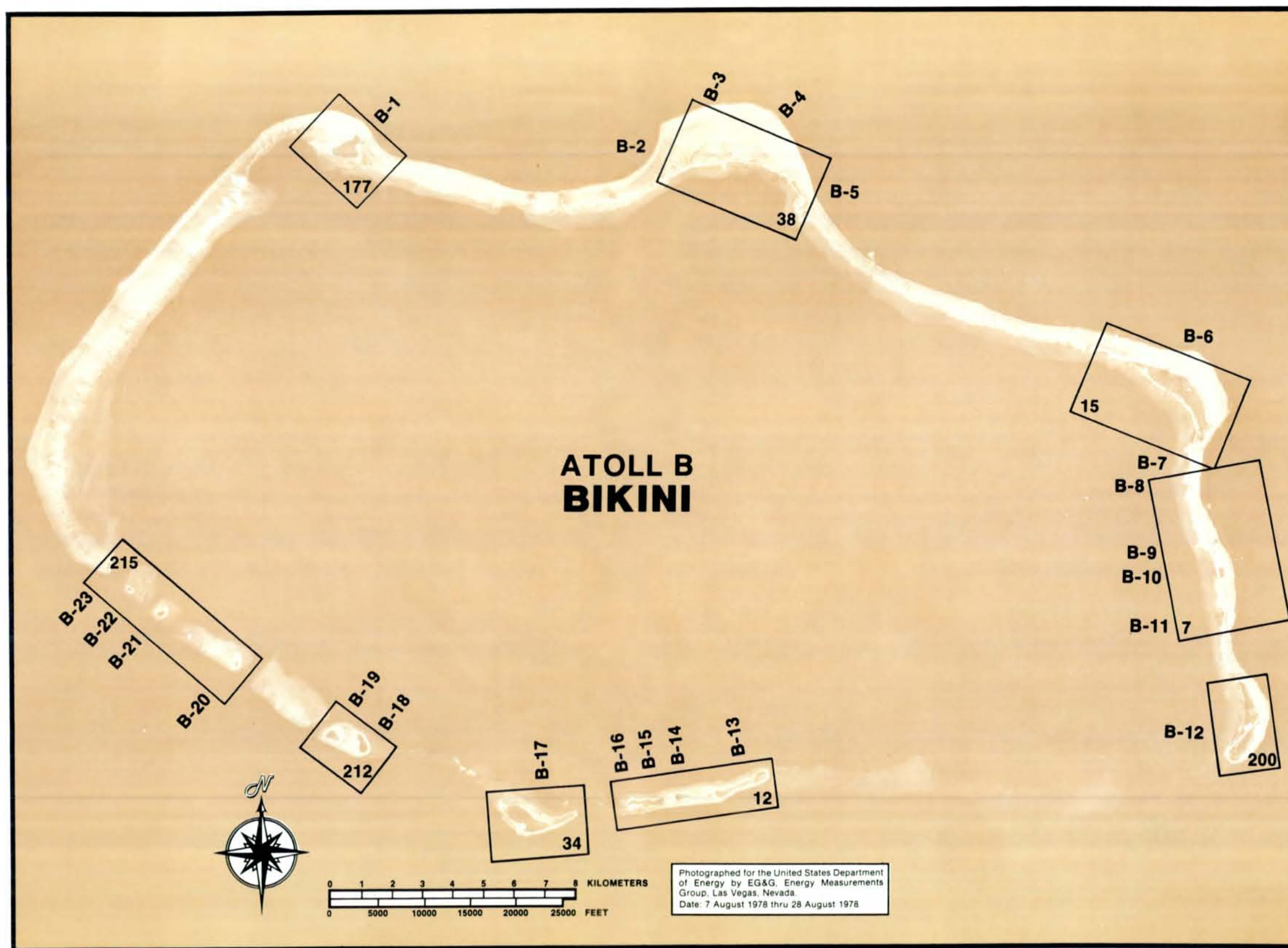


Figure D-151. BASE MAP KEY FOR BIKINI ATOLL. The photomosaic shows the area covered by each base map photograph and the photograph frame number used to identify each survey area.



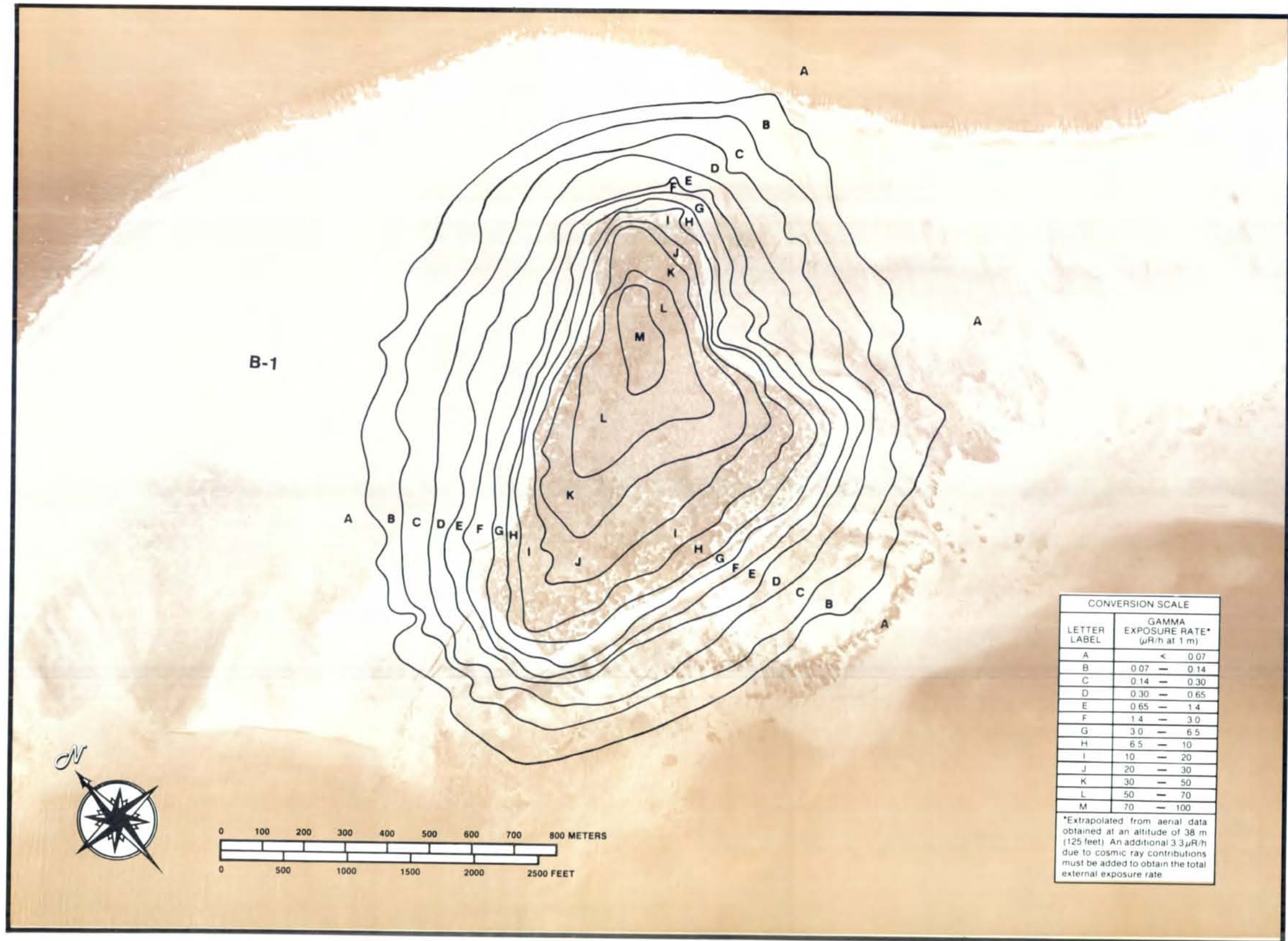


Figure D-152. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLAND B-1 AT BIKINI ATOLL. (Photograph Frame Number 177)





Figure D-153. CESIUM 137 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLAND B-1 AT BIKINI ATOLL. (Photograph Frame Number 177)



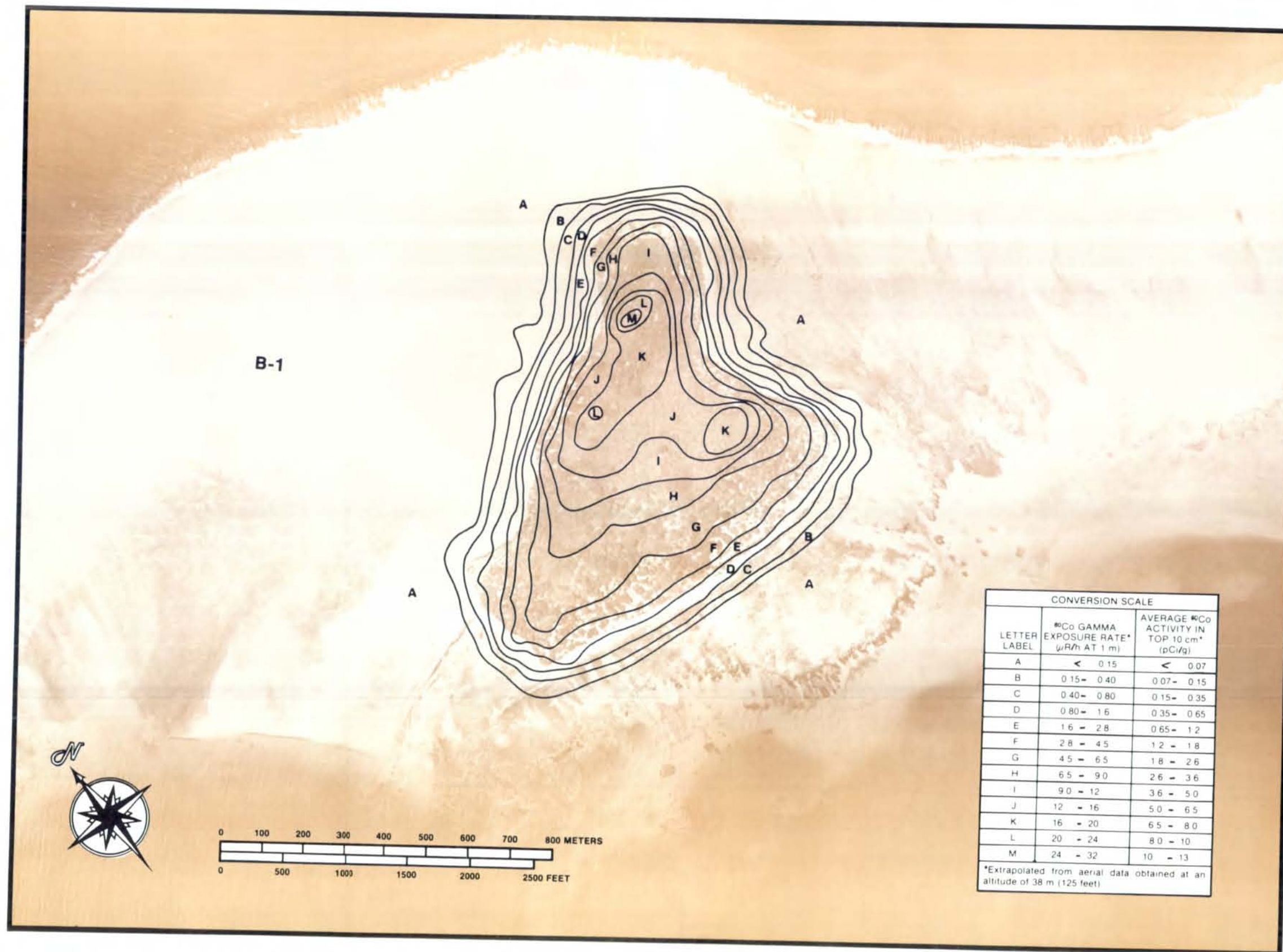


Figure D-154. COBALT 60 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLAND B-1 AT BIKINI ATOLL. (Photograph Frame Number 177)



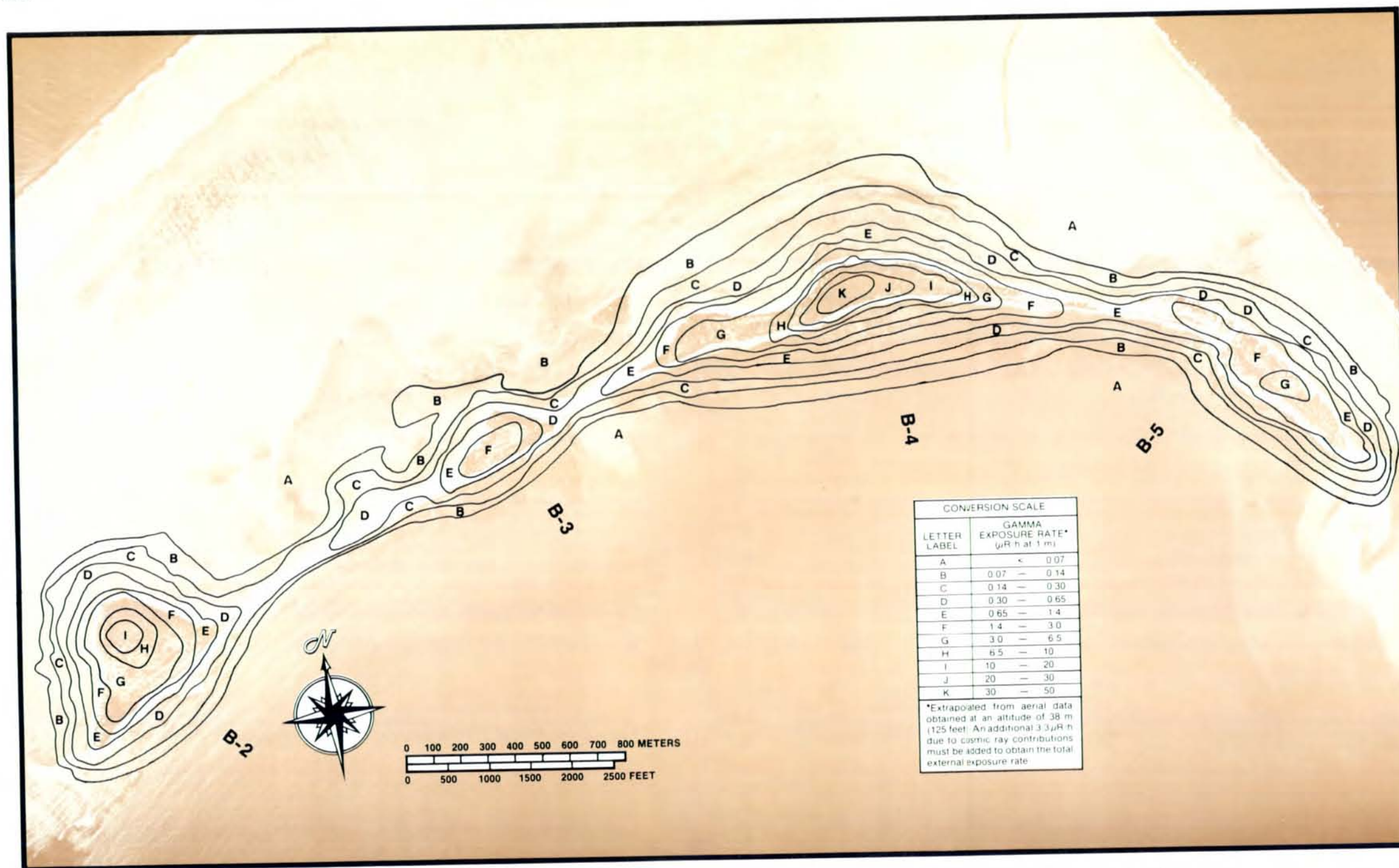


Figure D-155. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS B-2 TO B-5 AT BIKINI ATOLL. (Photograph Frame Number 38)



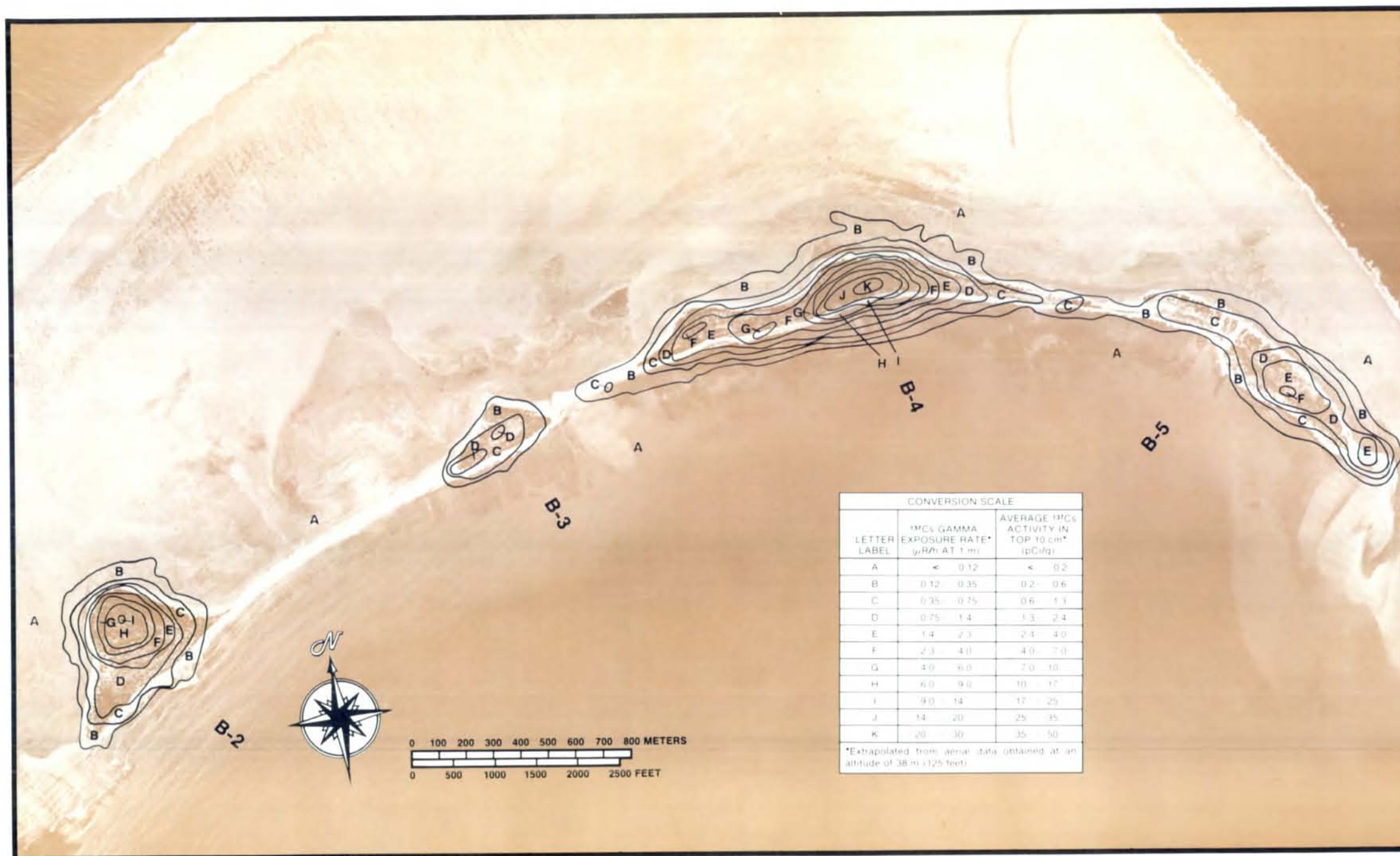


Figure D-156. CESIUM 137 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS B-2 TO B-5 AT BIKINI ATOLL. (Photograph Frame Number 38)



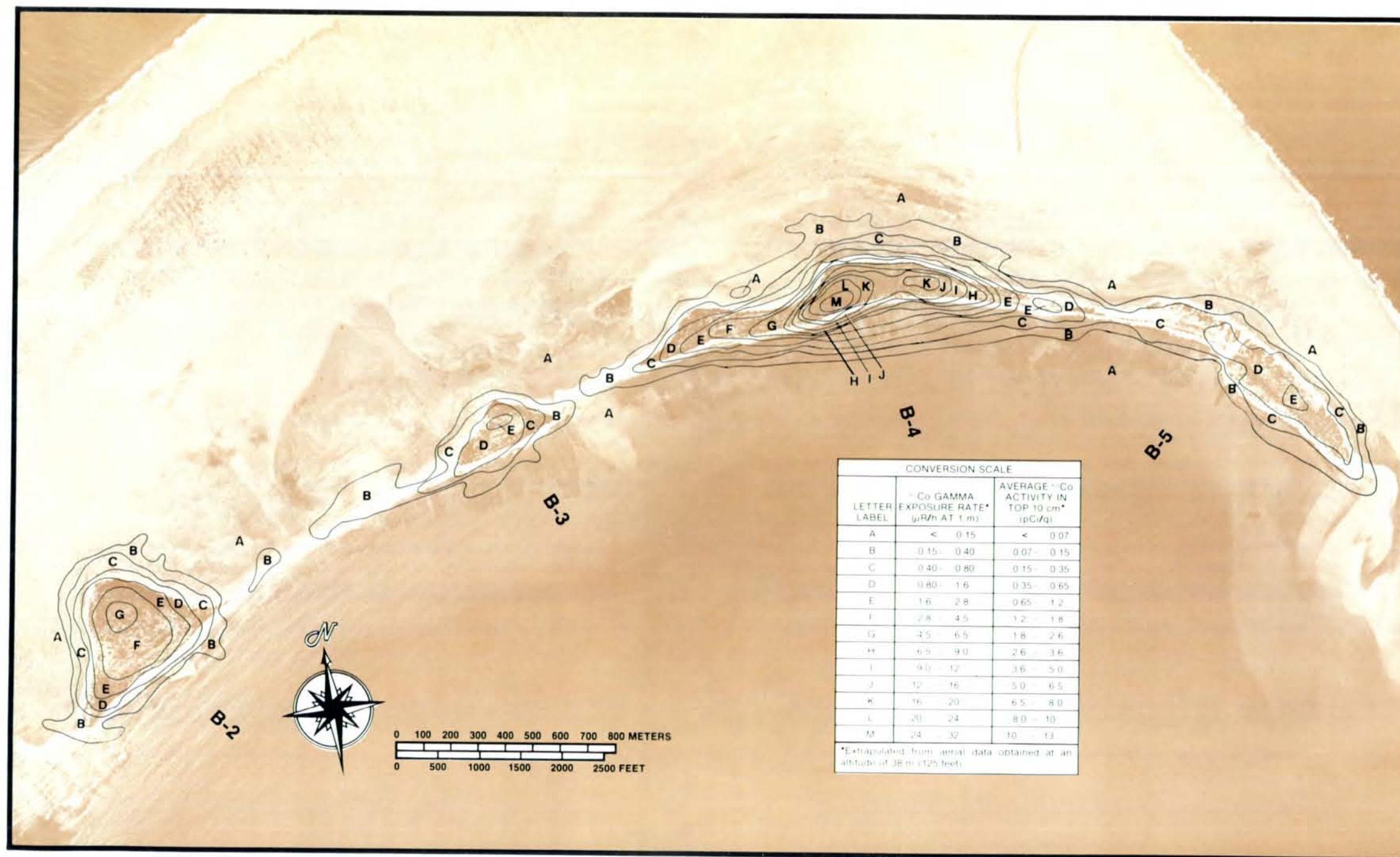


Figure D-157. COBALT 60 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS B-2 To B-5 AT BIKINI ATOLL. (Photograph Frame Number 38)



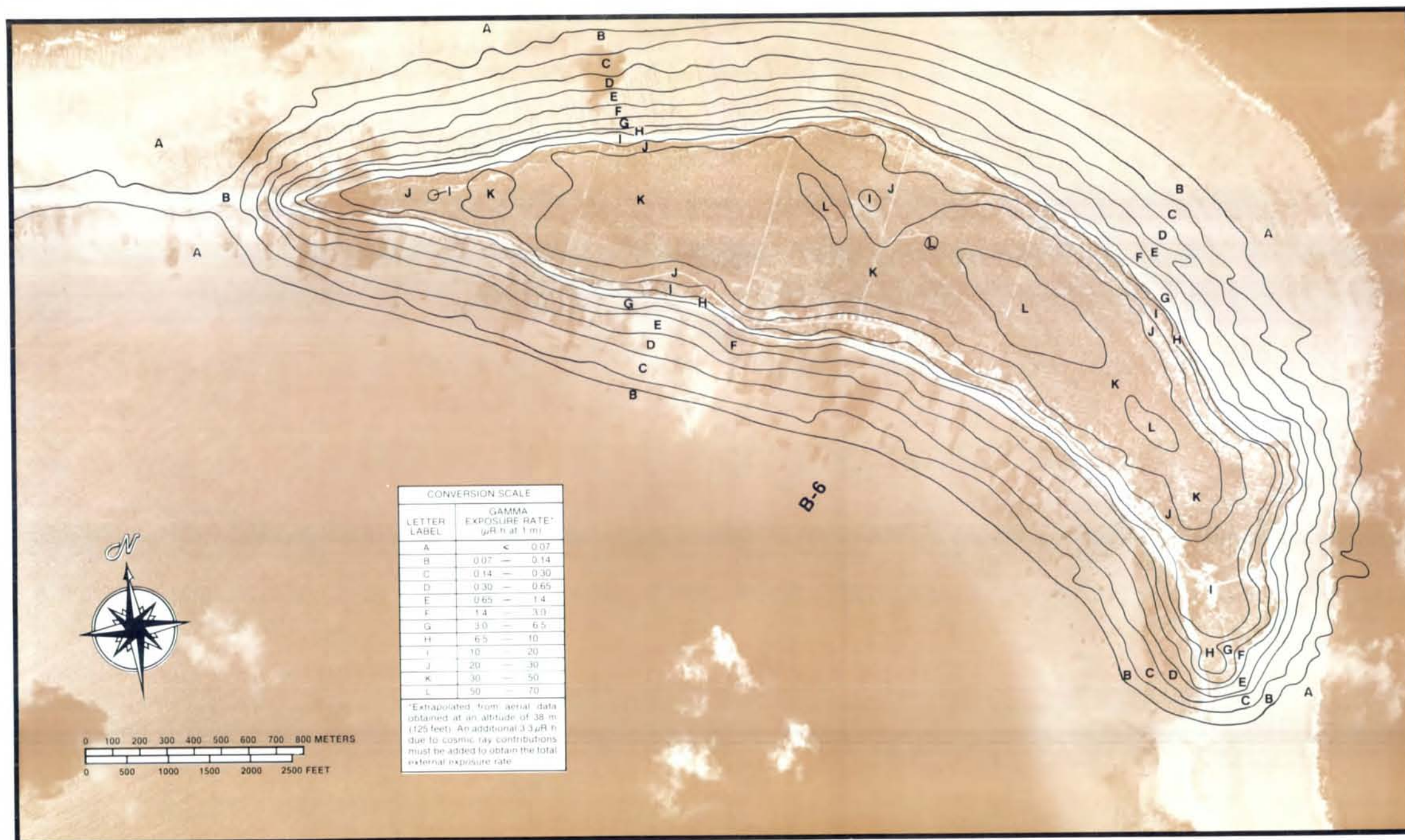


Figure D-158. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLAND B-6 AT BIKINI ATOLL. (Photograph Frame Number 15)



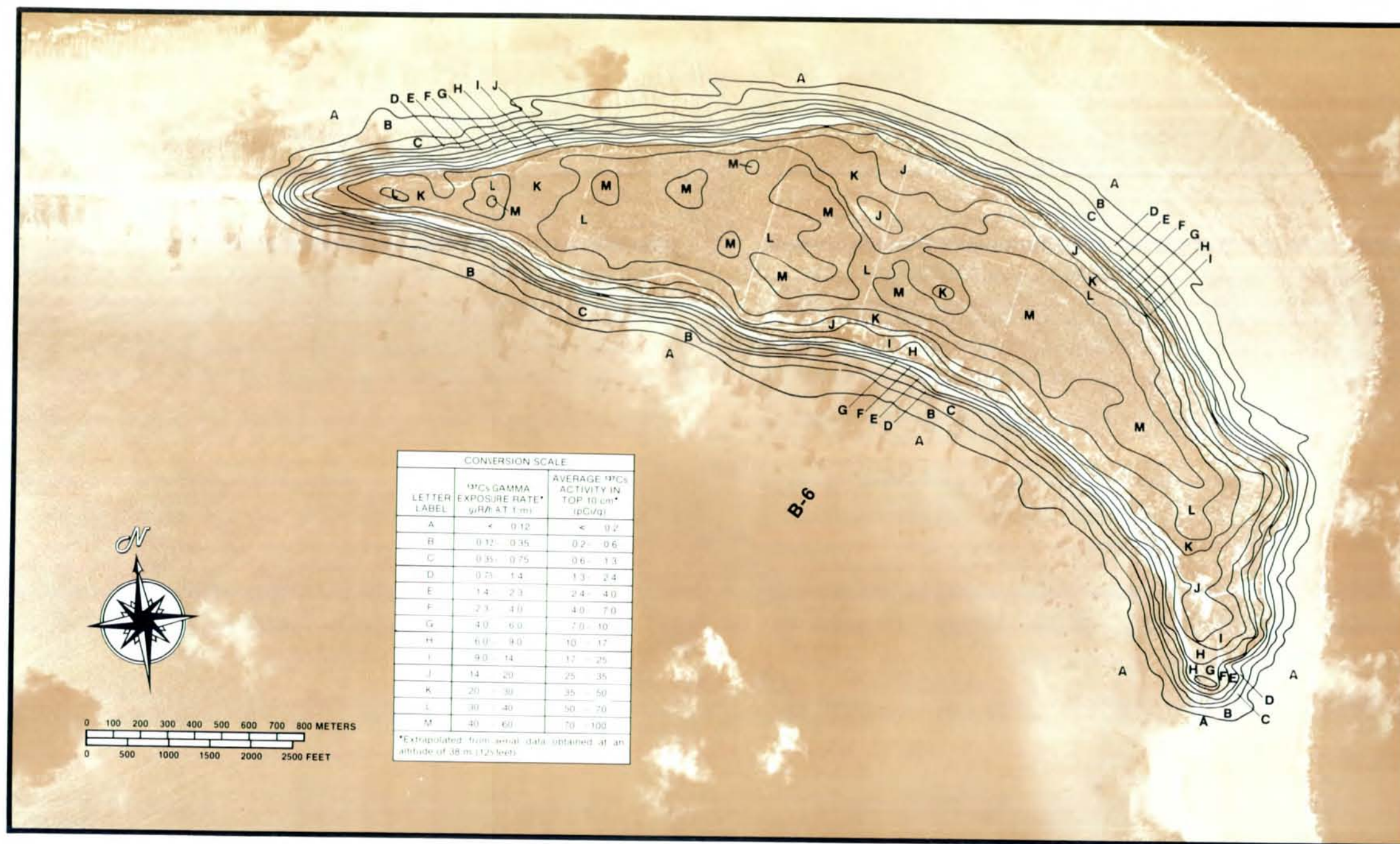


Figure D-159. CESIUM 137 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLAND B-6 AT BIKINI ATOLL. (Photograph Frame Number 15)



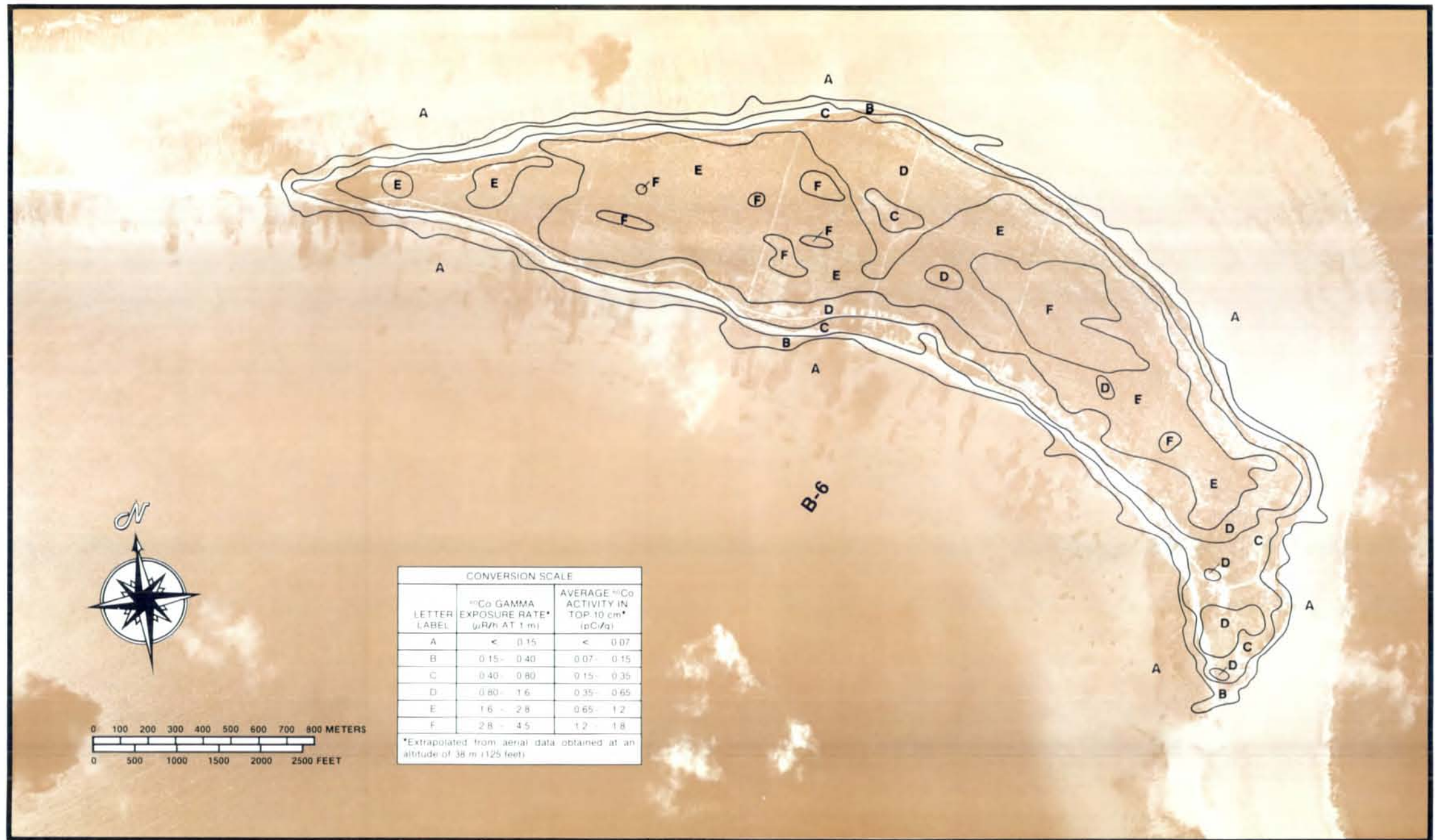


Figure D-160. COBALT 60 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLAND B-6 AT BIKINI ATOLL. (Photograph Frame Number 15)



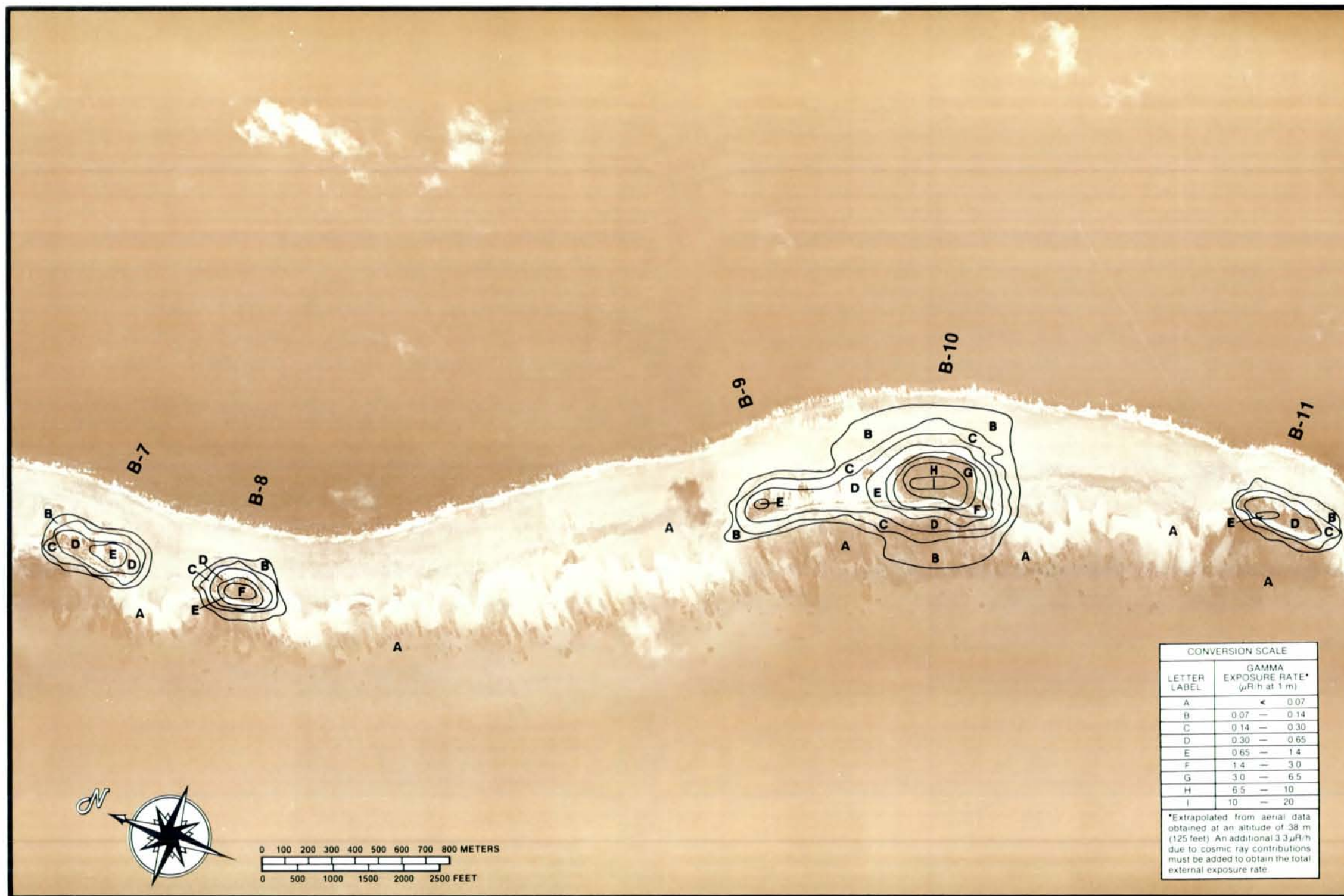


Figure D-161. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS B-7 TO B-11 AT BIKINI ATOLL (Photograph Frame Number 7)





Figure D-162. CESIUM 137 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS B-7 TO B-11 AT BIKINI ATOLL. (Photograph Frame Number 7)





Figure D-163. COBALT 60 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS B-7 TO B-11 AT BIKINI ATOLL. (Photograph Frame Number 7)



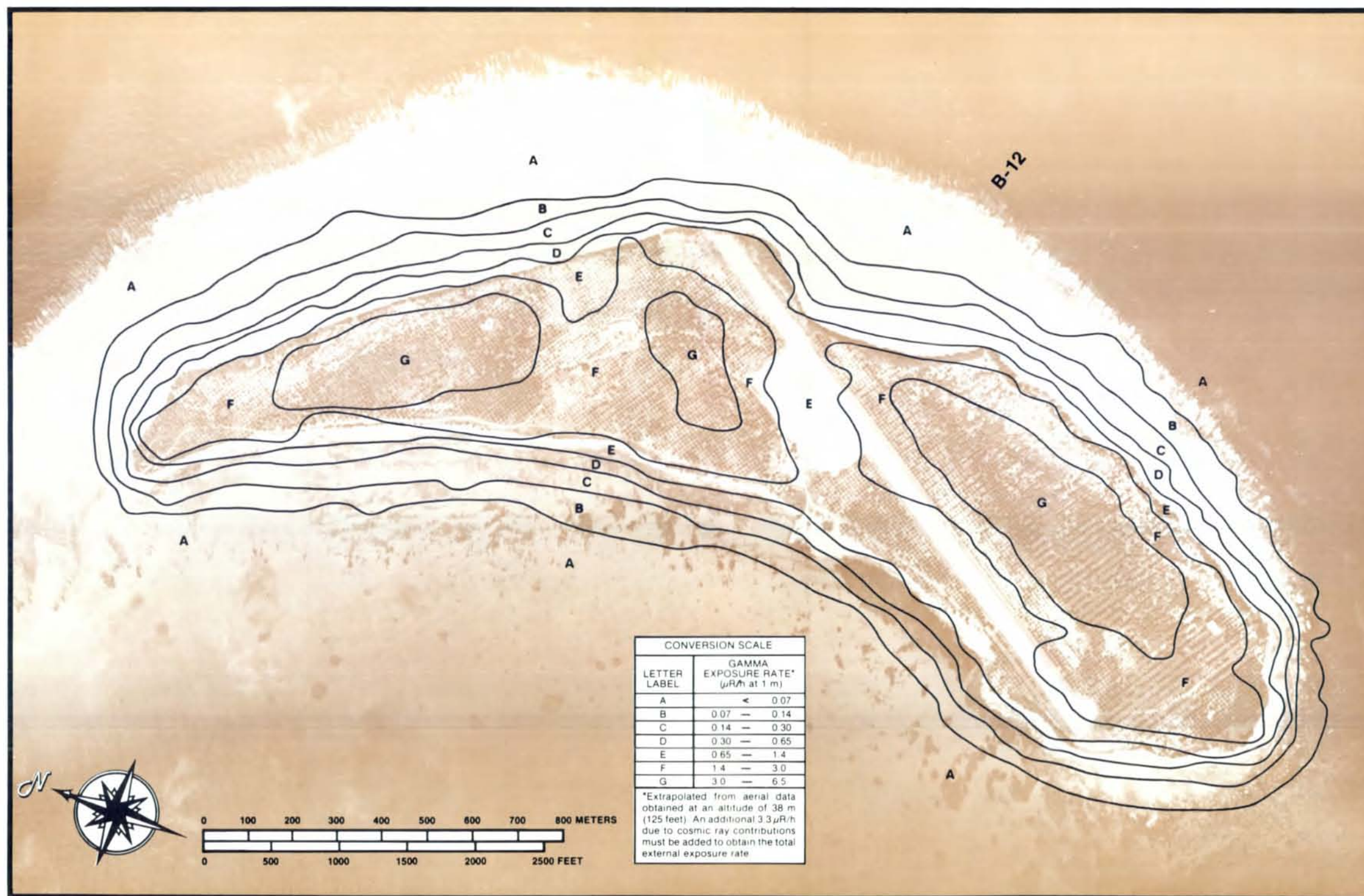


Figure D-164. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLAND B-12 AT BIKINI ATOLL. (Photograph Frame Number 200)





Figure D-165. CESIUM 137 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLAND B-12 AT BIKINI ATOLL. (Photograph Frame Number 200)



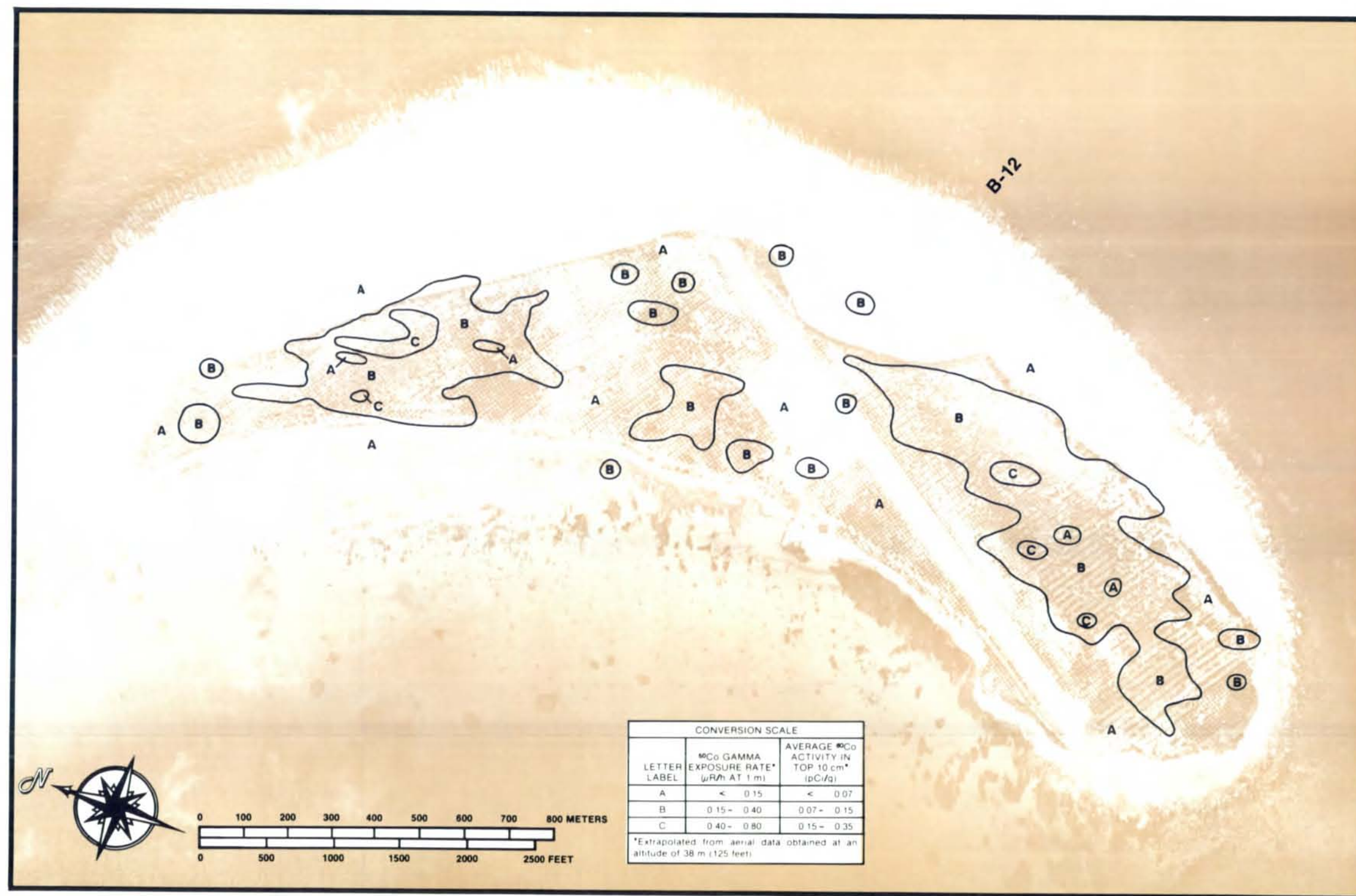


Figure D-166. COBALT 60 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLAND B-12 AT BIKINI ATOLL. (Photograph Frame Number 200)



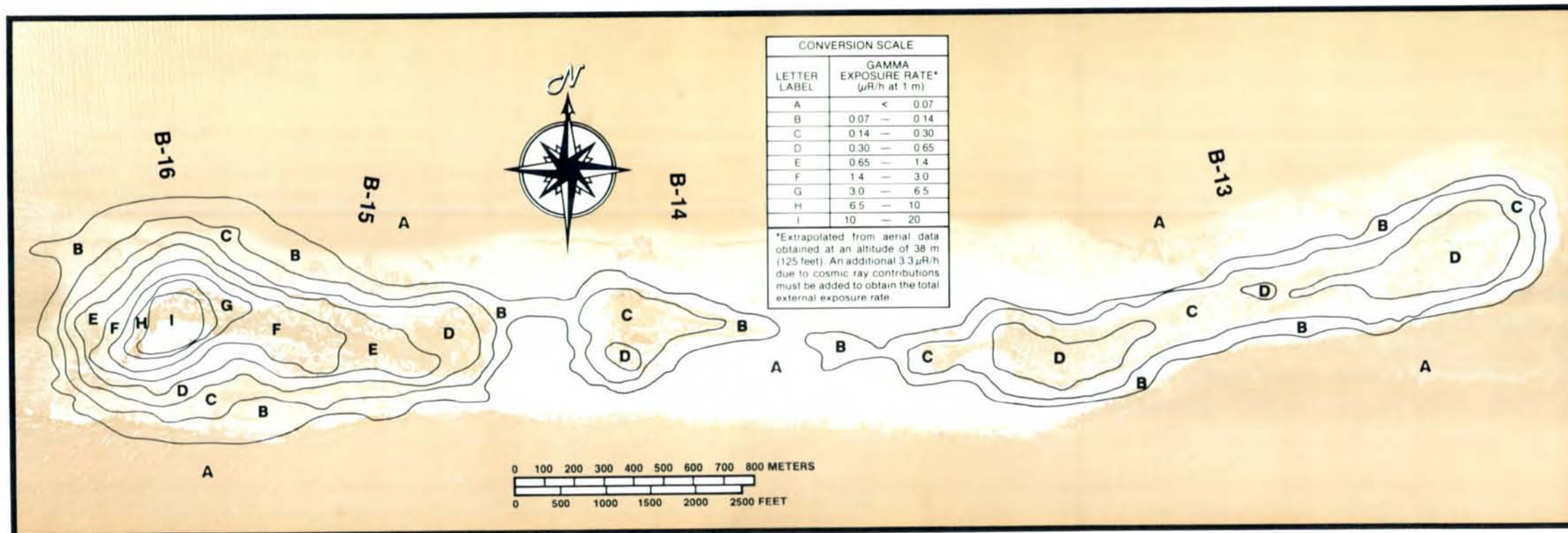


Figure D-167. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS B-13 TO B-16 AT BIKINI ATOLL. (Photograph Frame Number 12)

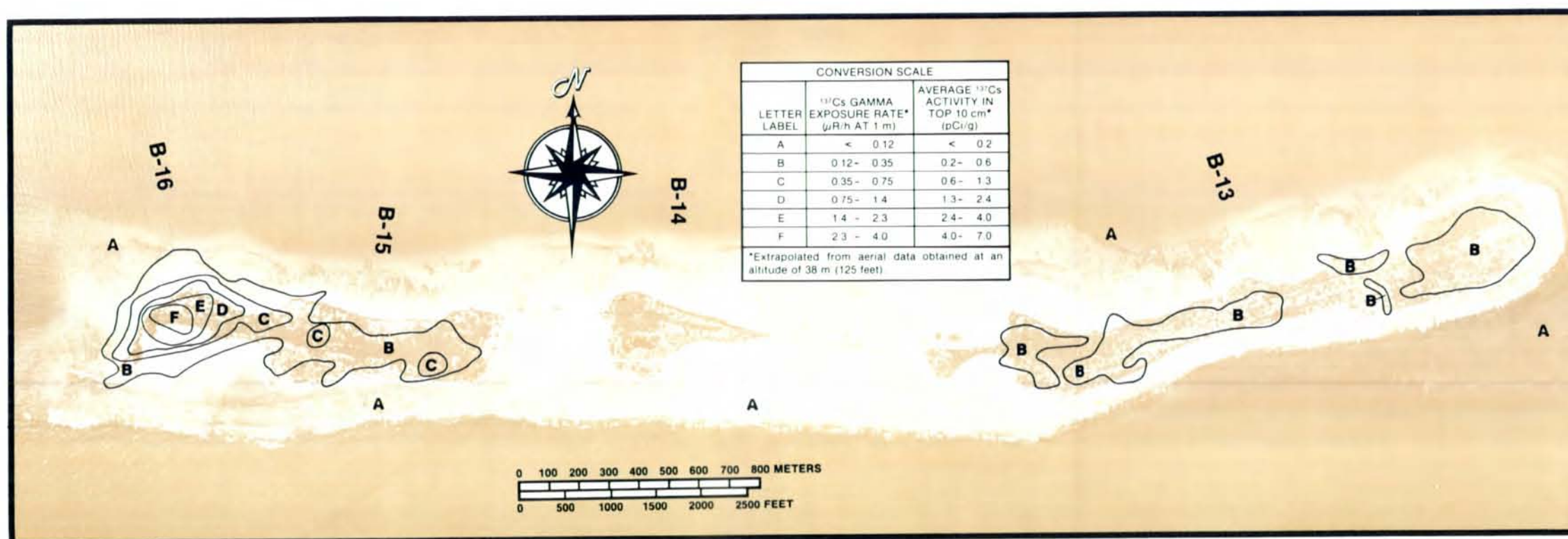


Figure D-168. CESIUM 137 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS B-13 TO B-16 AT BIKINI ATOLL. (Photograph Frame Number 12)



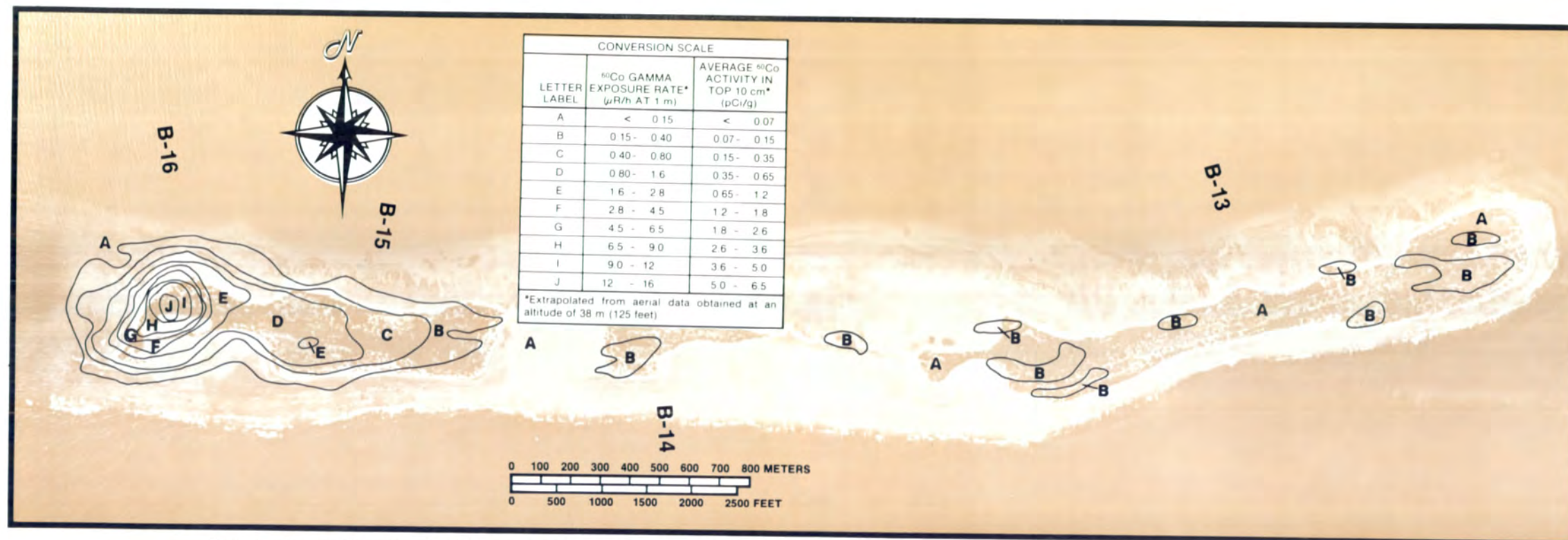


Figure D-169. COBALT 60 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS B-13 TO B-16 AT BIKINI ATOLL. (Photograph Frame Number 12)



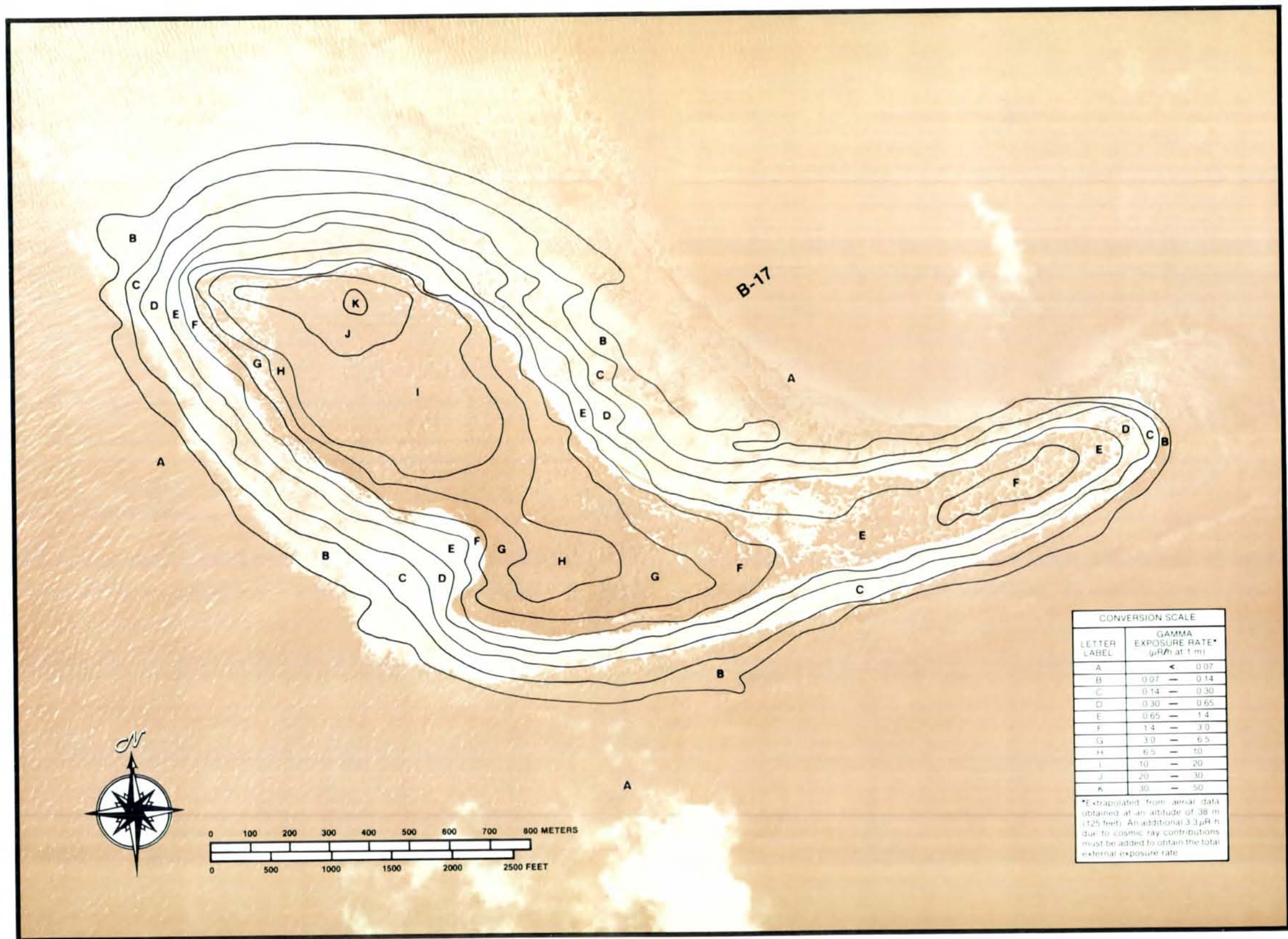


Figure D-170. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLAND B-17 AT BIKINI ATOLL. (Photograph Frame Number 34)





Figure D-171. CESIUM 137 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLAND B-17 AT BIKINI ATOLL. (Photograph Frame Number 34)





Figure D-172. COBALT 60 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLAND B-17 AT BIKINI ATOLL. (Photograph Frame Number 34)



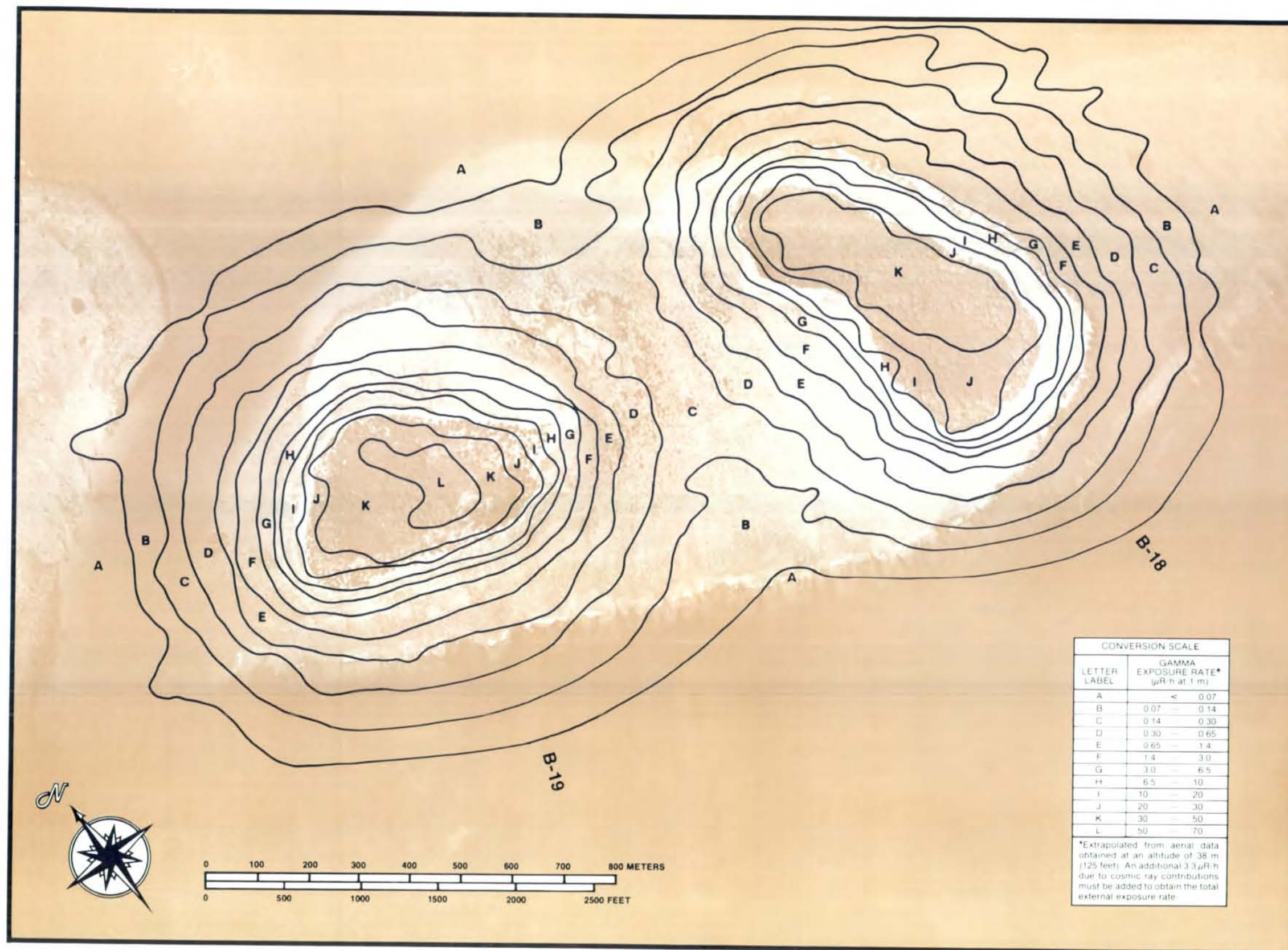


Figure D-173. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS B-18 TO B-19 AT BIKINI ATOLL. (Photograph Frame Number 212)



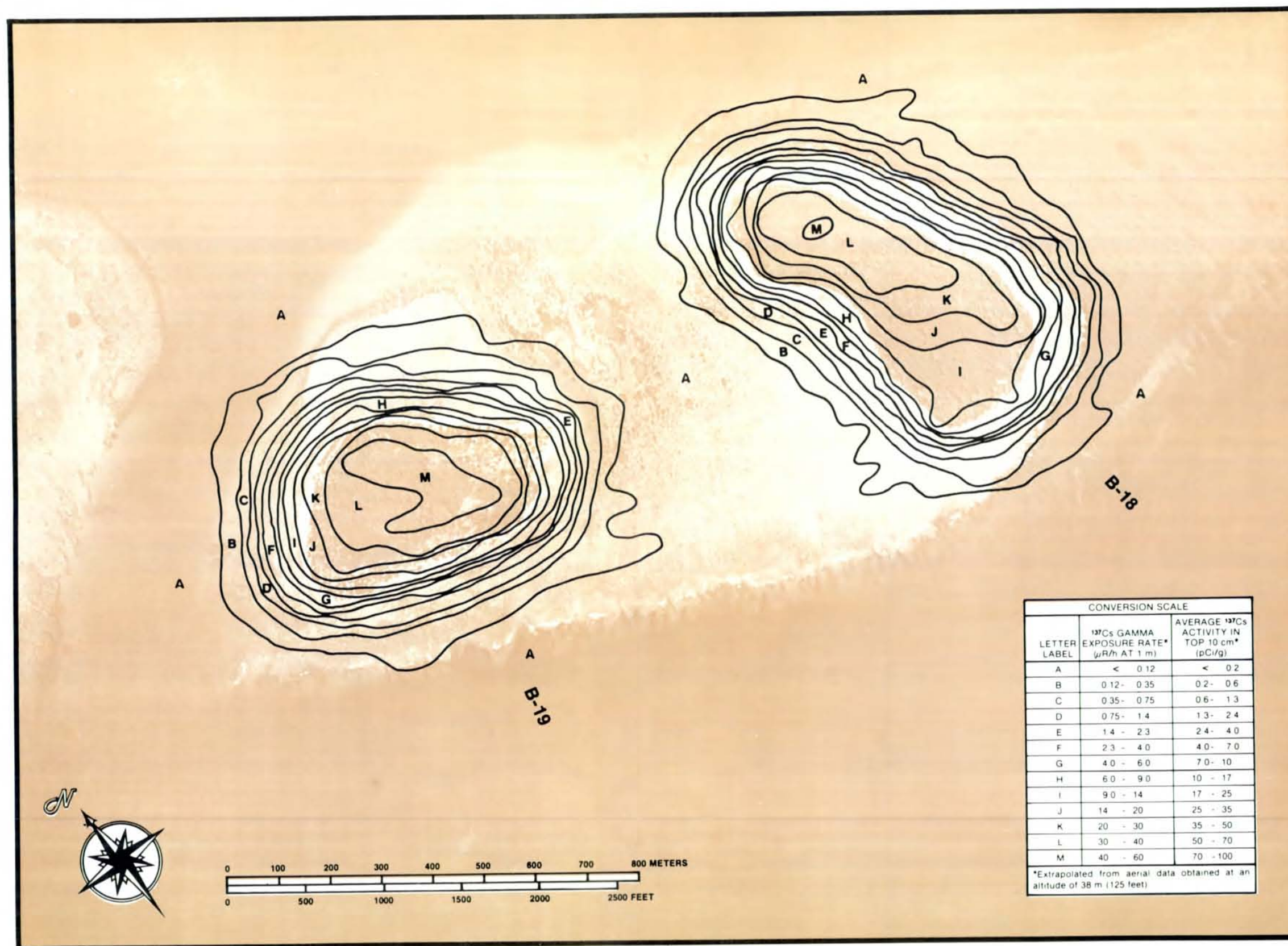


Figure D-174. CESIUM 137 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS B-18 TO B-19 AT BIKINI ATOLL. (Photograph Frame Number 212)



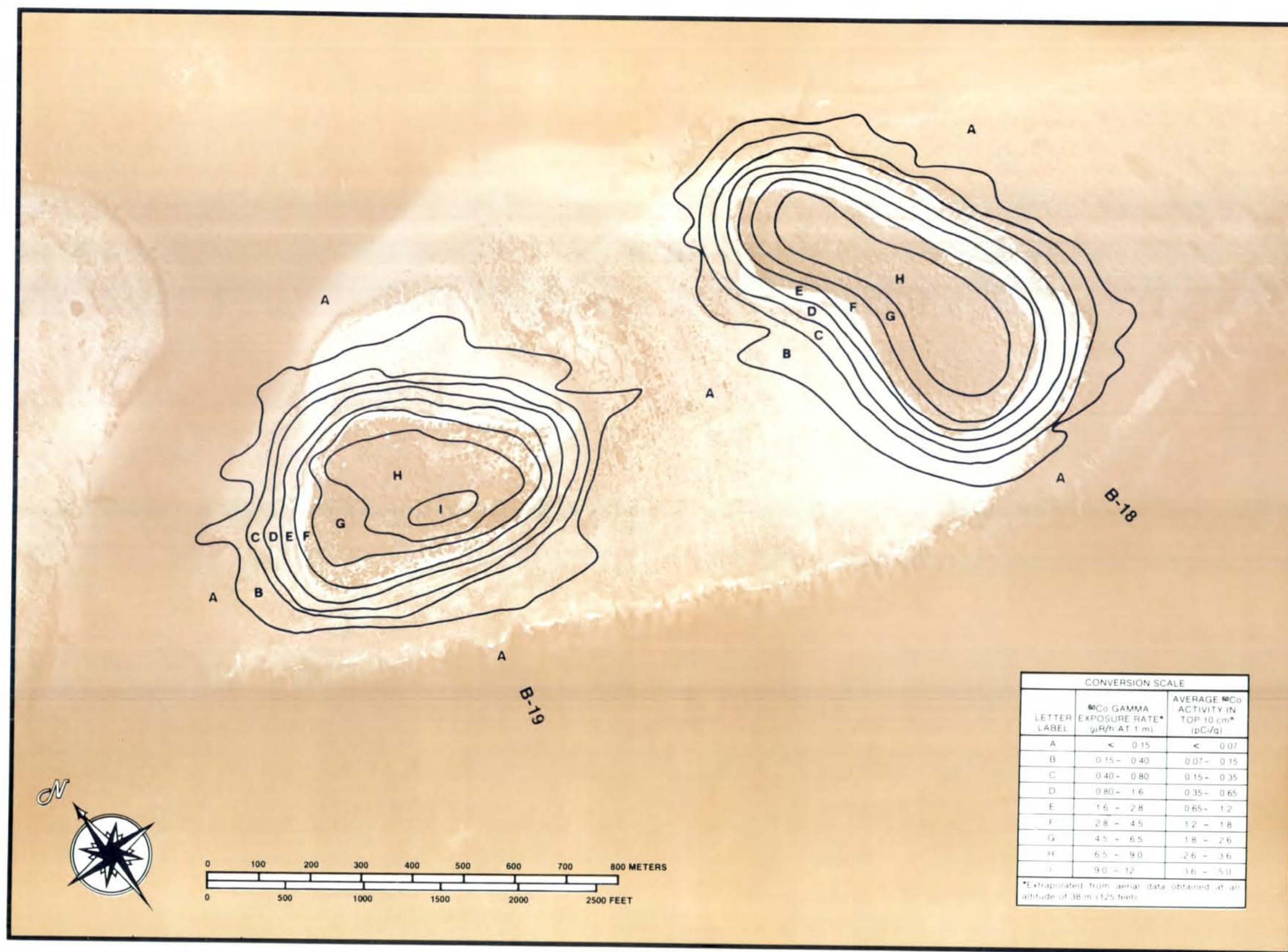


Figure D-175. COBALT 60 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS B-18 TO B-19 AT BIKINI ATOLL. (Photograph Frame Number 212)



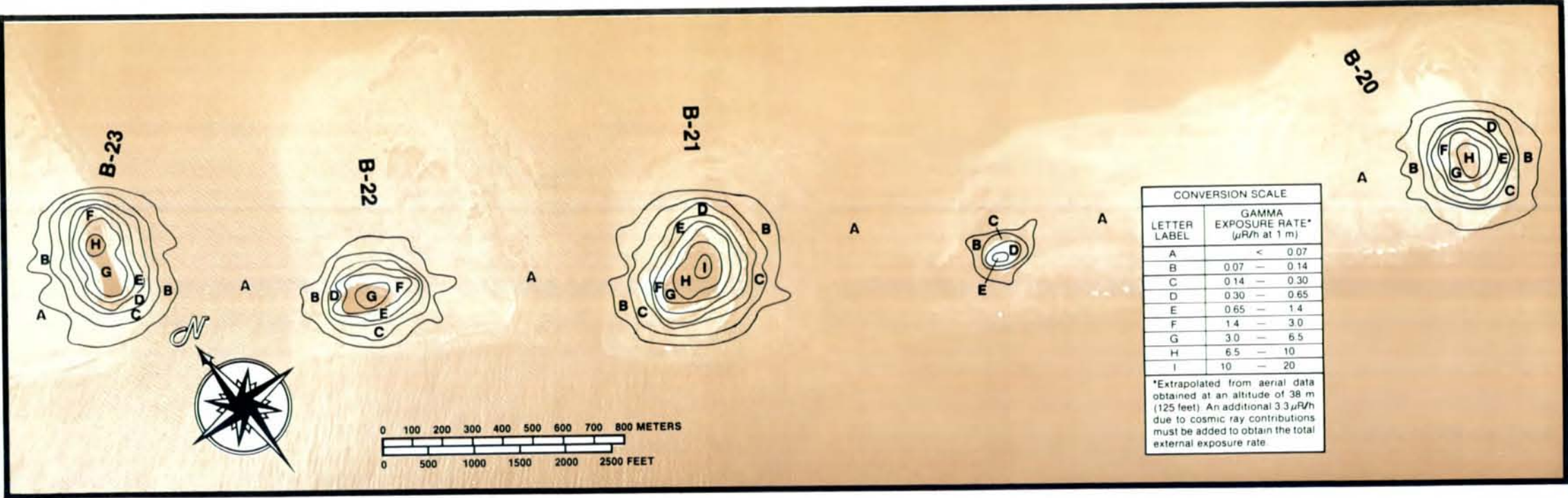


Figure D-176. TOTAL TERRESTRIAL EXPOSURE RATE CONTOURS FOR ISLANDS B-20 TO B-23 AT BIKINI ATOLL. (Photograph Frame Number 215)

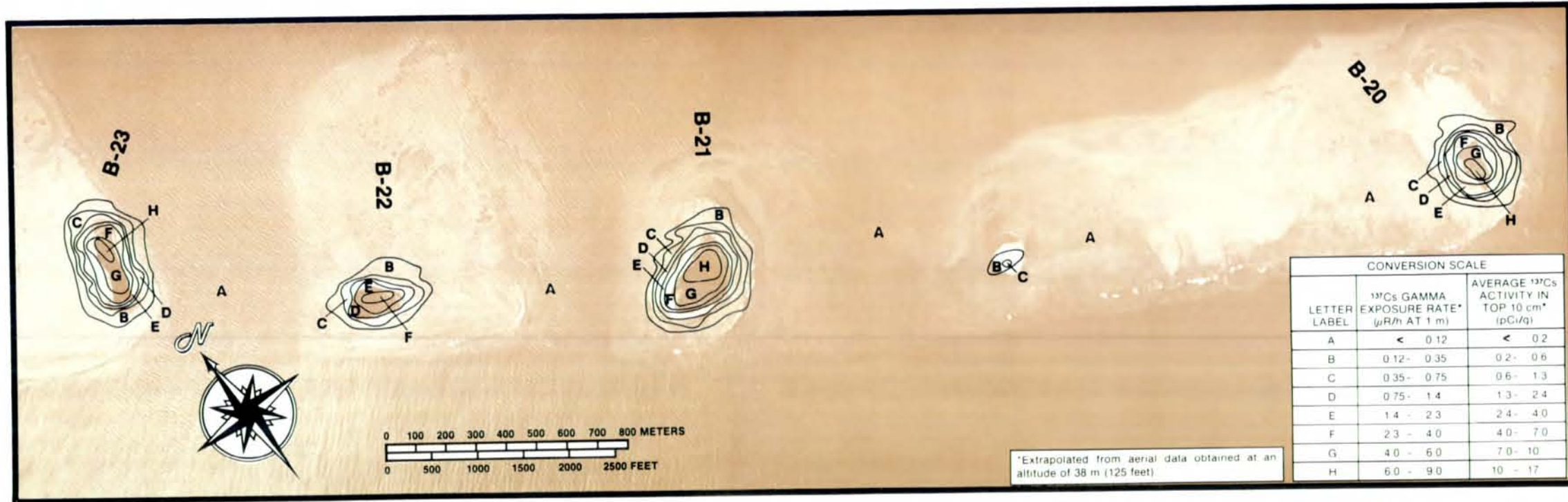


Figure D-177. CESIUM 137 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS B-20 TO B-23 AT BIKINI ATOLL. (Photograph Frame Number 215)



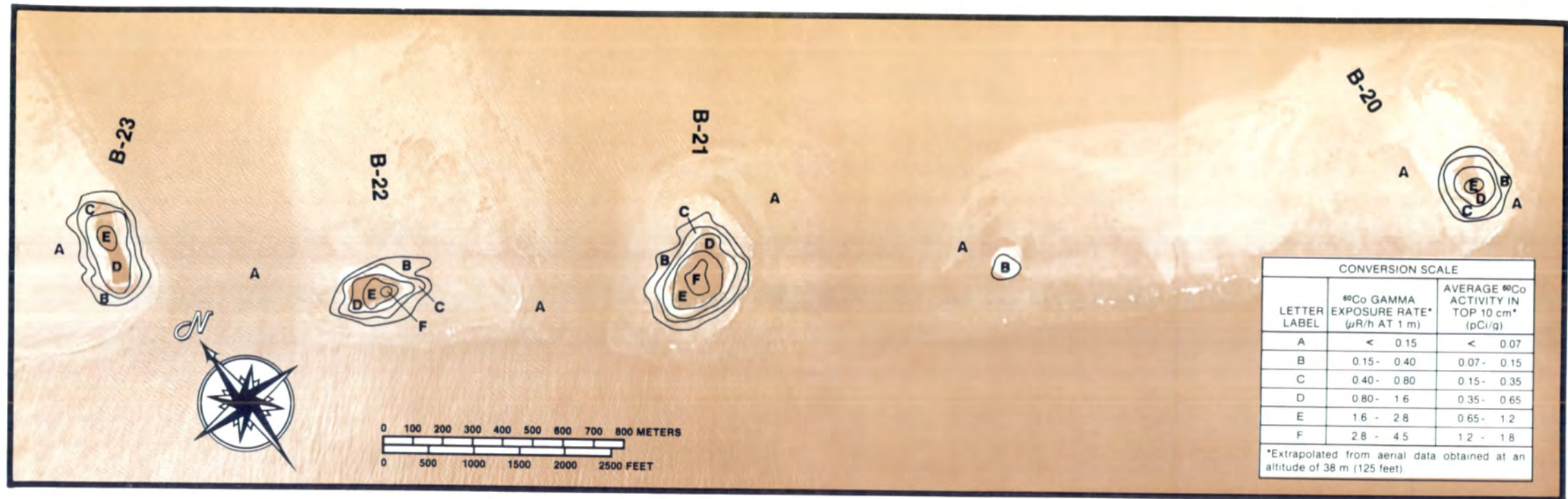


Figure D-178. COBALT 60 EXPOSURE RATE AND CONCENTRATION CONTOURS FOR ISLANDS B-20 TO B-23 AT BIKINI ATOLL. (Photograph Frame Number 215)



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The layout and graphics for this report were designed and executed by S.M. Freshwater.