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20. ABSTRACT (Continued)

this methodology. Doses for all other ships are summarized. Volume II (Appendix A) details the results for target ship personnel. Volume III (Appendix B) details the results for support ship personnel. Calculated doses for more than 36,000 personnel aboard support ships while at Bikini range from zero to 1.7 rem. Of those, approximately 34,000 are less than 0.5 rem. From the models provided, doses due to target ship reboarding and doses accrued after departure from Bikini can be calculated, based on the individual circumstances of exposure.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

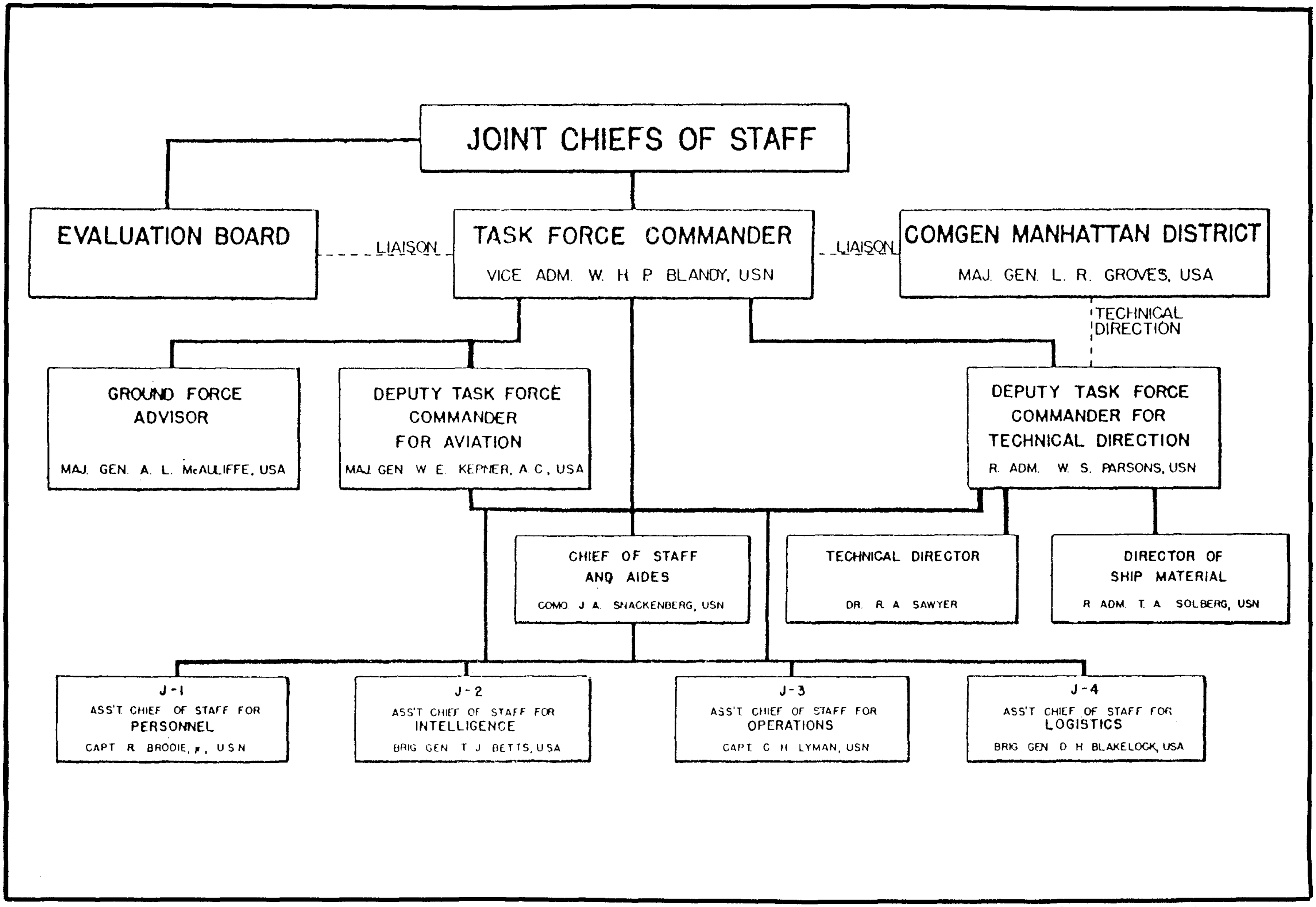
LIST OF TABLES

Section 1
INTRODUCTION

This report provides a description of the methodology and the results of the reconstruction of radiation doses received by test participants aboard the various support and target ships of Joint Task Force One at Operation CROSSROADS from 1 July 1946 until departure from Bikini Lagoon. The report consists of three volumes. Volume I, Methodology, contains the description of the dose reconstruction methodology, with supporting calculations. The methodology consists of modeling the radiation environment, determining the ship paths through this environment, and calculating the doses to personnel. The support ship USS RECLAIMER is selected to demonstrate the application of this methodology for a representative ship. This vessel is chosen because her movements were extensively documented, and because she was the flagship of the Director of Ship Material and therefore participated in nearly every maneuver and operation of radiological significance. The doses calculated for RECLAIMER personnel are compared with existing film badge data to gauge the accuracy of the results. Volume II (Appendix A, Target Ships) contains the results of target ship analyses. The data in this volume allow the calculation of doses received while aboard the target vessels. Volume III (Appendix B, Support Ships) contains the results of dose reconstructions for personnel aboard support ships during Operation CROSSROADS.

1.1 Joint Task Force One Organization

Joint Task Force One was established by the Joint Chiefs of Staff to conduct Operation CROSSROADS, the first nuclear test series following the World War II bombings of Hiroshima and Nagasaki. The task force staff organization is shown in Figure 1-1. Much of the documentation on which these dose reconstructions are based emanated from the offices of the Technical Director and Director of Ship Material. Joint Task Force One was dissolved 1 November 1946 and was succeeded by the Joint CROSSROADS Committee. This committee was disbanded 10 June 1947 after publication of the final CROSSROADS reports.



Source: Reference 21

Figure 1-1 Joint Task Force One Staff Organization

1.2 Shot Data

Operation CROSSROADS consisted of two nuclear detonations, Shots ABLE and BAKER, at Bikini Atoll in July 1946. The details of these shots are given in Table 1-1. Both nuclear devices were similar to that detonated over Nagasaki the previous year. Shot ABLE was a low airburst, Shot BAKER a shallow underwater detonation.

1.3 Target Ship Arrays

Since Operation CROSSROADS was primarily a Navy test, a large assortment of naval vessels was present in the lagoon during the operation. These various types of target and support vessels are listed for reference in Table 1-2.

Extensive arrays of target vessels were positioned in the lagoon of Bikini Atoll for both shots. Figures 1-2 and 1-3 outline the number and types of target vessels utilized for Shots ABLE and BAKER, respectively, while Figures 1-4 and 1-5 display the approximate target ship locations for each shot. The exact locations and orientations of most target vessels relative to surface zero are provided in Reference 1 (Chapters 10 and 20). While References 2 and 3 contain fairly complete listings of target vessels for Operation CROSSROADS, no single source has been found that contains a complete listing. Reconstructions of the target arrays reveal that there were 88 target vessels for each shot, of which 70 were anchored and 18 were beached. Between Shots ABLE and BAKER, some ships were removed from the target array and new ones added. In all, 95 naval units have been identified as target vessels during Operation CROSSROADS. A number of these were small non-commissioned or unmanned craft, some of which served as beached targets. The final count of target vessels for purposes of this analysis is 84; radiological data for these vessels are included in Appendix A, Target Ships. The remaining 11 vessels were either too small to be tracked or were sunk as a result of the tests.

1.4 Support Ships

A large number of support vessels were required to conduct the operation. The number and types of such vessels are summarized in Table 1-3 from data taken primarily from Reference 3. Of the 154 non-target support ships, it was possible to extract positional data from the deck logs of 121 ships in order to reconstruct their movements.

Table 1-1

Operation CROSSROADS Detonations

- SHOT ABLE

  Time: 0900 hrs, 1 July 1946
  Place: Bikini Lagoon
  Type Weapon: Plutonium Implosion
  Yield: 23 KT
  Type Burst: Airburst (520 ft) over water

- SHOT BAKER

  Time: 0835 hrs, 25 July 1946
  Place: Bikini Lagoon
  Type Weapon: Plutonium Implosion
  Yield: 23 KT
  Type Burst: Shallow Underwater (90 ft depth)

Table 1-2

Naval Vessel Types at Operation CROSSROADS

AD....Destroyer Tender
AG....Auxiliary Miscellaneous
AGC....Communication
AGS....Surveying
AH....Hospital
AKA....Attack Cargo Transport
AKS....Cargo Transport, General Stores
AN....Net Laying
AO....Oiler
AOG....Gasoline Tanker
AOW....Oiler/Water
AP....Troop Transport
APA....Attack Troop Transport
APB....Barracks Ship
APD....Troop Transport, High-Speed
APH....Hospital
APL....Troop Transport, Labor
AR....Repair
ARB....Battle Damage Repair
ARD....Dry Dock Repair
ARDC....Dry Dock
ARG....Engine Repair
ARL....Landing Craft Repair
ARS....Salvage
ARSD....Salvage Lifting Ship
ARST....Salvage Craft Tender
AS....Submarine Tender
ASR....Submarine Rescue
ATA....Auxiliary Ocean Tug
ATF....Fleet Ocean Tug
ATR....Ocean Rescue Tug
AV....Seaplane Tender
AVP....Seaplane Tender, Small
AW....Water Distilling
BB....Battleship
CA....Heavy Cruiser
CL....Light Cruiser
CV....Aircraft Carrier
CVE....Aircraft Carrier, Escort
CVL....Aircraft Carrier, Light
DD....Destroyer
IX....Unclassified Miscellaneous
LCI....Landing Craft, Infantry
LCM....Landing Craft, Mechanized
LCPL....Landing Craft, Personnel, Large
LCT....Landing Craft, Tank
LCVP....Landing Craft, Vehicle/Personnel
LSD....Landing Ship, Dock
LSM....Landing Ship
LST....Landing Ship, Tank
PGM....Motor Gunboat
SS....Submarine
WAGL....Coast Guard Auxiliary
YF....Covered Lighter
YMS....Mine Sweeper
YO....Fleet Oil Barge
YOG....Gasoline Barge
YOW....Oil/Water Barge
YP....Yard Patrol
YW....Water Barge

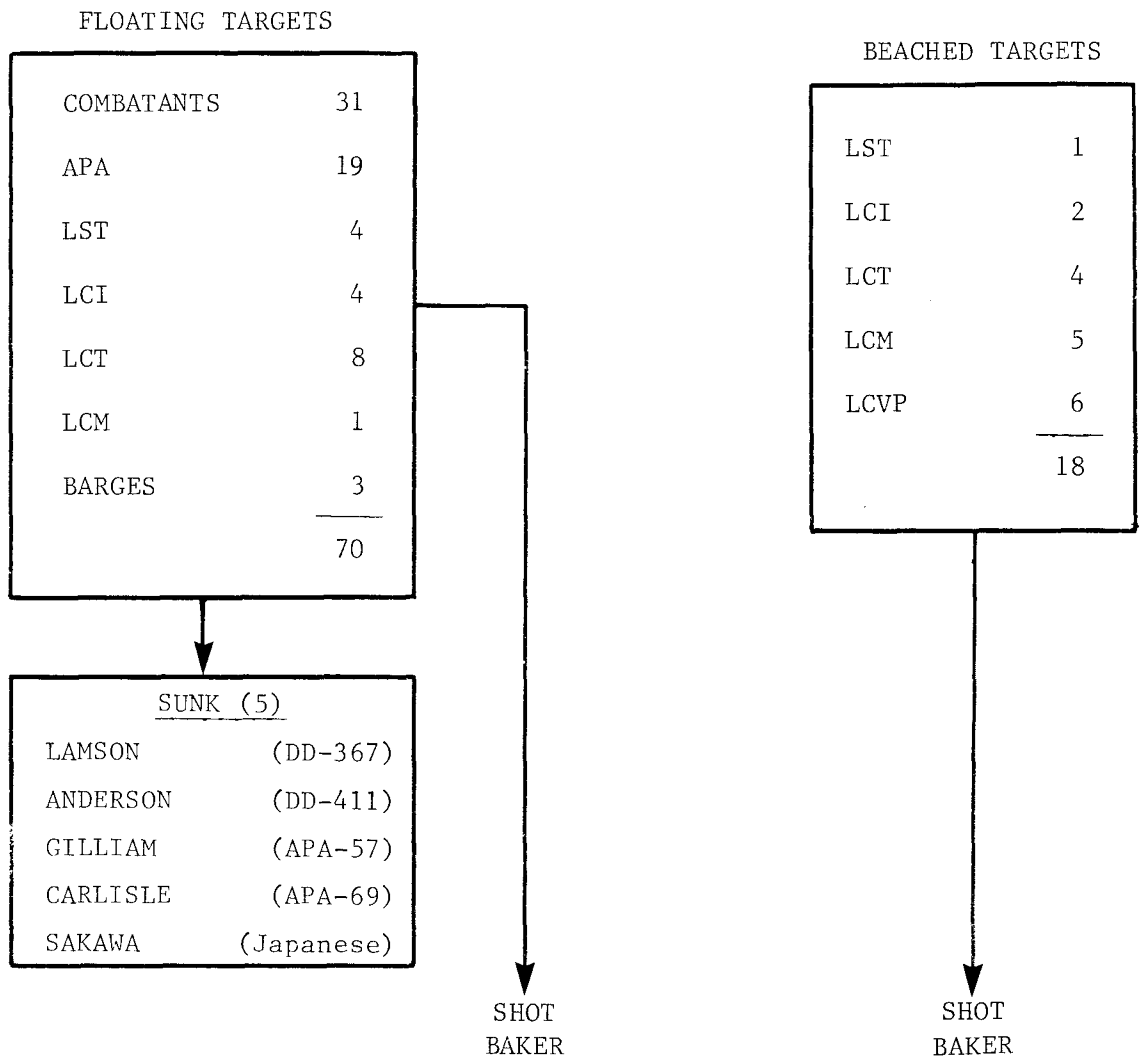


Figure 1-2 Summary of Shot ABLE Target Array

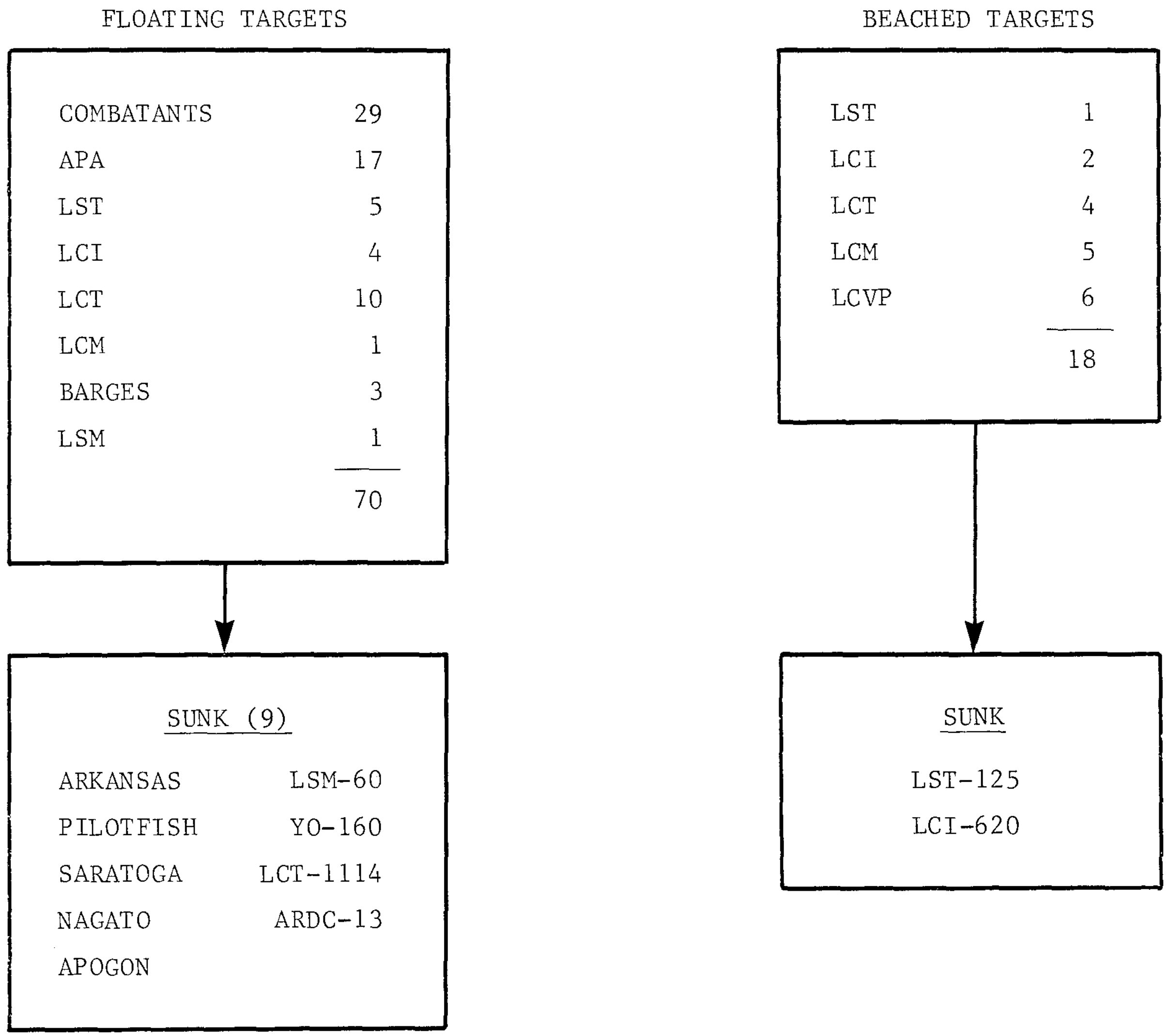


Figure 1-3 Summary of Shot BAKER Target Array

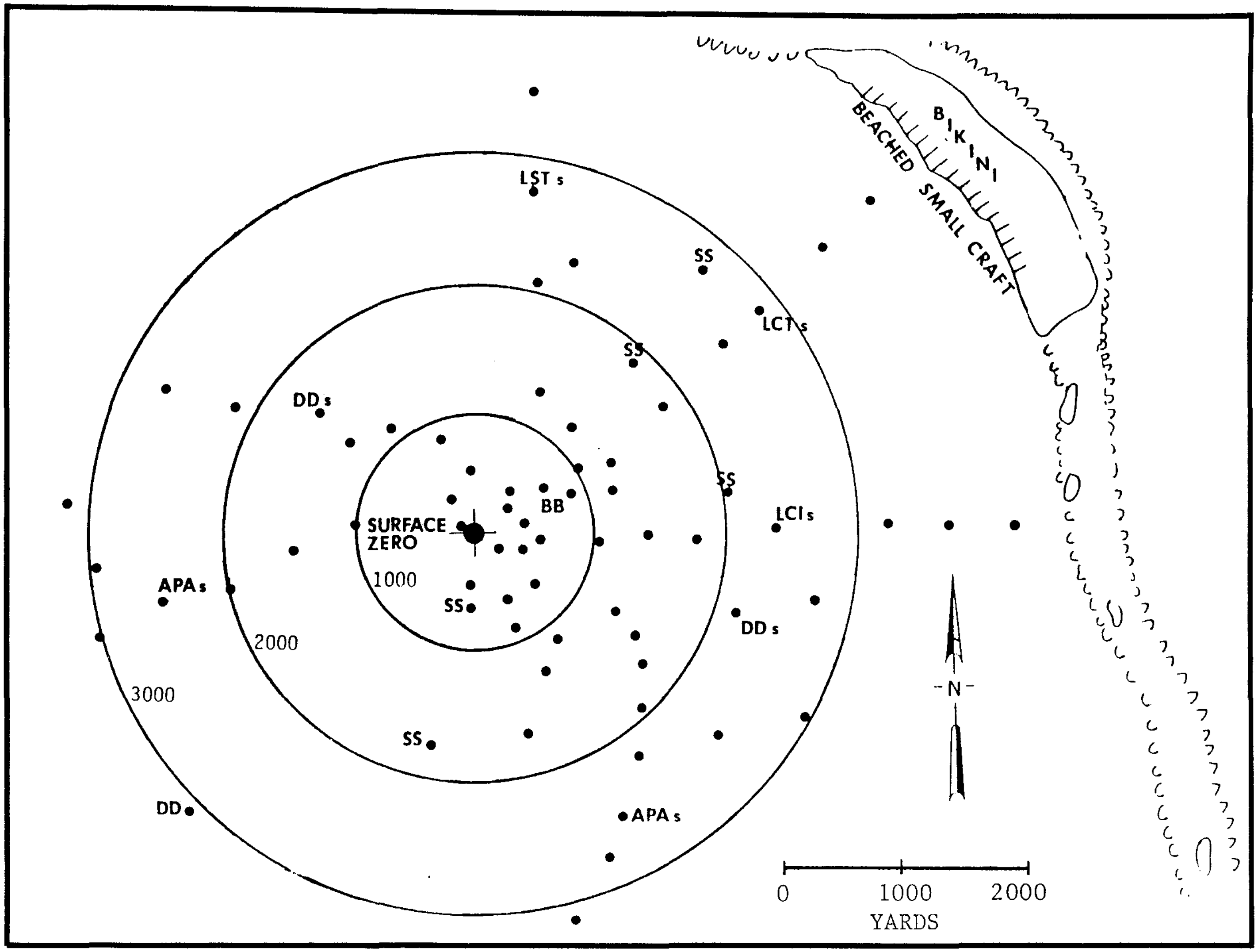


Figure 1-4 Shot ABLE Target Ship Locations

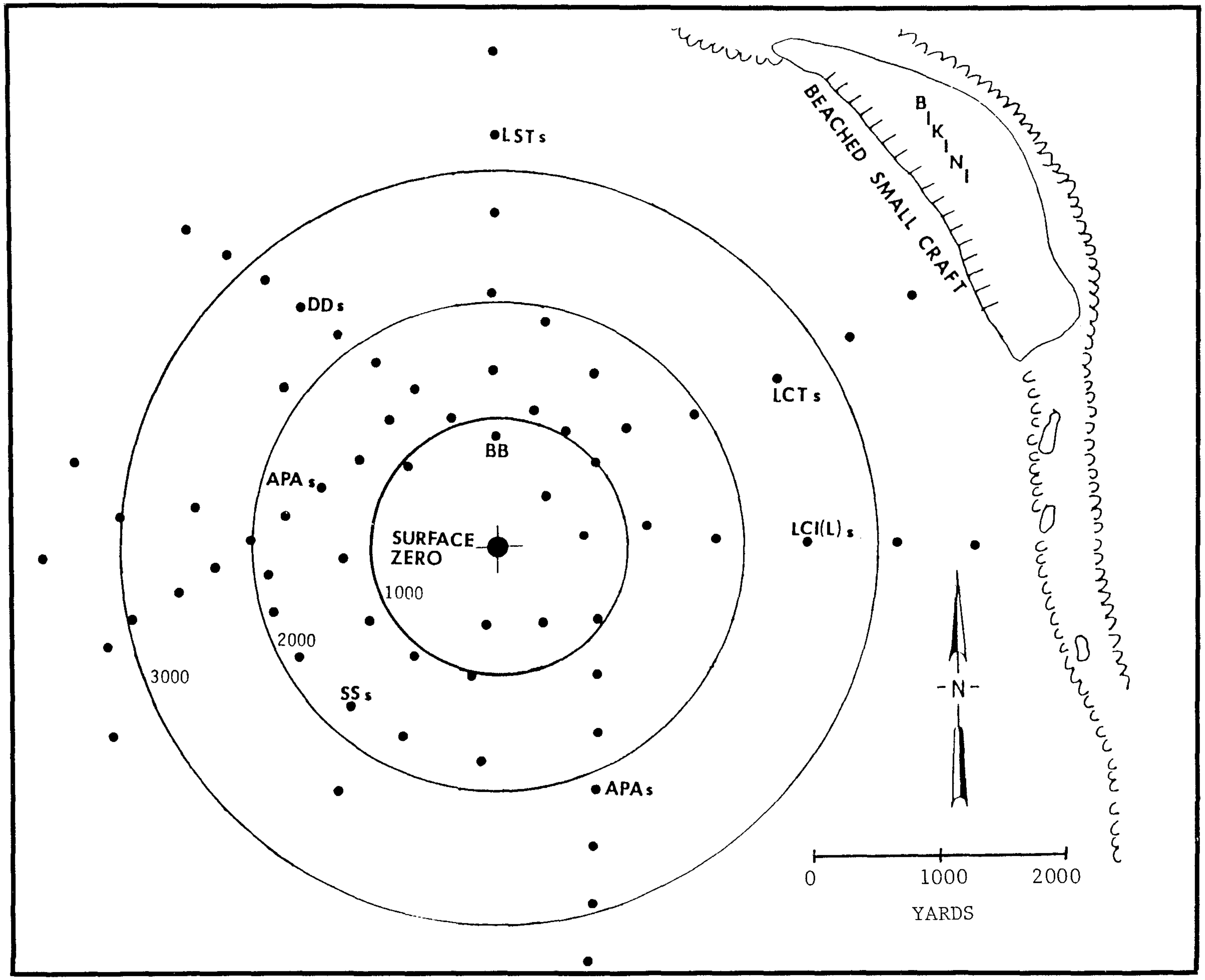


Figure 1-5 Shot BAKER Target Ship Locations

Table 1-3

Summary of Support Ships

Group/Unit	Number
Flag and Technical Group (AG, AGC, AH, AP, APA, APD, AV, CA, LCT)	11
Transportation Group (AGC, AKA, APA, LST)	18
Naval Air Group (AVP, CV, CVE, DD)	7
Surface Patrol Group (DD)	10
Salvage Group (AN, ARS, ARSD, ARST, ASR, ATA, ATF, ATR, LCT,	24
Service Group (AD, AG, AKS, AO, AOG, AR, ARB, ARD, ARG, ARL, AS, ATA, ATF, AW, IX, LST, YC, YF, YO, YOG, YW)	43
Dispatch and Boat Pool Unit (APB, LCI, LCT, LSD, PGM)	23
Medical Unit (AH)	2
Survey Unit (AGS, AKA, WAGL, YMS, YP)	11
Evacuation and Miscellaneous (APL, LCT, LST)	5
	154

The results of the dose calculations for these ships are contained in Appendix B. The other 34 were determined to be either small units with no permanently assigned crew, or non-commissioned vessels. No deck logs could be located for reconstruction of the movements of these vessels (types LCT, YO, YOG, YP, YF). The 34 naval units listed by the official historian as being support ships and participants of Operation CROSSROADS for which no deck logs have been located are:

LCT-581	LCT-1377	YF-753
LCT-746	LCT-1415	YF-754
LCT-1116	LCT-1420	YF-990
LCT-1130	LCT-1461	YF-991
LCT-1132	LIMESTONE (IX-158)	YF-992
LCT-1155	YC-1009	YO-132
LCT-1184	YF-385	YO-199
LCT-1268	YF-733	YOG-63
LCT-1341	YF-734	YOG-70
LCT-1359	YF-735	YP-636
LCT-1361	YF-752	YW-92

1.5 Navy Personnel Summary

Over 39,000 Navy personnel participated in Operation CROSSROADS. The distribution of personnel among the various types of support and target vessels is given in Table 1-4.

1.6 Dose Reconstruction Methodology

The methodology developed for dose reconstruction of Operation CROSSROADS personnel is shown schematically in Figure 1-6. The modeling of the radiation environment is described in detail in Section 2, the identification of relevant ship operations in Section 3, and the total dose reconstruction in Section 4. The basic approach used in dose reconstruction is to describe mathematically the radiation environment that existed in the Bikini Lagoon as a function of time and location, and then to overlay the physical movement of the naval units. The time integral of the radiation intensity at a vessel's location as it moves within the radiation environment determines the dose attributed to the crew of that vessel. Three major sources of radioactivity are considered: lagoon water, target ships, and support ship hull and internal (e.g., piping)

Table 1-4

Summary of Naval Personnel

Support Ships:

Flag and Technical Group	5140
Transportation Group	5288
Naval Air Group	4177
Surface Patrol Group	2376
Service Group	5344
Salvage Group	1698
Dispatch and Boat Pool	1539
Medical Unit	1258
Survey Unit	809
Evacuation and Miscellaneous	23
	27,652
JTF Staff and Air Units	2762*

Target Ships:

Non-remanned	7912
Remanned	1092
	9004**

Total:	39,418

*Doses for these personnel are derived from the support ships to which they were assigned.

**On transportation ships at time of shot and until radiologically safe to return to target ship.

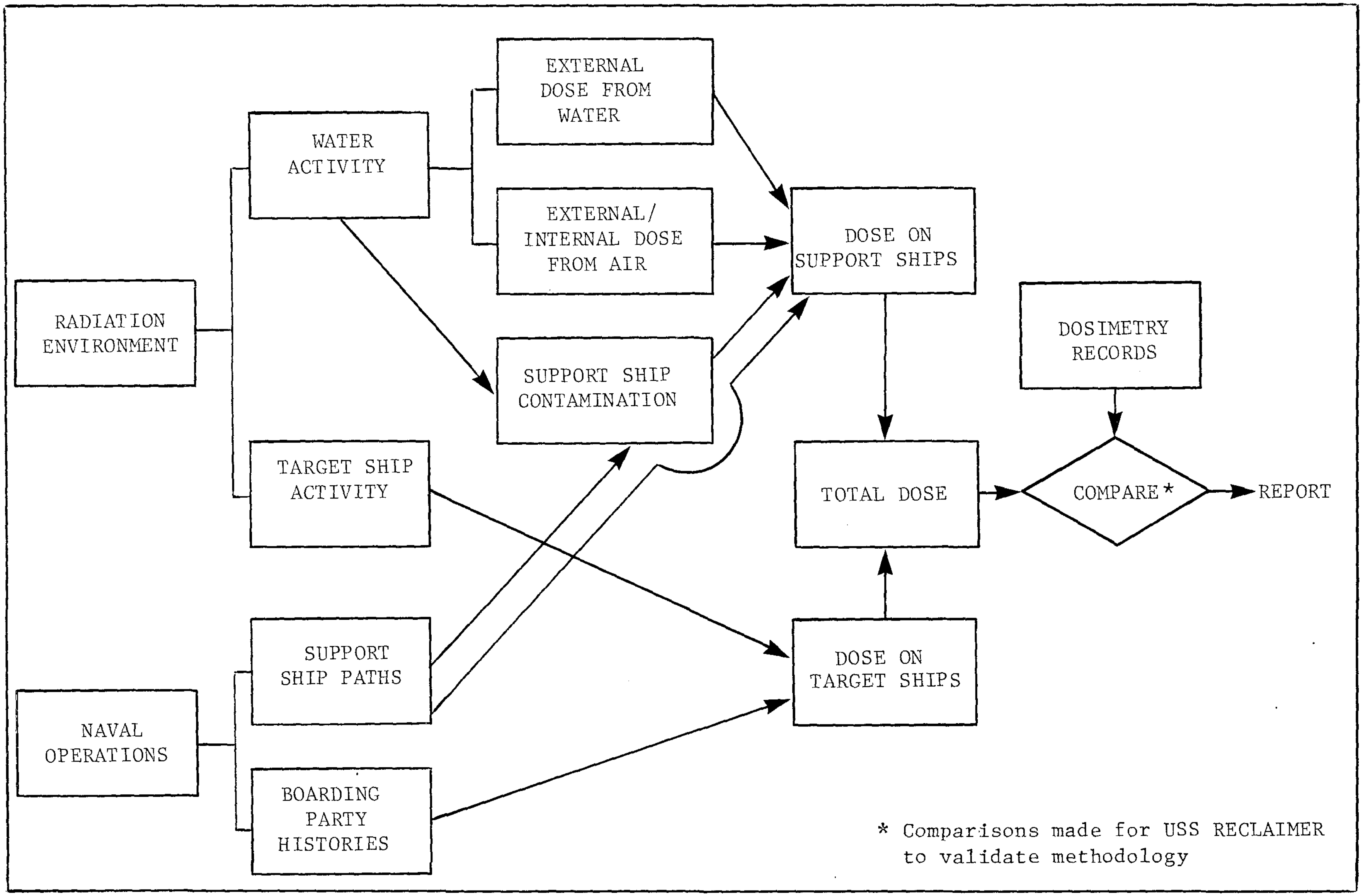


Figure 1-6 Dose Reconstruction Methodology

contamination. Suspended and dissolved fission products concentrated in the marine growth and rust on the hull at and below the waterline and in the internal salt water piping of support ships which sailed through contaminated water. Ship contamination is therefore considered for Shot BAKER only, since no fission products were detected in the lagoon water after Shot ABLE.

Section 2
RADIATION ENVIRONMENT

The radiation environments created at Bikini Atoll by Shots ABLE and BAKER were quite different--virtually all localized activity from Shot ABLE resulted from neutron activation, while Shot BAKER activity was predominantly from weapon debris. The magnitude of the radiation hazard after BAKER was much more significant than that of ABLE, and consequently the BAKER activity was measured and documented in more detail than was done for Shot ABLE. The measurements made to characterize the radiation environments were of two types: those taken by scientific personnel under the Technical Director, usually from samples (e.g., water, rust) collected in the lagoon and removed to a laboratory for analysis; and those made by radiation monitors for use by the Director of Ship Material in controlling operations in and around the radioactive areas. While the documentation on many of these measurements has not been located, sufficient information has been recovered to allow reconstructions of the environments for both shots. The approach taken here is to develop radiation intensity models from the best available data, and to use all other relevant documentation to check these models for consistency.

2.1 Shot ABLE Water Intensity

It is well-documented (References 1 (Chapter 17), 4 (Enclosure J), and 5) that virtually all the radioactivity observed in the lagoon after Shot ABLE was due to neutron activation, and that little fallout (fission products and unfissioned plutonium) was deposited locally. A theoretical analysis of neutron-activated seawater was performed with computer codes ORIGEN (Reference 6) and ANISN (Reference 7), using the salt concentrations of typical seawater given in Reference 8. The results indicate that the gamma radiation emitted in sodium-24 (Na-24) decay was the major contributor to the intensity above the seawater from shortly after detonation until approximately one week later. This is the period during which all significant operations took place in the vicinity of the target array following Shot ABLE. These conclusions are confirmed by analysis of water sample data found in the archives at Los Alamos National Laboratory. The water samples were taken on 1 July 1946 (ABLE day), and activities were measured at various intervals through 8 July. The decay curves, shown in Figure 2-1, clearly demonstrate that the early radioactivity (through

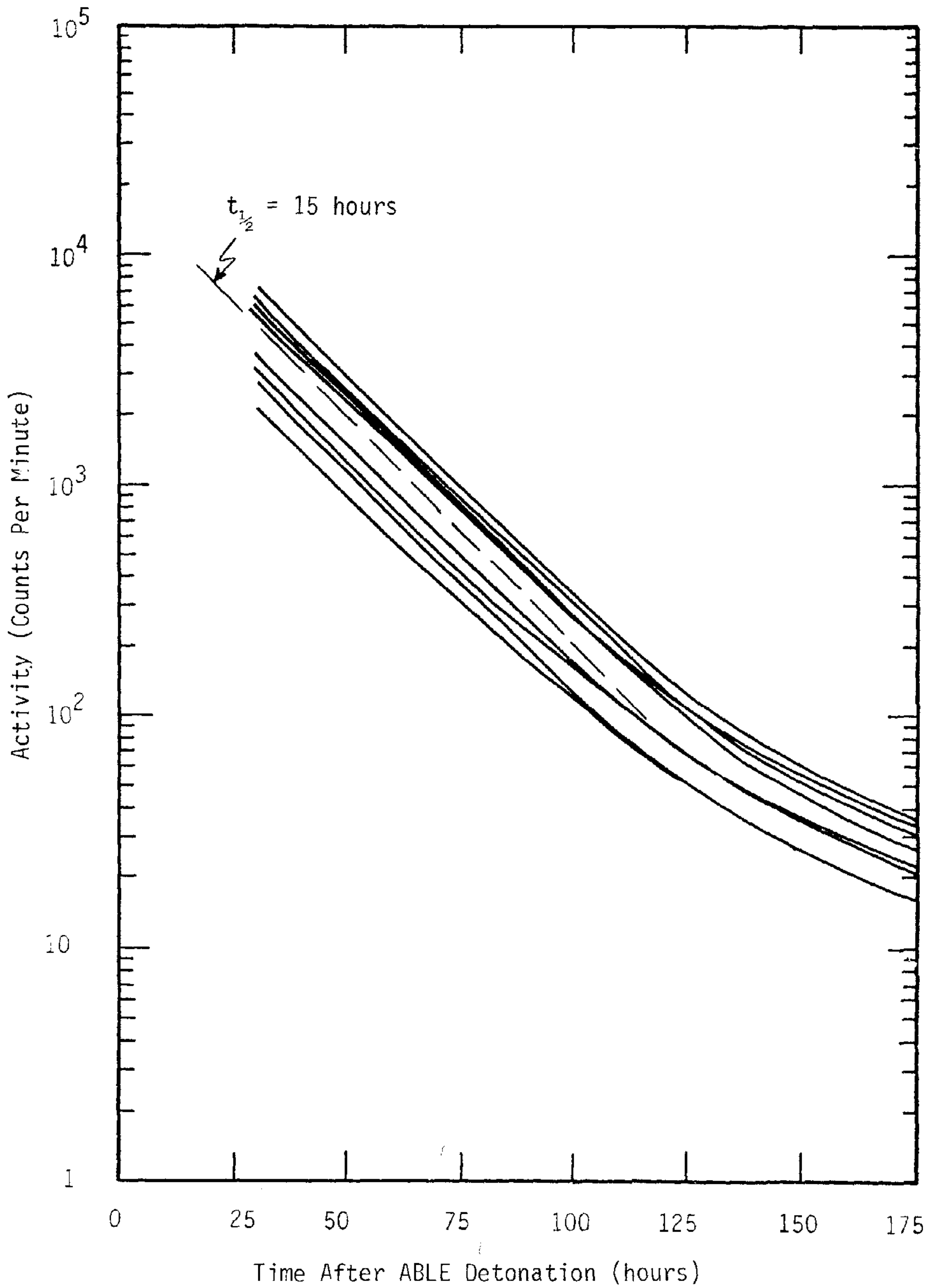


Figure 2-1 Decay of Shot ABLE Water Samples

the first 100 hours after detonation) was dominated by an isotope with a half life of approximately 15 hours; this isotope is Na-24. The change in slope evident in these curves indicates that another isotope (probably bromine-82) became significant after approximately five days. However, Na-24 would have continued providing the major contribution to the intensity above the water surface for another few days, due to the high energy of the Na-24 gamma rays (average energy greater than 2 MeV, compared to approximately 0.8 MeV for bromine-82). Therefore it is necessary to consider only one isotope, Na-24, in developing a water intensity model.

In determining the intensity from Na-24 in the lagoon water, it is necessary to specify the initial source distribution, model the time-dependent concentration of this isotope in the seawater, and develop a relation between waterborne activity and intensity in air. The initial distribution of radioactive sodium was closely related to the distribution of thermal neutrons at the water surface in the vicinity of surface zero (SZ). The approximate nature of the latter distribution is determined with computer code ATR4 (Reference 9); it appears that this distribution was so sharply peaked around SZ that, when considering subsequent diffusion, the initial distribution of Na-24 in the water can be taken as a point source at SZ for computational purposes. The concentration of Na-24 in the seawater changed with time due to horizontal diffusion, vertical diffusion, and radiological decay. Horizontal diffusion caused the radioactive area to spread, with the concentration at radius r and time t after detonation being approximately proportional to (Reference 8)

$$t^{-1} \exp\left[-r^2/4D_h t\right],$$

where D_h = horizontal diffusion coefficient (assumed to be constant in this simplified model). Due to vertical diffusion, the concentration of Na-24 in the upper layer of seawater decreased approximately as $t^{-1/2}$ (Reference 10), quickly becoming nearly uniform with depth. Radioactive decay caused a decrease in Na-24 concentration proportional to $e^{\lambda t}$, where $\lambda = 0.0462\ \text{hr}^{-1}$ (decay constant for Na-24).

The intensity (measured, for example, in roentgen (R)/hour) above such seawater is proportional to the activity density of Na-24 in the seawater (e.g., in curies/cm^3) which, in turn, is proportional to the concentration of Na-24. In each decay, a Na-24 nucleus emits two gamma rays with energies of 1.37 and 2.75 MeV, respectively.

Calculations performed with the radiation transport code ANISN (Reference 7) indicate that this decay results in an intensity of 3.51 R/hr at one meter above the water surface when the activity density of the water is one microcurie of Na-24 per cm^3. This value decreases only slightly to 3.44 at 2.7 meters and 3.23 at 9.1 meters above the water surface. Therefore, within at least ten meters of the water surface, the distance above the surface is not a significant parameter in determining intensity. Within this region above the surface, where personnel aboard ships are likely to be located, the intensity may be expressed as

$$I(r, t) = t^{-3/2} \exp\left[-A \left(\frac{r^2}{t}\right) - \lambda t + B\right],$$

where parameter A depends on the horizontal diffusion coefficient, and B depends on the horizontal and vertical diffusion coefficients and the total number of neutrons captured in the water. The values of the diffusion coefficients and number of neutrons absorbed are largely uncertain; therefore A and B are empirically determined by fitting this expression to the existing measurements of intensity at specific times and locations.

Much of the recorded intensity data is contained in the messages from the Radiological Safety Control Center, which specify the coordinates of the 0.1 R/day and 1.0 R/day isointensity contours at frequent time intervals following the ABLE detonation. These contours, referred to as the "blue line" and "red line", respectively, in CROSSROADS literature, have the following significance. The daily dose tolerance allowed for most personnel during Operation CROSSROADS was 0.1 R/day. Therefore, a ship theoretically could have operated outside the blue line for an indefinite period without exceeding this tolerance. Operation between the blue and red lines was permitted only for certain ships ("red line ships"), and only for durations such that the daily tolerance was not exceeded. The red line was not to be crossed by any vessel. The red and blue line contours, although generally not closed due to insufficient numbers of readings, can be approximated by circles of appropriate radii. These radii are presented in Table 2-1, together with various other data found in the literature. The red line was eliminated early on the morning of ABLE +1 day (A+1), indicating that the maximum water intensity fell below 1 R/day during the previous night. The blue line was eliminated at 1008 hours on A+1. These data ($I = 0.1$ R/day = 0.0042 R/hr, $r = 0$, $t = 25$ hours) are used to evaluate the parameter B, giving

Table 2-1

Shot ABLE Water Intensity Data

Source	Radius (m)	Time After Detonation (hrs)	Reported Intensity (R/hr)	Model Intensity (R/hr)
References 5, 11	0	2	1.0	0.53
RSCC*	900	4	0.042	0.068
Reference 4	810**	4	0.021	0.081
RSCC	1800	4	0.0042	0.0043
RSCC	2600	4.75	0.0042	0.0002
RSCC	1800	6.75	0.0042	0.0077
RSCC	1500	22.3	0.0042	0.0035
RSCC	700	24.7	0.0042	0.0039
Reference 4, RSCC	0	25	0.0042	0.0042

*Radiological Safety Control Center
**Inferred from reference, which was not specific.

B = 0.503. The remaining data in Table 2-1 are then used to determine a mean value of the parameter A to be 4.56×10^{-6}. In these calculations, t is in hours, r in meters, and intensity I in R/hr. It may be noted that the associated value of the horizontal diffusion coefficient,

$$D_h = \frac{1}{4A} = 5.5 \times 10^4 \ m^2/hr,$$

is in excellent agreement with a value of 5.4×10^4 m^2/hr derived by W.H. Munk, et. al. (Reference 12) from a study of the diffusion of radioactive material deposited in the lagoon water by Shot BAKER.

The intensities calculated from this model are displayed in Table 2-1 for times and radii corresponding to the available data. With the exception of two outlying data points, the agreement between the model and observed intensities is generally good. The intensity equation derived above can be used to predict isointensity contours at specific times. The radii of the 0.1 R/day and 1.0 R/day contours are plotted in Figure 2-2 as functions of time, and the predicted red and blue contours are compared with the reported red and blue lines in Figure 2-3 for 1255 hours on ABLE day. It is found that better agreement between model and measurement can be achieved by allowing the radially symmetric intensity pattern to drift northward (azimuth 10^o) at a speed of approximately 900 meters per day. This correction is included in all Shot ABLE dose calculations.

2.2 Shot ABLE Target Ship Intensity

The radioactivity detected on the target ships after Shot ABLE was due almost entirely to neutron activation of ship materials (Chapter 17 of Reference 1, Enclosure J of Reference 4). However, since the activity levels were rather low, few measurements were documented, thus necessitating the calculations which follow.

Listings of the elemental compositions of seven vessel types, representing most of the ships present in the target array for Shot ABLE, were found in the Operation CROSSROADS files in the archives at Los Alamos National Laboratory. This information is presented in Table 2-2. By analyzing the radioactive isotopes produced by thermal neutron capture in the ship material, and the gamma rays emitted

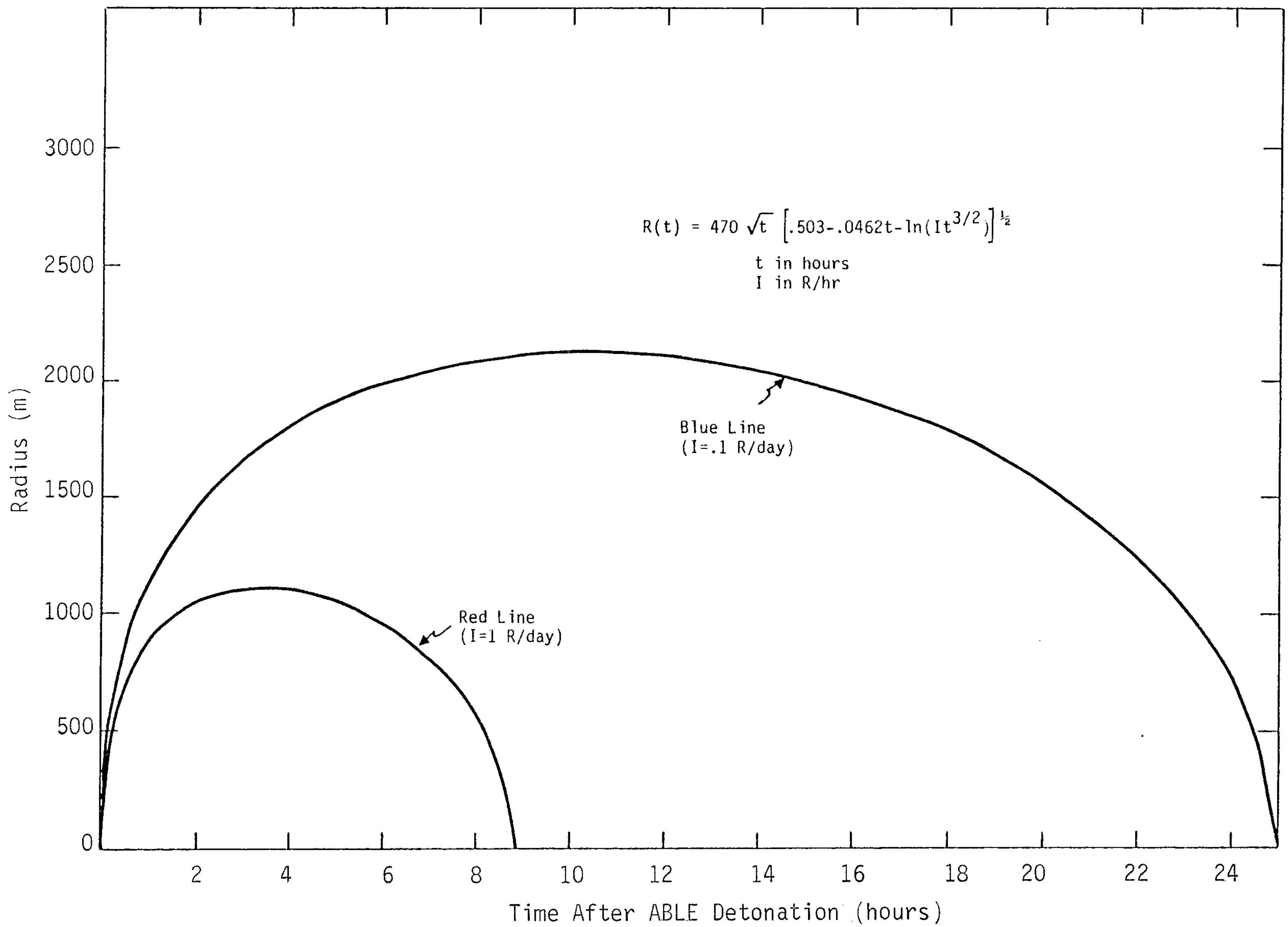


Figure 2-2 Theoretical Model of Shot ABLE Water Intensity

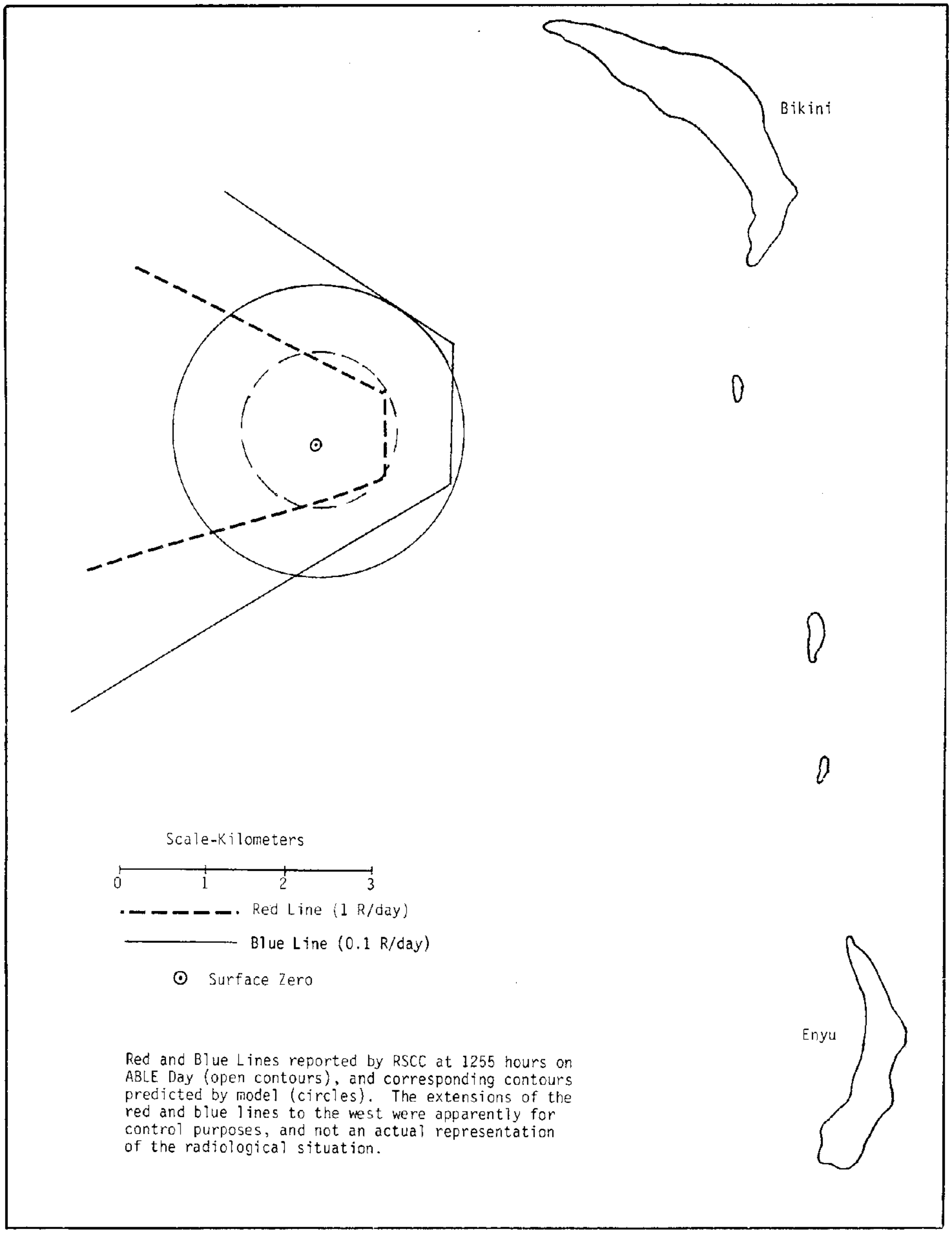


Figure 2-3 ABLE Day Red and Blue Lines

Table 2-2

Elemental Compositions of Various Vessel Types

(Quantities in this table are elemental weights in pounds)

Element	Battleship	Heavy Cruiser	Carrier	Light Carrier	Destroyer	Submarine	Attack Troop Transport
Iron	4.8+7*	1.9+7	6.2+7	2.1+7	2.3+6	2.5+6	9.6+6
Aluminum	4.2+5	2.4+5	1.6+6	6.2+5	1.5+5	1.6+4	2.6+4
Magnesium	6.2+3	3.6+3	2.3+4	9.4+3	2.3+3	2.3+2	3.9+2
Copper	2.0+6	1.3+6	2.8+6	1.3+6	3.4+5	3.0+5	2.5+5
Nickel	9.7+5	3.8+5	1.1+6	4.5+5	4.7+4	4.0+4	5.4+4
Chromium	5.9+5	2.0+5	9.0+5	2.2+5	2.6+4	2.3+4	2.3+4
Tungsten	6.2+2	5.1+2	7.0+2	5.0+2	1.5+2	8.0+1	3.9+2
Molybdenum	2.4+4	9.6+3	2.1+4	9.7+3	1.8+3	1.3+3	5.2+3
Vanadium	6.4+3	2.6+3	6.3+3	2.6+3	4.8+2	3.6+2	1.4+3
Zinc	1.5+5	5.0+4	2.0+5	6.3+4	2.2+4	2.6+4	2.0+4
Lead	1.2+5	6.9+4	1.2+5	6.3+4	1.4+4	4.3+5	1.3+4
Tin	7.0+4	4.6+4	9.8+4	4.6+4	1.3+4	1.1+4	8.8+3
Antimony	7.0+3	4.6+3	9.8+3	4.6+3	1.3+3	1.1+3	8.8+2
Manganese	3.3+5	1.3+5	4.1+5	1.3+5	1.8+4	9.0+3	5.8+4
Cadmium	4.9+3	2.0+3	4.9+3	2.0+3	3.7+2	2.7+2	1.1+3
Sulfur	2.2+4	9.0+3	2.9+4	9.0+3	1.1+3	1.1+3	4.5+3
Phosphorus	2.2+4	9.0+3	2.9+4	9.0+3	1.1+3	1.1+3	4.5+3
Silicon	2.2+5	8.8+4	2.8+5	9.4+4	1.0+4	1.0+4	3.6+4
Carbon	1.5+5	5.8+4	1.9+5	6.5+4	6.7+3	7.0+3	2.9+4
Beryllium	6	4	6	4	2	2	.2
Cobalt	7.5+2	7.1+2	7.0+2	5.7+2	2.0+2	8	7.4+1
Titanium	5.4+3	3.0+3	5.5+3	2.7+3	4.2+2	4.8+2	4.8+2
Mercury	4.9+2	3.9+2	5.2+2	3.7+2	2.5+2	4.7+1	2.3+2

*Read as $4.8 \times 10^{+7}$

Source: Los Alamos National Laboratory archives.

therefrom, it is possible to calculate the relative levels of intensity induced by a fixed neutron fluence in the various types of vessels as a function of time after detonation. In these calculations, it is assumed that the ships were homogeneous mixtures of the materials given in Table 2-2, that all vessels had similar average densities, and that the contribution to the intensity from the activation of extraneous materials placed on or in the target ships (e.g., various types of military equipment placed on deck for effects testing) was negligible. The relative intensities at 24 hours after detonation, normalized to the intensity on a destroyer, are presented below.

Ship type	Relative intensity at t = 24 hours*
Destroyer (DD)	1.000
Submarine (SS)	0.737
Heavy Cruiser (CA)	0.539
Light Carrier (CVL)	0.495
Carrier (CV)	0.379
Battleship (BB)	0.363
Attack troop transport (APA)	0.256

*For fixed neutron fluence. These values are later designated M_i.

These values are most strongly affected by the fraction of copper present in the ship material. The time dependence of the intensities for the seven vessel types is shown in Figure 2-4, where the curves have been normalized to the intensity at 24 hours. The initial slope of these curves is due to the decay of copper-64 with a 12.8 hour half-life.

Vessel types LST, LCI, and LCT, for which elemental composition data are lacking, were determined to be similar in material composition to a destroyer, submarine, and heavy cruiser, respectively, and hence should display similar intensity and decay characteristics. These relationships are assumed for calculations involving these three types of ships.

The results of the neutron activation calculation allow an estimate of relative intensity levels at arbitrary times for various types of vessels exposed to identical neutron fluences, i.e., at a fixed range from SZ. It is necessary to develop a method of estimating intensity level as a function of range. Ideally this range dependence would

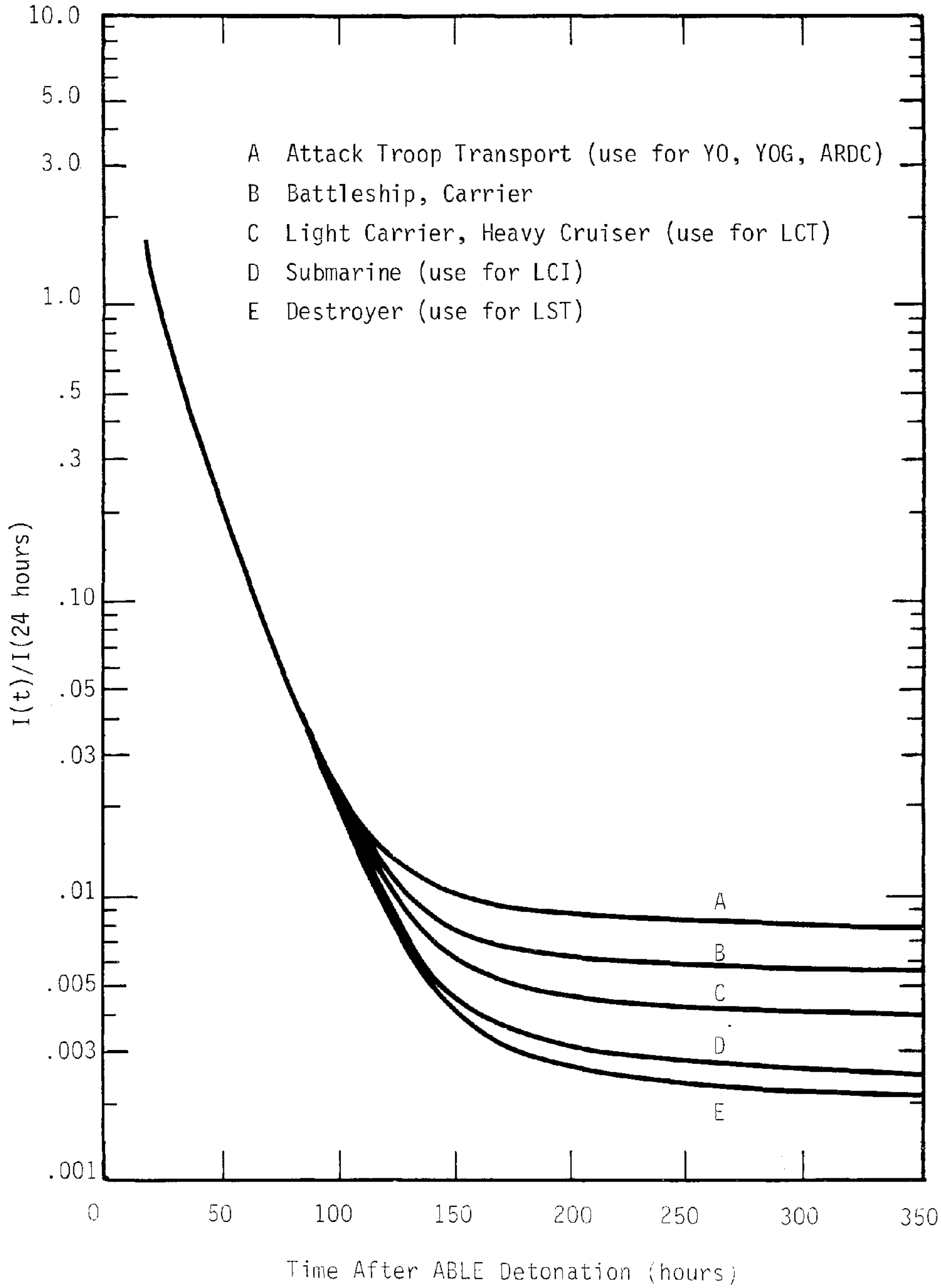


Figure 2-4 Shot ABLE Ship Intensities Relative to Intensity at 24 Hours

be estimated from thermal neutron fluence data, since the absorption of thermal neutrons is responsible for most activation interactions. Thermal neutron measurements were made during Shot ABLE, using activation of phosphate pills to determine the fluences at numerous locations on various target ships. The results are presented in Appendix XIII of Reference 15, a technical report compiled shortly after the ABLE detonation. Unfortunately the experimental technique and analysis of the data appear to have serious shortcomings (e.g., most activation samples were placed in shielded locations which were not well documented); consequently the data are considered unreliable. A much more sophisticated effort was undertaken by Dr. G. A. Linenberger of Los Alamos to measure fast neutron fluence by activation of sulfur samples placed on the target ships. These data, contained in Reference 16, are fit with the expression:

$$\phi = R^{-2} \exp\left[-\frac{R}{\lambda_f} + B\right],$$

where ϕ = fast neutron fluence,

R = slant range,

λ_f = fast neutron relaxation length = 209.1 yards,

B = constant.

To develop the Shot ABLE ship activation model, it is assumed that the range dependence of ship activation was approximately the same as that of the fast neutron fluence. This assumption is valid, since the relaxation length for thermal neutrons is comparable to that of fast neutrons for typical neutron fission spectra transported in an air-over-seawater geometry (References 13, 14).

The ship activation model is given by the expression

$$I_i(t) = CM_i f_i(t) R_i^{-2} \exp(-R_i/\lambda_f),$$

where

$I_i(t)$ = activation intensity on target ship i at time t,

M_i = intensity of ship i at t=24 hours relative to that of a destroyer,

$f_i(t)$ = intensity of ship i at time t relative to that at t=24 hours (given in Figure 2-4),

R_i = slant range of ship i.

Here C is a constant which, ideally, is independent of target ship. A numerical value for C is determined by fitting the model to exterior ship intensity readings, a summary of which is given in Table 2-3(a). Data from the YO 160 and ARDC 13 cannot be used here, since elemental compositions of these vessels are not available. With intensity I in R/day and range R in yards, a good fit to the remaining data is achieved with $C = 1.1 \times 10^7$. With this, absolute intensities in R/day at 24 hours after detonation are calculated for all target vessels except the YO 160, YOG 83, and ARDC 13. All such intensities greater than 1 mR/day are listed in Table 2-4.

The vessels YO 160, YOG 83, and ARDC 13 were not similar in composition to other ships in the target array. However, intensity readings on the YO 160 and the ARDC 13 are available, as given in Table 2-3, so that these vessels may be normalized separately. It is assumed that the YOG 83 was similar in composition to the YO 160, and that the time-dependence of the intensity for these three vessels is similar to that of the attack troop transport. The 24-hour intensities thus derived are included in Table 2-4.

In summary, the intensity on a ship at time t is estimated by obtaining the 24-hour intensity from Table 2-4 and using the appropriate curve in Figure 2-4 to determine the factor which adjusts the 24-hour value to the value at time t. Ships not listed in Table 2-4 are considered to have had negligible induced intensity (<1 mR/day at 24 hours after Shot ABLE).

The consistency of these results is tested by comparing them with relevant statements on ship intensities contained in References 1, 4, 18, 19, and 20, and by analyzing the radiological reports and boarding times of target vessels documented in References 21 and 22. Reference 1 states that 13 vessels had intensities greater than 0.1 R/day on ABLE + 1 day; 14 such vessels are predicted by this model, as shown in Table 2-4. The most radioactive ships after Shot ABLE, as listed in the cited references, agree well with those predicted by the model. The maximum intensity of 8 R/day reported on the ARKANSAS (A+1 day reading) by Reference 1 was apparently a local "hot spot", composed mostly of radioactive sodium in a pool of water on deck. The reports of the radiological and reboarding status of the target ships, as given in References 21 and 22, generally agree with model predictions. An apparent exception is that six vessels (CATRON, SARATOGA, PENNSYLVANIA, LCT 874, LST 661, and

Table 2-3

Shot ABLE Target Ship Intensities

Vessel	Slant Range (yds)	Time of Reading (hrs)	Intensity Measurement (R/day) Average	Maximum
(a) Exterior Readings				
CRITTENDEN (APA)	619-753	28	0.3	0.5
INDEPENDENCE (CVL)	586-720	30	0.24	0.34
SKATE (SS)	436-513	54	0.4-0.8	4.8
		~75	0.4	--
NEVADA (BB)	639-811	28	--	0.45
		32	--	0.43
ARDC 13	852-973	5.5	0.2	--
		25.5	0.2	--
YO 160	550-660	30	0.7	--
(b) Interior Readings				
SKATE (SS)	436-513	~96	0.03	0.06
APOGON (SS)	951-1051	26.5	0.003	0.006*
PARCHE (SS)	1377	24.5	0.3**	0.3**
DENTUDA (SS)	1938-1956	24	0	0
TUNA (SS)	2200-2234	48	0	0

*Maximum reading of 0.072 R/day taken around clock and depth gauges in control room probably due to radium dials.

**Questionable data; see text.

Sources: Exterior data for days A+1 and A+2 taken from radio messages; SKATE 75-hour data from Reference 17. Interior data taken from Commanding Officer letter reports.

Table 2-4

Calculated Average Exterior Ship Intensities at 24 Hours after Shot ABLE
(Vessels not listed have calculated intensities less than 0.001 R/day)

Ship	Intensity (R/day)
ARKANSAS (BB)	0.44
NEW YORK (BB)	0.001
NEVADA (BB)	0.43
PENNSYLVANIA (BB)	0.001
NAGATO (Japanese battleship)	0.11
PENSACOLA (CA)	0.31
SALT LAKE CITY (CA)	0.11
SAKAWA (Japanese cruiser)	2.7
PRINZ EUGEN (German cruiser)	0.011
INDEPENDENCE (CVL)	1.0
TALBOT (DD)	0.04
RHIND (DD)	0.11
STACK (DD)	0.013
WILSON (DD)	0.005
HUGHES (DD)	0.18
SKIPJACK (SS)	0.04
SKATE (SS)	6.7
APOGON (SS)	0.12
PARCHE (SS)	0.01
LST 52	0.005
LCT 816	0.009
LCT 818	0.004
BANNER (APA)	0.008
BARROW (APA)	0.003
BRULE (APA)	0.027
CRITTENDEN (APA)	0.40
DAWSON (APA)	0.073
FALLON (APA)	0.004
YO 160	3.9
YOG 83	0.10
ARDC 13	0.91

TUNA) were reported "Geiger Sour" (i.e., having intensities greater than 0.1 R/day) on ABLE day, whereas the calculated intensities on vessels at these ranges are much lower. At the times these reports were made, the six vessels were located on or within the radiological blue line, indicating that the surrounding radioactive water, and not the ships themselves, was the major source of the intensity. Subsequent reports on these vessels indicate that they soon became "Geiger Sweet" (having average intensities less than 0.1 R/day) when the blue line had receded past their positions.

In addition to the exterior ship intensity readings on which this model is based, interior submarine intensity readings found in Commanding Officers' reports are included in Table 2-3(b). The measured interior intensities on the SKATE and APOGON are significantly smaller than the exterior intensities predicted by the model; this is consistent, since the interiors of the surfaced submarines were strongly shielded from the neutron fluence by the surrounding seawater. Both the data and model give negligible intensities for the DENTUDA and TUNA. The reported 0.3 R/day intensity on the interior of the PARCHE, however, is anomalous. Although the PARCHE was approximately 300 yards farther from surface zero than the APOGON, this intensity is two orders of magnitude larger than that measured for the APOGON. The A+1 PARCHE intensity data consist of sixteen reported readings for various interior locations, each recorded as ".3". Such uniformity is inconsistent with readings on other submarines. Further, the PARCHE was declared "Geiger Sweet" at 0935 hours on 2 July (Reference 21), indicating that the intensity levels at that time were below 0.1 R/day. Thus, these reported A+1 intensity readings on the PARCHE appear to be in error.

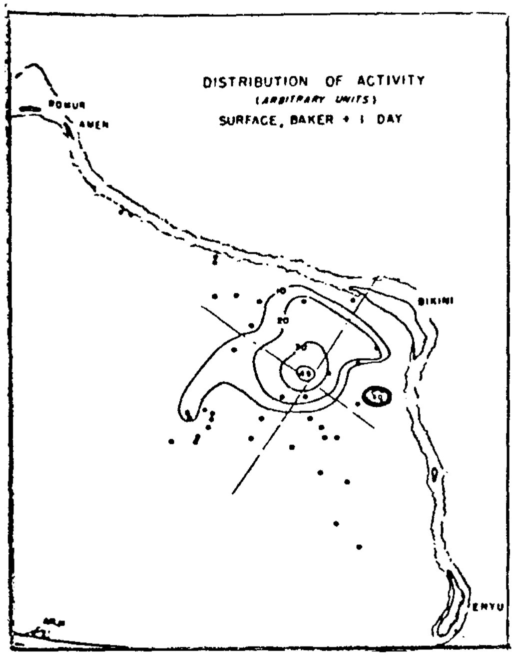
2.3 Shot BAKER Water Intensity

The radiological environment after Shot BAKER was dominated by fission products deposited in the water and on the target ships. Extensive measurements of water activity (e.g., in Curies/liter) were made by scientific personnel under the Technical Director. Unfortunately, only fragments of this information have been located. Concurrently, radiological patrols were reporting intensities (in R/day) above the water to the Radiological Safety Control Center; this information exists in the form of red (1.0 R/day) and blue (0.1 R/day) line coordinates, used by the Director of Ship Material to control ship movement in the lagoon. Both sets of data are utilized in the development of the Shot BAKER water intensity model.

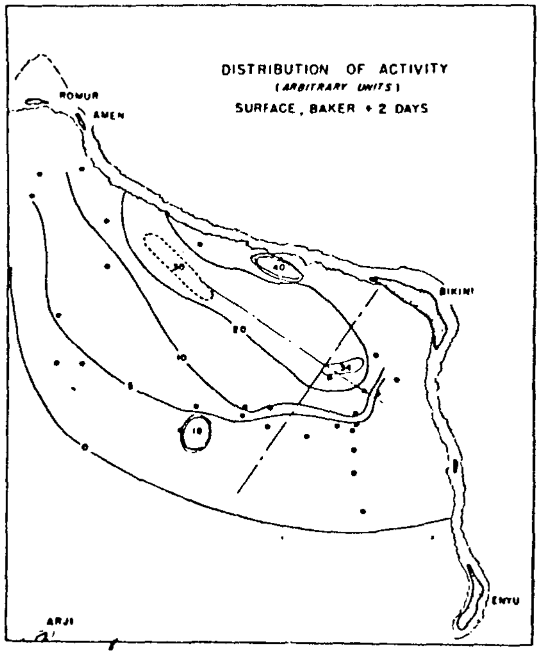
Perhaps the best source of post-BAKER water activity data is Reference 12, which gives activity contours for one, two, and three days after the BAKER detonation. These contours, reproduced in Figure 2-5, are labeled in "arbitrary radiation units", or aru, which were normalized to a fixed time to correct for decay. This time normalization was performed so that the effects of diffusion could be examined. The normalization procedure is not described in the article, so the precise definition of aru is uncertain. Another valuable source of information is a set of tables authored by Dr. Kenneth G. Scott, which appeared in an unpublished manuscript (Reference 23) assembled by Dr. J. O. Hirschfelder and found in the archives at the Los Alamos National Laboratory. These tables include information on maximum radiation intensities and contaminated areas, total radioactivity in lagoon water, and simultaneous measurements of water activity and intensity. A third significant source of water activity data is Appendix V of Reference 24, a technical report submitted in September 1946 covering the BAKER detonation. This document contains tables giving total radioactivity in lagoon waters and variations in activity with depth for five days following the BAKER shot, with more detailed information presented on the water activity distribution on the fifth day after detonation (B+5). Other sources of water activity data include References 1 (Chapter 27), 4 (Enclosure J), and 21.

The red and blue line coordinates are contained in the transcripts of radio messages found at the Federal Records Center in Suitland, MD. Red line data are given for BAKER day through B+2; the red line was eliminated at 1455 hours on B+3. Blue line data are given through B+4; the blue line was eliminated at 0959 hours on B+5. Examples of red and blue lines for days B+1, B+2, and B+3 are presented in Figure 2-6.

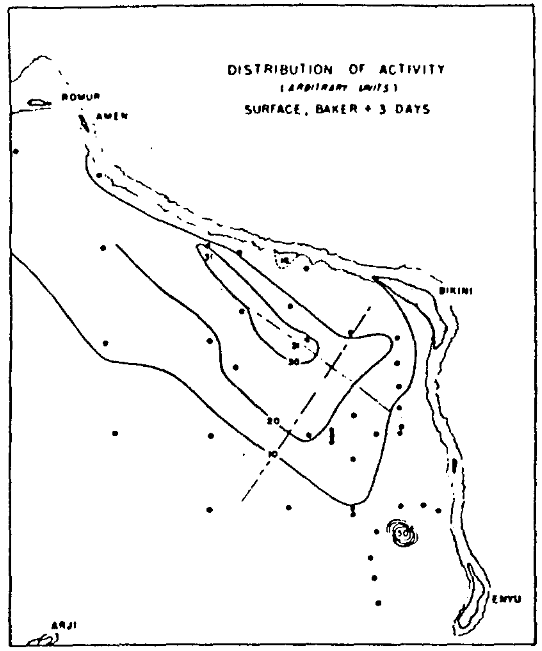
The radiological condition of the lagoon water after B+5 is largely unknown. There is evidence that the water intensity decreased significantly between B+5 and B+8. Enclosure F of Reference 4 discusses the natural flushing of the lagoon water between five and eight days after BAKER day, thereby reducing water activity to very low levels by B+8. This is supported by data appearing in Reference 24, indicating a rapid decrease in the activity concentration in the lagoon water between these dates. The only quantitative data available on the water environment beyond B+8 is contained in a message from the Radiological Safety Officer (COL S.L. Warren) to CJTF-1 on 15 August 1946, in which he states "Lagoon water average 0.02 to 0.03 R per day."



BAKER + 1 DAY



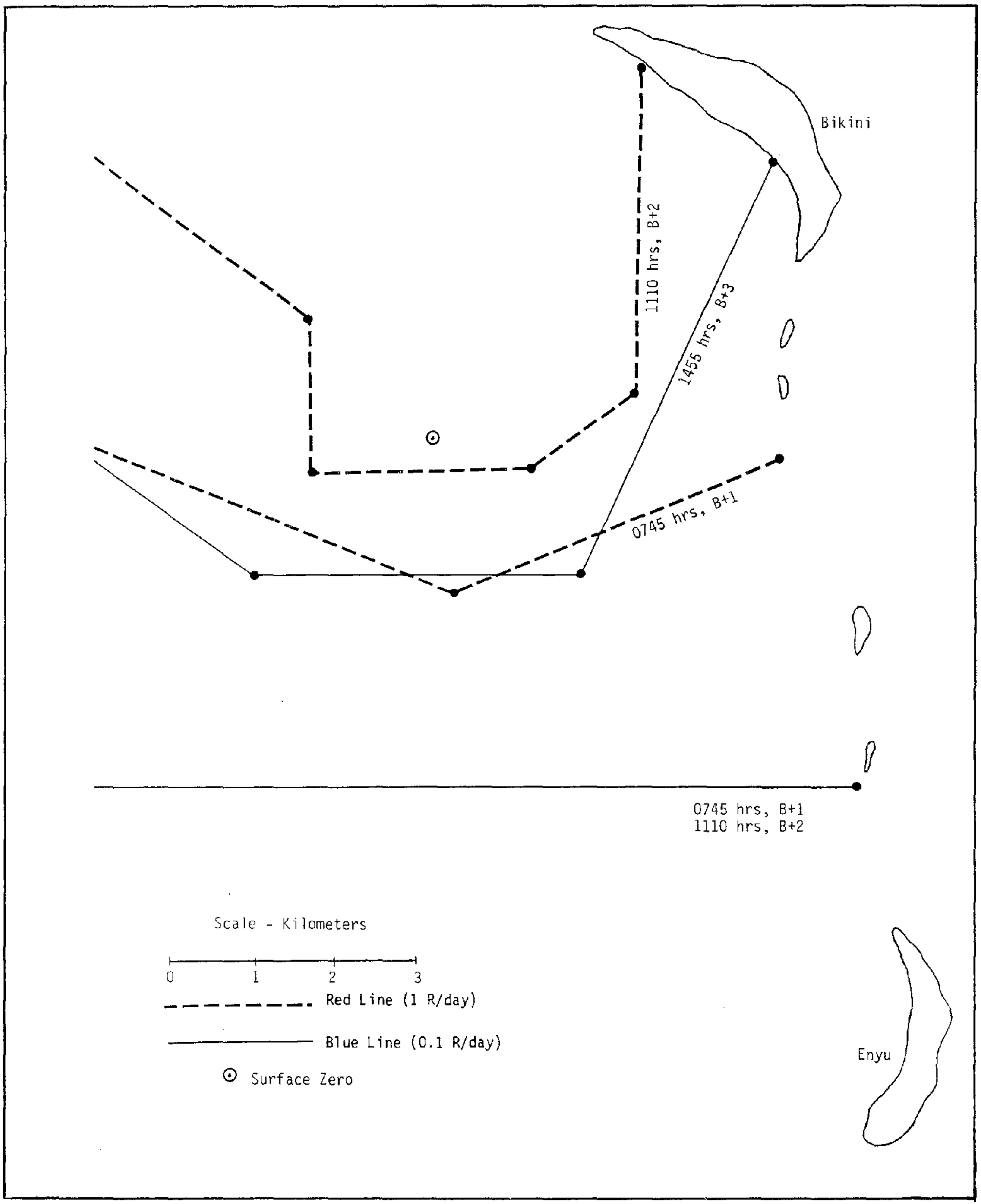
BAKER + 2 DAYS



BAKER + 3 DAYS

Source: Reference 12

Figure 2-5 Shot BAKER Water Activity



Source: RSCC Messages

Figure 2-6 Red and Blue Lines after Shot BAKER

Water of such intensity must have been contained within a relatively small region of the lagoon, since it is easily demonstrated that the initial inventory of fission products available from a 23 kt detonation was much too small for intensities of this level to have existed throughout the lagoon three weeks after the shot. Unfortunately, the location of the contaminated pool is unspecified in the message.

The BAKER water intensity model is developed to estimate the intensity at any location in the lagoon at any time after the BAKER detonation. A summary of the data base utilized in the construction of this model is given in Table 2-5. A general computer-based calculational methodology based on this model estimates doses for specific ship paths through BAKER-contaminated water from B+1 until final lagoon departure. Due to the lack of data available for BAKER day, this day is not included in the generalized methodology. Doses accrued on BAKER day are analyzed separately, using primarily red/blue line information and data from ship logs. The development of this model is subsequently discussed.

To develop the model, the intensity distribution throughout the lagoon at a reference time on each of days B+1 through B+5 is approximated from available data. The graphical activity contours (in units of aru) provided in Reference 12 for days B+1 through B+3, and the areas within various activity density contours (in microcuries/liter) given in Reference 24 for B+5, form the basis of the intensity distribution modeling for this period. It is first necessary to convert these contours to intensity contours. The most direct method to achieve this conversion is the use of red/blue line data to calibrate the contours for each of these four days. The advantage of utilizing the red/blue lines, which were employed at CROSSROADS to control ship movements, is that those portions of the intensity contours most important in calculating personnel doses are modeled most accurately. The B+4 intensity contours are developed by using the area-integrated surface activity (in units of square miles-millicuries per liter, as given in Reference 24) and red/blue line data to interpolate between the B+3 and B+5 contours. It is assumed that, except for a contaminated pool that persisted in the vicinity of the target array (and apparently formed the basis of Warren's observation), the intensity distribution on B+5 decreased linearly to zero by 200 hours after the detonation (B+8). The intensity in the vicinity of a ship is estimated by linearly interpolating in time between the intensities at the ship location derived from the two reference intensity distributions bracketing the time of interest.

Table 2-5

Summary of Shot BAKER Water Contamination Data

	Day:						
	B	B+1	B+2	B+3	B+4	B+5	After B+5
Activity contours (graphical) (Reference 12)		x	x	x			
Activity contours (areas) (Reference 24)						x	
Integrated surface activity (Reference 24)		x	x	x	x	x	x
Red/blue lines (RSCC messages)	x	x	x	x	x		
Total contaminated area/max intensity (References 5, 23)	x	x	x	x	x	x	x
S.L. Warren message (dated 15 August 1946)							x

The intensity level reported in the Warren message forms the basis for characterizing the contaminated water environment for the month of August 1946. It is reasoned that the lagoon intensity levels observed by Warren (0.02-0.03 R/day on 14 August, B+20) were limited in spatial extent by the total activity deposited in the lagoon, which is calculated to have been 5×10^9 Curies at H+1 hour (Reference 24). Assuming a $t^{-1.3}$ decay (Reference 4) coupled with a 3.2 percent per day depletion by flushing (Enclosure F of Reference 4), the total activity available in the lagoon is calculated for each day. This activity is assumed to have been confined to a cylindrical slug of water 150 feet deep (the average depth of the lagoon), having a vertical distribution such that the surface concentration is about one order of magnitude higher than the concentration near the lagoon bottom. This distribution is consistent with the vertical profile data reported in Reference 24 for several days after detonation. Maintaining this vertical activity gradient throughout the period of interest, despite its likely dissipation through mixing, high-sides the intensity at the surface and thus the dose to shipboard personnel.

The radius of the cylinder is determined in the following manner. The intensity above the surface of the contaminated water, which is assumed uniform throughout the contaminated region, is modeled as a function of time by fitting a logarithmic function to the intensity readings of 0.1 R/day on B+5 (when the blue line was eliminated) and 0.025 R/day on B+20 (Warren's data). The activity concentration of the water corresponding to an intensity level as measured above the surface is then determined from measurements reported by Scott (Table 20.15 of Reference 23), which indicate that an activity concentration of one microcurie per liter of lagoon water (in situ) resulted in an intensity of approximately 0.024 R/day above the surface. This is in general agreement with a measurement taken by USS BURLESON personnel on B+5 (Reference 21, 0.029 R/day/μCi/l) and the results of calculations with the radiation transport code ANISN (Reference 7, 0.013 R/day/μCi/l). The required radius of the contaminated pool follows from the activity available in the lagoon on the day of interest, the assumed vertical profile, and the surface concentration on that day. The radius is approximately 5000 yards from B+8 through B+40. It is assumed that the decaying pool remained centered on surface zero, encompassing most of the target array and thereby maximizing potential exposure to this radioactivity. Ship movement data are then used to determine the periods when each ship was in contaminated water of the specified intensity.

2.4 Shot BAKER Target Ship Intensity

The contamination of target vessels from the BAKER detonation was quite extensive, due primarily to the base surge (a cloud of contaminated water droplets formed by the underwater detonation) and early rainout of fission products. The base surge extended approximately 1800 yards upwind, 2700 yards crosswind, and 4000 yards downwind, to the northwest (Reference 25). Target ships within the base surge generally received significant contamination, while many ships on the outer portions of the array experienced only light contamination. Detailed documentation of intensity levels exists for most of the target vessels. Appendix VII of Reference 24 lists maximum topside, average topside, and average interior readings for virtually every target vessel for numerous days following the BAKER shot. While these data are often inconsistent, and individual readings may be questionable, they nevertheless provide the best available estimates of target ship intensities. Also included in Reference 24 are readings taken alongside many of the target vessels during the period when they were too radioactive to board. Daily target ship status reports and transcripts of radio messages (found at the Federal Records Center) also contain detailed target ship radiological data. In addition, References 1 (Chapter 27), 4 (Enclosure J), 20, 21, and 22 quote numerous intensity readings for the target ships. Dr. W. E. Strope, in Reference 25, has evaluated much of this topside intensity data for many target ships.

The target ship intensity model for Shot BAKER is developed by accumulating all available data on ship intensities and organizing them in graphical form. It had been observed that the intensities on target ships generally followed a $t^{-1.3}$ decay law, exclusive of decontamination (Reference 4). Therefore, the ship intensity data are fit with such curves except during documented periods of decontamination. When decontamination is known to have taken place, intensity-time curves based on $t^{-1.3}$ decay are fit separately to the data taken before and after decontamination, while the data taken during decontamination are used to empirically construct a curve connecting these segments. When data are available, separate curves are constructed for average topside, amidships (alongside), and below deck readings. An example is shown in Figure 2-7 for the USS PENSACOLA. For each event involving a target ship (moored alongside, boarding, etc.), the appropriate ship intensity curve is used to estimate the radiation environment. Target ship intensity curves so derived are presented in Appendix A.

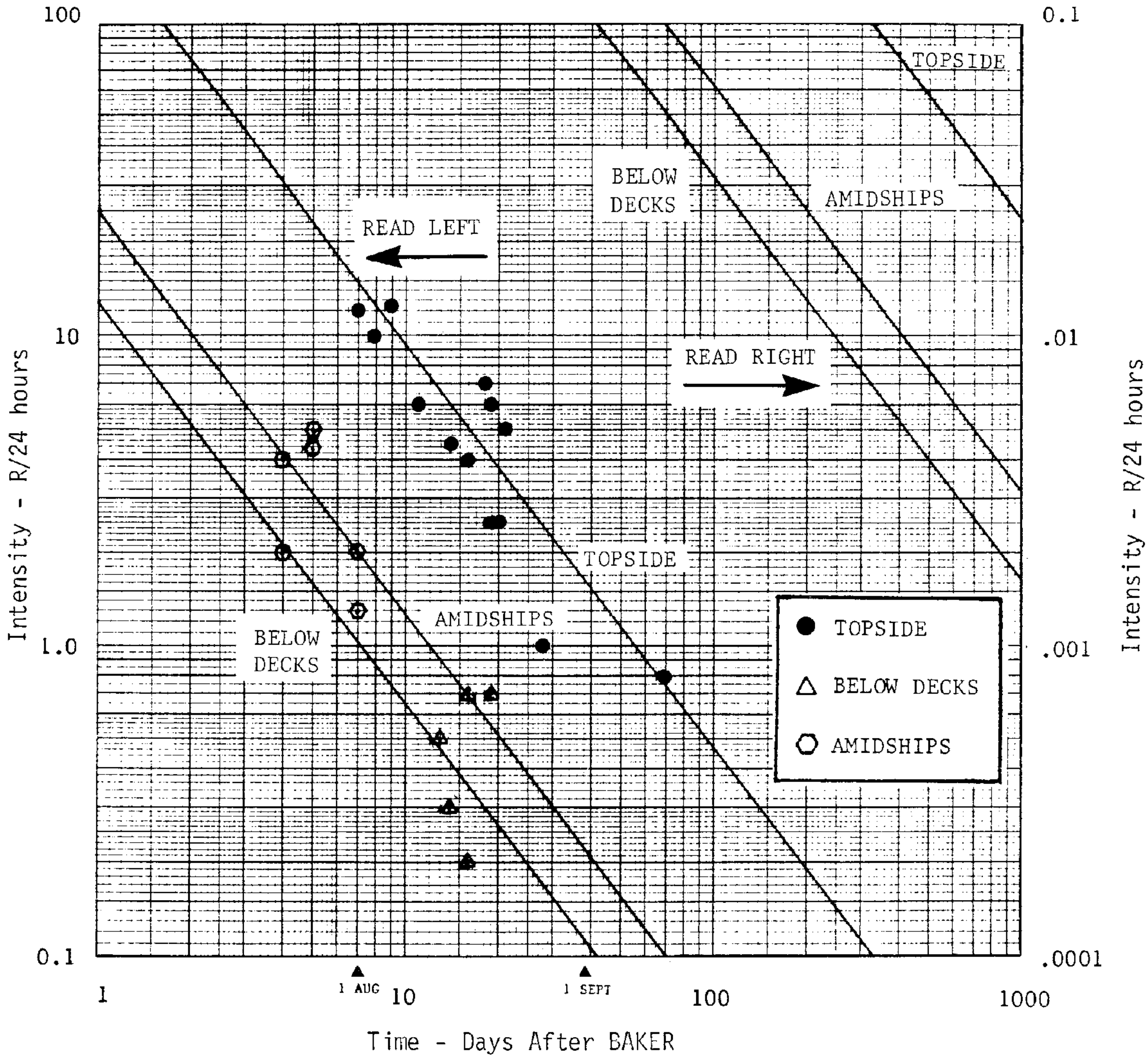


Figure 2-7 USS PENSACOLA (CA-24) Post-BAKER Ship Contamination

2.5 Shot BAKER Support Ship Contamination

During post-BAKER operations it quickly became apparent that support ships, when operating in contaminated water, accumulated radioactive materials on their underwater hulls and in salt water lines and evaporators. The resulting interior intensities were sufficiently large on some early re-entry ships, notably the PGMs, to require overnight crew evacuation (Reference 33). The intensities in other support ships were reduced to or maintained at a tolerable level through such decontamination processes as "hogging" (scraping the ship hull with rope or chain) or steaming in open seas. The physical processes responsible for this radioactive accumulation appear to include assimilation of radionuclides by aquatic organisms (e.g., algae and barnacles) that were or became attached to the ship, and ion-exchange absorption of the polyvalent fission products by inert material (e.g., paint or rust) on the ship hull or in the piping (References 24 and 34). A ship contamination model based on the microscopic details of these mechanisms is not feasible, due to the complexity of these processes and the uncertainties in the initial conditions of the hulls/piping and lagoon water contamination composition. The approach taken here is to develop a mathematical model that describes the macroscopic features of the support ship contamination process in a manner consistent with the observed data and underlying physics.

Two basic assumptions are made in developing this model. The first is that the mixture of fission products present in the accumulated radioactive material on the hull and in the piping of a support ship decayed radiologically as $t^{-1.3}$. This decay rate was verified experimentally for fission products deposited in seawater and on the decks of target ships (Reference 4). It is possible that selective absorption of fission products took place on the hull and in the piping of the support ships, such that a decay rate different than $t^{-1.3}$ could be applied; however, since specific data on this point are lacking, the referenced decay rate is used. The second assumption is that the rate of contamination buildup on the hull and interior piping is initially proportional to the radiation intensity of the water surrounding the ship, but, as buildup progresses, a limiting or saturation value of contamination is approached asymptotically. Such a saturation effect has been observed in the accumulation of radioactive isotopes in various equatic organisms (References 34 and 40). Saturation is indicated by hull intensity readings taken on various ships after their departure from the lagoon.

Specifically, the amount of foreign matter (i.e., fission products) accumulating on the hull and piping is assumed to approach saturation, therefore, the radiation intensity of the saturation level of this material decays as $t^{-1.3}$. The exterior intensity of the saturated hull at time t after detonation is therefore assumed to have the mathematical form

$$I_{sat}(t) = St^{-1.3},$$

where S is a constant.

With these assumtions, the intensity I_o of the contaminated hull of a support ship at time t may be written

$$I_o(t) = I_o(t - \Delta t) \left[\frac{t - \Delta t}{t}\right]^{1.3} + C \left[1 - \frac{I_o(t)}{St^{-1.3}}\right] I_w(t) \ \Delta t,$$

where $I_w(t)$ = intensity of surrounding water at time t,

Δt = small interval of time,

C = constant.

The first term of the right represents the contribution from previously accumulated contamination, while the second term is the contribution from the contamination accumulated between $t - \Delta t$ and t. The factor

$$1 - \frac{I_o(t)}{St^{-1.3}}$$

insures that this contribution vanishes as saturation is approached, that is, as

$$I_o(t) \longrightarrow St^{-1.3}.$$

By rearranging this equation, taking the limit as Δt becomes very small, and solving the resulting differential equation, one obtains

$$I_o(t) = St^{-1.3} \left[1 - \exp \left\{- \frac{C}{S} D_w(t)\right\}\right],$$

where

$$D_w(t) = \int_o^t \tau^{1.3} I_w(\tau) \, d\tau.$$

Note that $I_w(t)$ is determined from the BAKER water intensity model and the ship path through the contaminated water. It is evident that saturation is approached as the integral $D_w(t)$ becomes large; this occurs as a ship spends sufficient time in contaminated water.

The constants S and C in the contamination model are evaluated from support ship intensity data found primarily in messages sent to CJTF-1 by radiological safety officers at various shipyards. Combined beta-plus-gamma intensities were measured at points external to the hulls of numerous support ships during post-CROSSROADS decontamination operations, and were generally reported as port and starboard average and maximum intensities. Much of these data cannot be used in this analysis, because readings were taken after the hulls were partially decontaminated (by scraping) in the shipyard, or because the hulls were wet when readings were taken (the emission of beta particles from the contaminant material is inhibited when the material is wet; the intensity appears to be sensitive to the amount of moisture present). Intensity readings taken on dry, unscraped hulls were reported for nine support ships. This limited data set was selected for use in evaluation of S and C, since inclusion of the scraped and/or wet data would introduce a bias toward lower dose estimates. In addition, various reported intensity readings for three other ships are considered of similar quality. Reference 27 contains wet unscraped hull readings for the USS ROCKBRIDGE, with the notations that "readings on hull will be 3-6 times higher when dry." A factor of six is thus used to determine an equivalent average dry hull intensity. Reference 35 gives an exterior hull reading on the USS SAIDOR, while Reference 36 gives an interior hull reading for the USS MOUNT McKINLEY. The intensity readings for these twelve ships constitute the data base for determining best estimates of constants S and C. These intensity data are included in Table 2-6.

In performing the evaluation of S and C, the various hull readings are first converted to exterior hull gamma intensities. Since the beta particles (electrons) were almost completely attenuated by the hull material, while the gamma intensities experienced a much smaller attenuation (Reference 26), it is the gamma radiation that contributes to dose on the interior of the ship. Consequently, the exterior hull gamma reading is used as an indicator of the level of ship contamination. Contained in the reported hull intensity data are five sets of gamma and beta-plus-gamma readings, each set taken concurrently during decontamination operations. These data indicate

Table 2-6

Contamination Model Data Base

Ship	Type Reading	Date of Reading	Reported Intensity (mR/day)	S (mR-day$^{0.3}$)
QUARTZ (IX)	Dry hull, $\beta+\gamma$	22 Oct 46	22**	1172
HESPERIA (AKS)	Dry hull, $\beta+\gamma$	6 Nov 46	21*	1355
BRAMBLE (WAGL)	Dry hull, $\beta+\gamma$	2 Nov 46	23*	1410
SAIDOR (CVE)	Gamma	30 Aug 46	7.2	1518
MOUNT MCKINLEY (AGC)	Interior	19 Aug 46	10	1573
ROCKBRIDGE (APA)	Wet hull, $\beta+\gamma$	3 Oct 46	12***	2820
HUNTINGTON (DD)	Dry hull, $\beta+\gamma$	4 Nov 46	20	1257
SUMNER (DD)	Dry hull, $\beta+\gamma$	4 Nov 46	27	1699
INGRAHAM (DD)	Dry hull, $\beta+\gamma$	4 Nov 46	29	1824
MOALE (DD)	Dry hull, $\beta+\gamma$	4 Nov 46	43	2683
PGM-23	Dry hull, $\beta+\gamma$	2 Nov 46	51	3092
PGM-24	Dry hull, $\beta+\gamma$	2 Nov 46	27	1624

* Arithmetic average of reported port and starboard average intensities.

** Average of 7 hull readings.

*** Average of 22 hull readings.

that the approximate gamma intensity can be derived from a beta-plus-gamma reading by multiplying the latter quantity by 0.078. The value is consistent with various beta-gamma ratios measured during the CROSSROADS operation (Reference 38 and 39).

The resulting set of 12 exterior hull gamma intensities indicates that a form of saturation may have been acting to limit the accumulation of contaminant materials on the support ships. When these intensities are adjusted (via $t^{-1.3}$) to equivalent readings taken on the same day, the adjusted intensities are similar in magnitude, even though the ships' exposure histories were quite different. Thus, it appears probable that all ships that spent sufficient time in contaminated water approached a limiting value of the amount of accumulated contaminant material and that at some later date these ships all exhibited similar contamination intensities, independent of the details of their individual exposures to contaminated water.

To evaluate S and C, the exterior hull gamma intensity derived for each of the 12 ships is adjusted to the value that would have existed on the day the support ship departed Bikini Lagoon. According to statements presented in Reference 2, steaming in uncontaminated water at full speed for 24 hours reduced the accumulated activity by 50 percent, but continued steaming did not result in further reduction. Reference 37 reports that the USS HENRICO experienced "a period of leaching the first night at sea, bringing her hull down to 0.4 (of departure intensity) and the auxiliary condensor down 0.6, but effecting the evaporators but little." In the present analysis, it is assumed that both hull and pipe intensities were reduced to half of their departure values during the first day after departure from the lagoon. An assumption concerning the subsequent radiological and physical decay of the remaining radioactive material must be made. Data presented in Reference 37 indicates that the decay during the first few days following departure may have been greater than $t^{-1.3}$ (due to continued leaching), but that at later times the decay rate decreased significantly. Due to lack of definitive data on which to construct reliable post-departure intensity-time curves, the standard $t^{-1.3}$ decay rate established for deposited BAKER fission products is used. The calculated intensity at lagoon departure, $I_o(t_f)$, for each of the twelve ships in the data base is determined by increasing the reported intensity by a factor $(t_r/t_f)^{1.3}$, where t_r is the time of the intensity reading, and t_f is the time of final lagoon departure; this adjusted value is then multiplied by two (to account for initial leaching of radioactive material in clear water) to arrive at $I_o(t_f)$. Substituting into the previously equation, one arrives at a relation between the constants S and C:

$$I_o(t_f) = St_f^{-1.3} \left[1 - \exp \left\{ -\frac{C}{S} D_w(t_f) \right\} \right].$$

Thus, for each of the twelve ships, curves of S versus C are constructed. These curves have the general form shown in Figure 2-8 for representative ships. While unique values of S and C cannot be determined from these curves directly, they may be evaluated with one additional curve constructed from data given in Reference 2:

> After re-entry of the non-target vessels to the lagoon, the same tendency of radioactive materials to adhere to the outer shell below the waterline was observed. The conditions here were ideal for ion-exchange and although the water itself showed intensity of radioactivity at and near the surface of only about .01 R/day, the active material was absorbed so efficiently from the lagoon waters that within a period of three days several of the non-target vessels began to show geiger counter readings of greater than 0.1 R/day of gamma radiation inside the hull in the vicinity of the waterline.

This statement appears to refer to support ships that re-entered the lagoon on BAKER day, and therfore applies to the first three days after detonation. It is assumed that the maximum hull reading was 0.12 R/day after three days; the S-versus-C curve described from these values is shown schematically in Figure 2.8. As shown in the diagram, the latter curve crosses those derived from the support ship intensity data base in such a manner that unique values of S and C can be assigned to each of the twelve ships. The values of S thus determined are given in Table 2-6. It is seen that the individual values of S vary within each group. Part of this variation is undoubtedly due to the simplicity of the basic model, uncertainities in the calculated water intensities $I_w(t)$, and uncertainities in the exterior hull readings due to instrument inaccuracies and nonstandard measurement techniques. However, much of this spread may be physical, representing variations in the amount of accumulated contaminaant material on ship hulls due to differences in type and condition of paint (Reference 2), cleanliness of the hull while at Bikini, and decontamination actions taken while in the lagoon.

The values of S used in this analysis are the geometric mean values of S appearing in the table, grouped by ship type. Specifically, S = 2240, 1800, and 1570 mR-day$^{0.3}$ for PGMs, destroyers, and all other ships, respectively. The range in the derived values of C is small, and the dose calculations are relatively insensitive to the exact value chosen. An average value of C = 11.0 day^{-1} is used for all support ships.

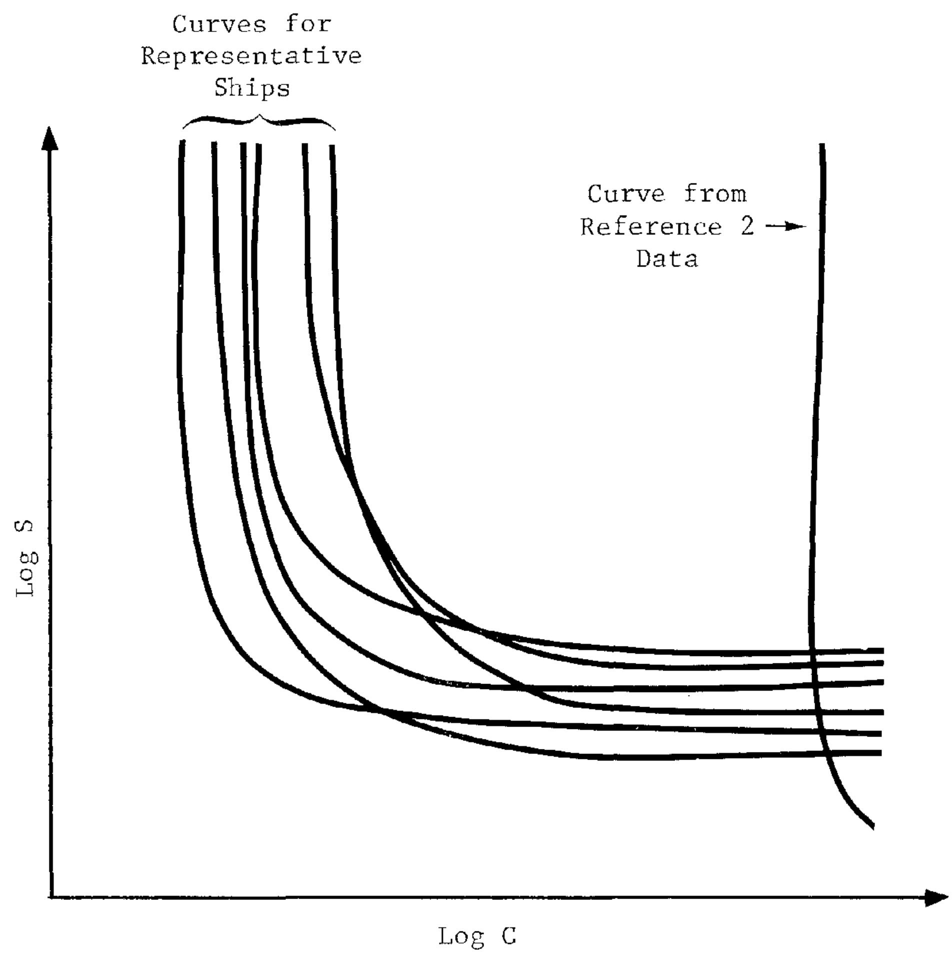


Figure 2-8 Ship Contamination Model Parametric Curves

A method is now developed whereby the exterior hull gamma intensity (the I_o calculated as described above) is used to determine interior ship intensities resulting from exterior hull contamination and contamination in salt water piping. A contaminated ship is modeled as a three-level structure with vertical sides (hull), as shown in Figure 2-9. The relevant geometric parameters are indicated in the figure. The hull contamination is modeled as a number (ten was found to be sufficient) of infinite line sources on each side of the lower exterior of the structure. The interior piping consists of two water mains (also taken as line sources) above level 2 in the structure. The structure is assumed to be symmetric about the centerline. Eight parameters (W, H, h_1, v_1, v_2, t_1, t_2, t_3) are determined for each ship type from analyses of ship diagrams. The value of Z (height above deck) is taken as 4.5 feet, the approximate height of a chest-worn badge. It is necessary to relate intensities measured in the salt water mains (I_p) to the exterior hull gamma intensities (I_o), which are assumed to have been read with the detector held at the nominal water line of the ship and with the hull exposed (i.e., in dry dock or listed to the other side). Readings available for the USS SAIDOR (Reference 35) and the USS ROCKBRIDGE (Reference 27) indicate that $I_p \approx 1.5\ I_o$. This relationship is assumed to hold for all ships.

With the sources now fixed, the interior ship intensities are calculated. This step requires the computation of the attenuation and buildup of gamma radiation through the material interposed between each element of source radiation and the point of interest, and the summation (integration) of contributions from all source elements. This is accomplished by means of the kernel technique with the Taylor form of the buildup factor (Section 3.8 of Reference 28). A gamma energy of 0.8 MeV (representative of gamma radiation from fallout material) is assumed. The resulting relative intensity (i.e., relative to exterior hull gamma intensity, I_o) distribution for each of the three levels of a destroyer is displayed in Figure 2-10. The relative intensity averaged over all three levels is used for contamination dose calculations in this report. These averaged relative intensities, referred to as apportionment factors, F_a, are listed in Table 2-7 for all ship types of interest.

Finally, an estimate is made of the intensity in the engine room of a ship. From the intensity data referenced above for the SAIDOR and ROCKBRIDGE, and from values given for the A.M. SUMNER in a radio message transmitted on 28 July 1946, it

REPRESENTATIVE SHIP TRANSVERSE CROSS SECTION AMIDSHIPS

W - SHIP BEAM
H - AVERAGE HEADROOM
V_1 - DISTANCE FROM LEVEL 2 DECK TO WATERLEVEL
V_2 - VERTICAL DISTANCE OF WATER MAIN BELOW LEVEL 1
h_1 - HORIZONTAL DISTANCE OF WATER MAIN FROM OUTER SHELL
t_1 - AVERAGE THICKNESS OF SIDE SHELL PLATING
t_2 - AVERAGE THICKNESS OF LEVEL 1 PLATING
t_3 - AVERAGE THICKNESS OF LEVEL 2 PLATING
Z - REPRESENTATIVE FILM BADGE HEIGHT (4.5 FT)

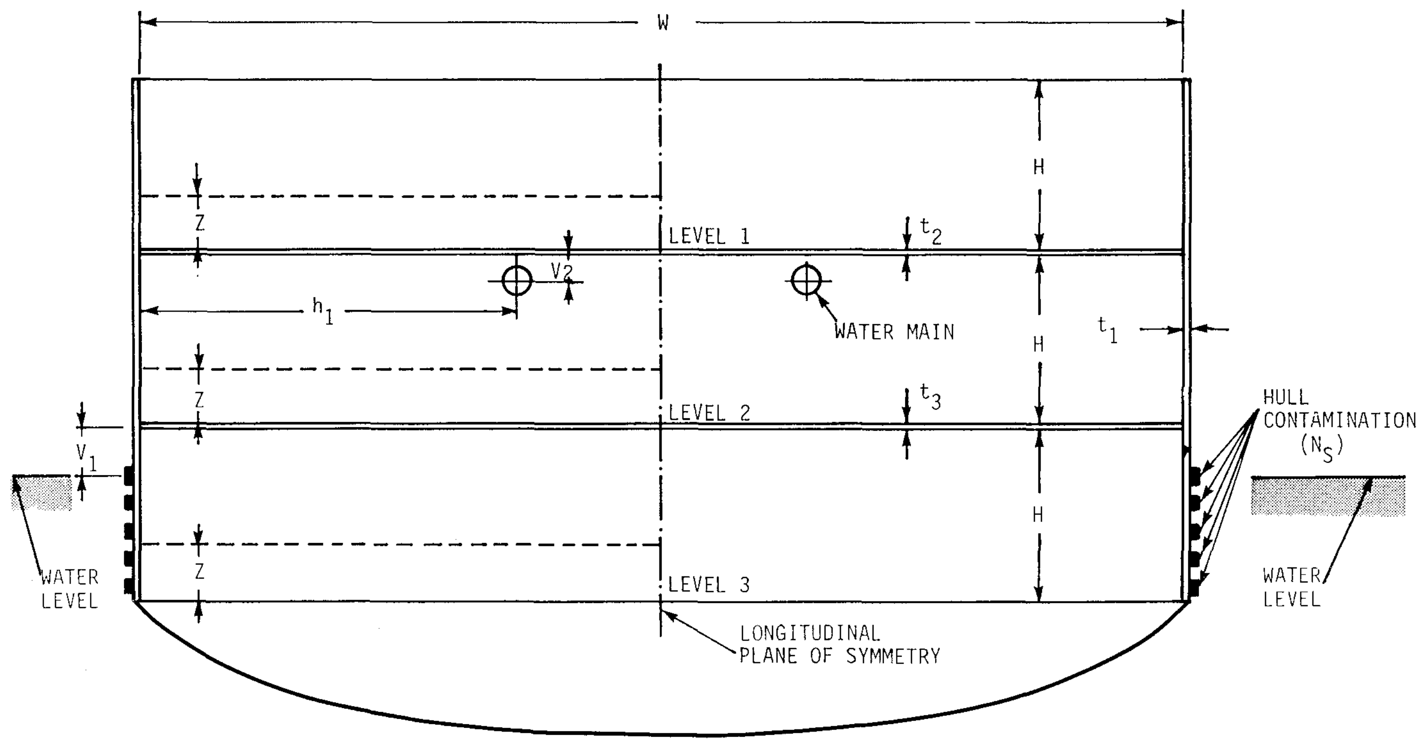


Figure 2-9 Support Ship Contamination Model

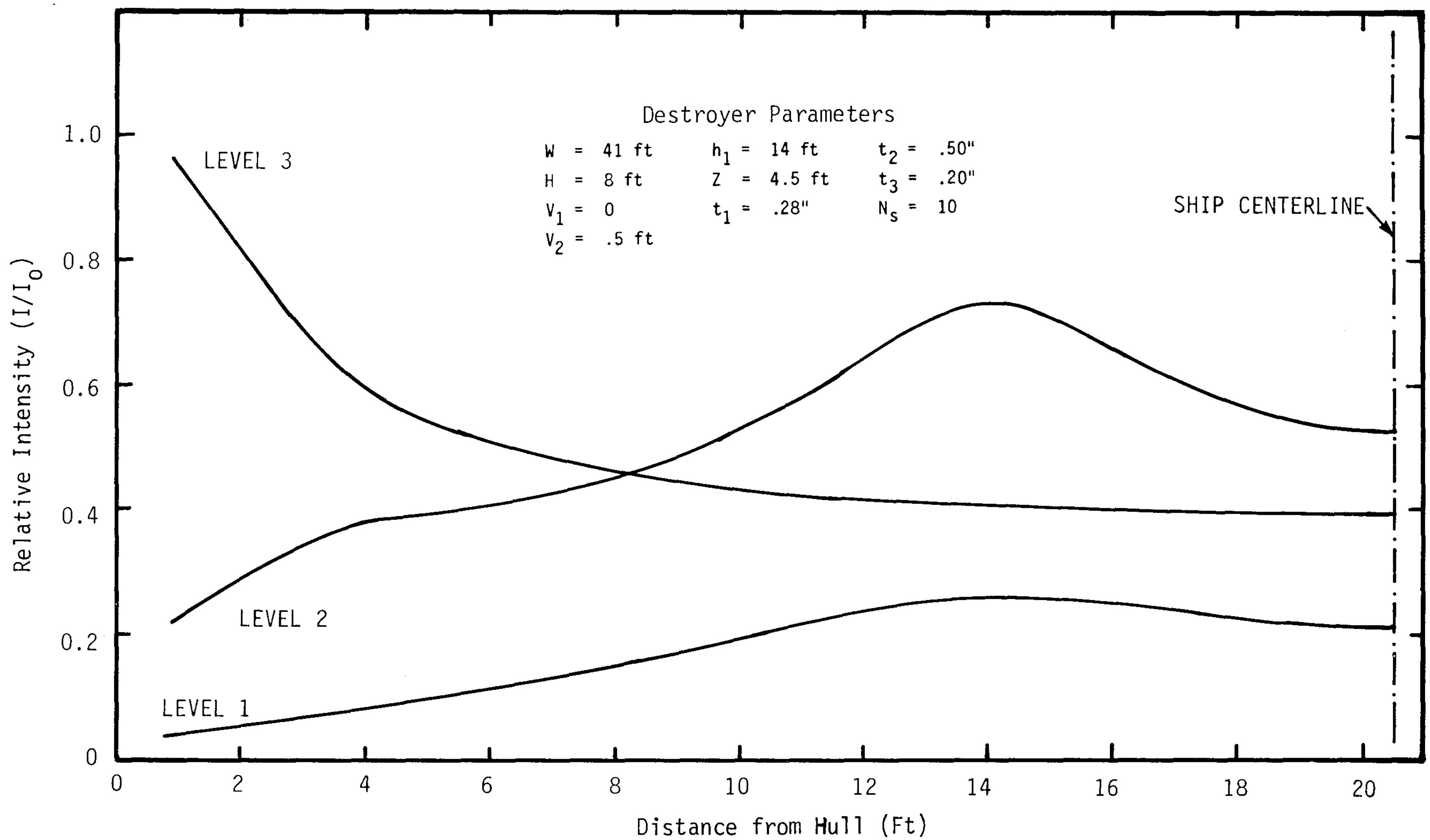


Figure 2-10 Interior Intensity Distribution for a Destroyer

Table 2-7

Ship Apportionment Factors

TYPE	SHIP	DESIGNATION	F_a*
I	Destroyer	DD	.39
II	Cruisers	CA-131	.05
III	Carrier, Light	CVE	.10
IV	Mine Sweepers	YMS	.55
VA	Salvage & Rescue	AN, ARS, ARSD-1, ASR-1, ASR-8 ATA, ATF, ATR, WAGL-392	.39
VB	Small Survey	AGS (8, 10, 13) (not AGS-4)	.55
VC	Patrol Boats	PGM	.67
VIA	300' Merchant	APD-27, AVP-49	.29
VIB	400-435' Merchant (C2 Types)	AG, AGC, AGS-4, AKA-21, AKA-44, AKA-99, AKA-101, AKS-4, AKS-13, APA 58, 67, 77 APA 228-237	.20
VIC	465-508' Merchant (C3 & C4 Types)	AH-4, 12, 13, AV-5, 14, 17 APA-27, APA-33, APA-45 LSD-5, LSD-25	.15
VIIA	Tankers 300'	AOG(W)-11	.33
VIIB	Tankers 400'	AW-2	.28
VIIC	Tankers 500'	AOW-61, AO-54, AO-69	.24
VIII	Tenders & Repair	AD-14, AS-11, AR-6	.15
IXA	Landing Craft	LCI	.57
IXB	Landing Craft	LCT	.43
IXC	Landing Craft	LST, ARL-24	.33
X	Barges	YO, YOG, YW	.57

*The apportionment factor F_a is the average interior ship intensity relative to the exterior hull gamma intensity. It is calculated by averaging the interior intensity distribution over the three levels of the ship model.

appears that evaporators and associated equipment have average intensities (I_e) similar to those of pipes, i.e.,

$$I_e \approx 1.5\, I_o.$$

Therefore, the engine room is estimated to have an average intensity no greater than this value.

Section 3
NAVAL OPERATIONS

Only those portions of the CROSSROADS ship activities before and after tests ABLE and BAKER that are pertinent to radiological examination are discussed. Elaborate fleet operation plans were established by CJTF-1 for safety and operational control purposes. These plans are recorded in Reference 29. The ocean in and around Bikini Lagoon was sectioned into specific geographic regions. Centered on the Delta Beacon on Bikini Island, designated Point Auto, concentric circles and radials were drawn. The resulting annular sectors were assigned various automobile names. The sector chart, defining the operating areas for the task groups of the Joint Task Force, is shown in Figure 3-1. A sector axis was drawn through sections Benz and Graham. Radiological axes based on the local surface wind directions for ABLE and BAKER were established at azimuths 050° and 120°, respectively. The sector axis was then aligned with the radiological axis and the sectors were rotated accordingly. Each ship was assigned an operating area based on these sectors.

3.1 Pre-Shot Evacuation

On the day before each test, 30 June and 24 July, the crews manning the target ships, approximately 9,000 personnel, were transferred to various units of the transportation group. Other transportation units visited the neighboring islands and took native personnel aboard in case a permanent evacuation might become necessary as a result of radioactive fallout. The various operating groups took positions as specified by the CJTF-1 Operation Order 1-46 and the sector chart of Figure 3-1 to await the test. Figure 3-2 shows the locations of the operating groups prior to the BAKER detonation; the radiological axis for this shot was at 120°, as indicated.

3.2 Post-Shot Maneuvers

Immediately after Shots ABLE and BAKER, the PGMs, salvage units and technical group reentered the lagoon in that order. The 20 LCPL craft, each normally manned by a boat officer and a crew of four, were lowered into the lagoon to accompany the PGMs into the target array to define the radiological environment. The Director of Ship Material, located on the USS RECLAIMER (ARS-42), supervised

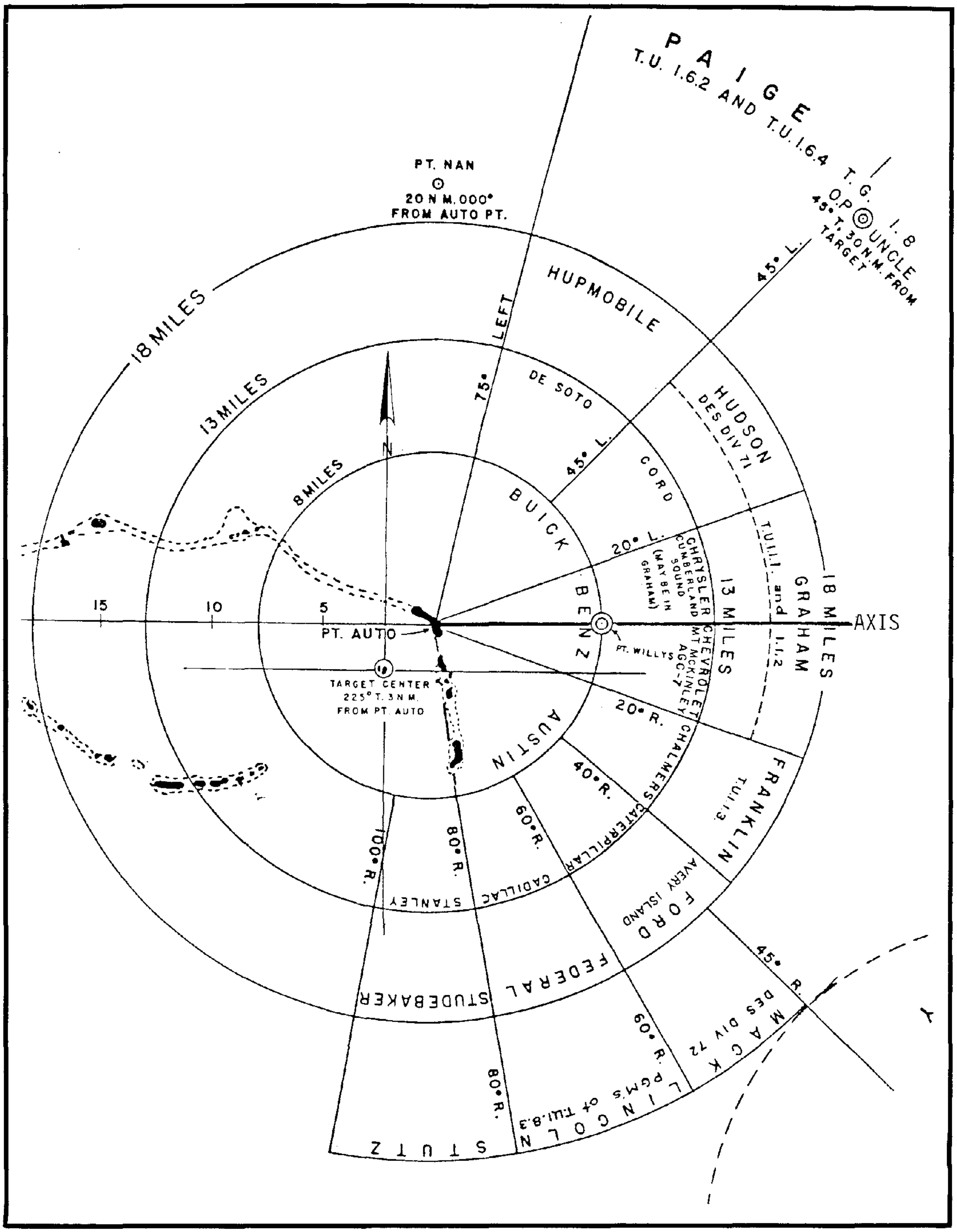


Figure 3-1 CJTF-1 Sector Chart

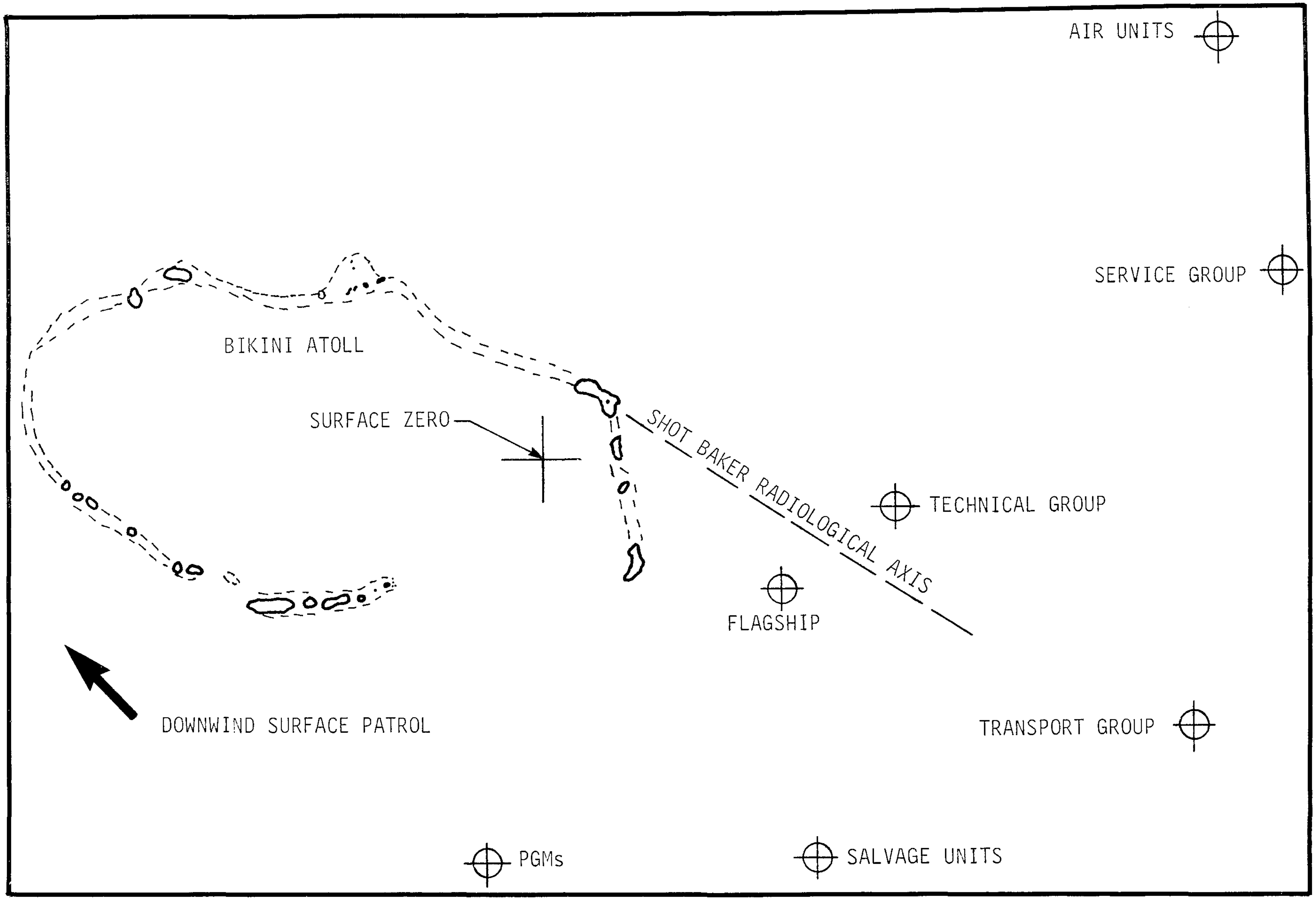


Figure 3-2 Group Locations at BAKER Detonation

the initial damage survey of the target array and also reported radiological readings of the water and target ships. The remaining salvage units and the technical group remained near the lagoon entrance, well outside radioactive waters. Their general location upon reentry are shown in Figure 3-3.

Little detailed information is available on the actual movements of the PGMs and LCPLs. Figure 3-4 shows the sector assignments of the PGMs for a hypothetical wind of 070°, nearly the actual condition for Shot ABLE. One hour before Shot ABLE, the sector assignments were shifted one segment clockwise for each PGM patrol and their attached LCPLs. The assignments of LCPLs and patrol areas for both shots are given in Table 3-1.

Table 3-1

PGM Patrol Assignments

Metal/ PGM	Assigned LCPLs*	Assigned Sector: ABLE	BAKER
Steel 32	A4 A5 B18 B20	Greece	France
Nickel 31	B15 B16 B17	France	England
Iron 29	B12 B13 B14	England	Denmark
Gold 25	B9 B10 B11	Denmark	Chile
Cobalt 24	B6 B7 B8	Chile	Brazil
Brass 23	A1 A2 A3 B19	Brazil	Argentina

*As specified in Operation Plan

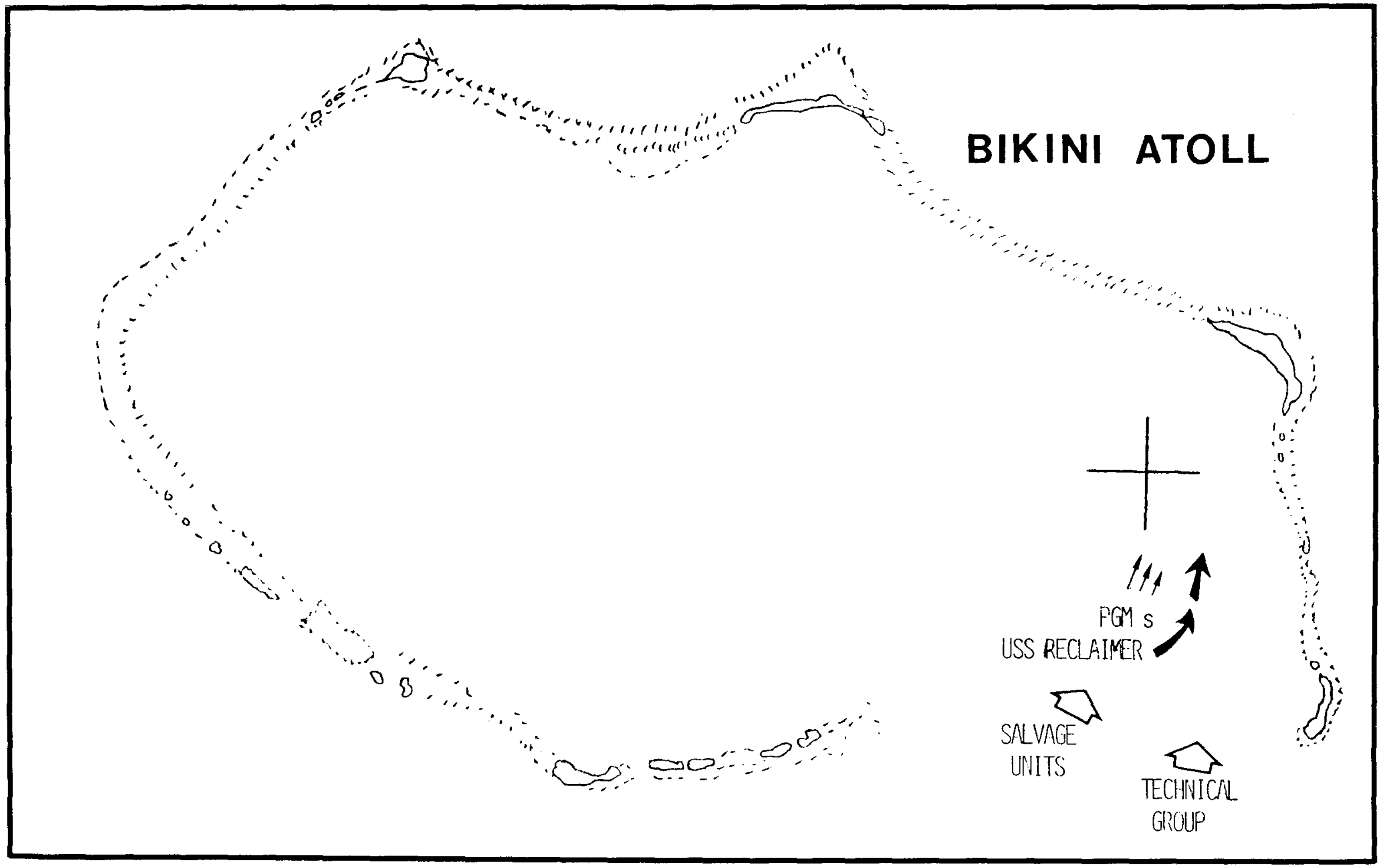


Figure 3-3 Post-BAKER Reentry

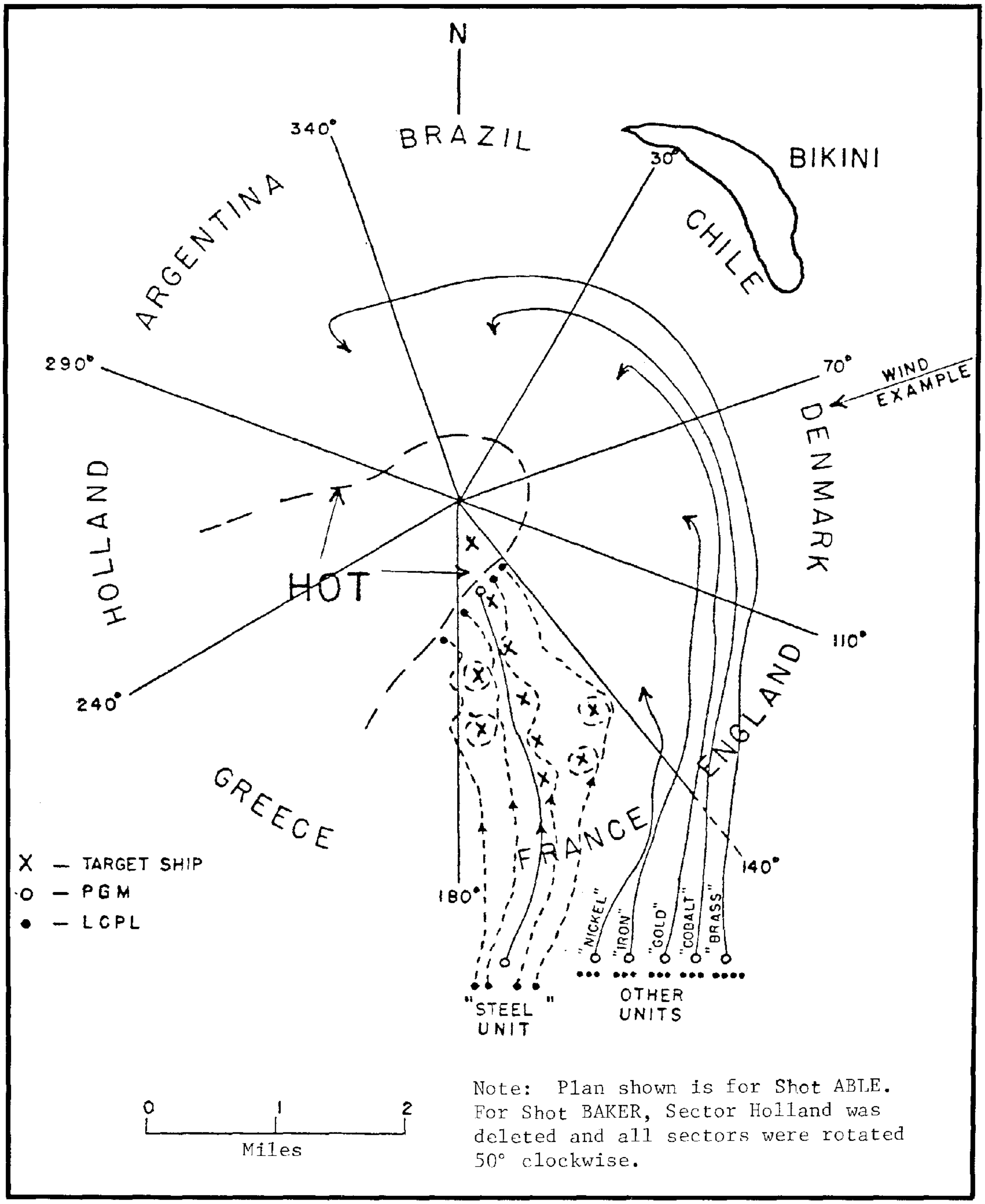


Figure 3-4 PCM Operation Plan

On ABLE day, the PGMs and attached LCPLs proceeded into the lagoon and to their assigned sectors. Beginning at the outside of the target array, the patrols proceeded toward the center of the array, reporting radiological intensities as they converged. In this manner, the red (1.0 R/day) and blue (0.1 R/day) lines were specified. The LCPLs then began to circle the target ships in their assigned sectors and report the radiological status of the water around the ships. On ABLE day plus one (A+1), the lagoon patrol followed straight grid lines and made east-to-west sweeps through the target array, allowing early clearance to be given to the center portion of the array. In the late morning on A+1, the blue line was discontinued. Later that day, the lagoon patrols searched for and identified remaining radiologically hazardous areas. By A+2, most of the target ships had been cleared, and the LCPLs of the lagoon patrol had become a water taxi service, performing various jobs not specified in the Operation Plan.

The PGMs and assigned LCPLs followed similar radiological reconnaissance procedures in the lagoon after Shot BAKER. Because of the intensity and size of the contaminated area, only seven target ships were cleared on BAKER day. During these patrols, some crews on the PGMs and LCPLs entered radiological "hot" spots and reached or exceeded their daily tolerance of radiation (0.1 R/day) in a period of several hours. Patrols were continued on subsequent days and by B+2, the water around approximately half of the target ships had been cleared. By B+5, the blue line and boating restrictions had been eliminated.

As previously stated, incomplete information exists on the actual movements of the PGMs and LCPLs while they were performing their assigned tasks. The PGM deck logs typically note "... various courses and various speeds while on radiological patrol ...". While not every position and maneuver is recorded, sufficient information is available on the PGMs to reconstruct major movements, from which dose calculations can be made. There is insufficient information, however, to accurately determine the movements of the LCPLs, and thus to reliably reconstruct doses for the crews. Fortunately, most of the crew members were issued film badges at the beginning of each day, and records exist on the dose levels for each crew for the periods 1-3 July 1946, and 25-31 July 1946. Dosimetry for the LCPLs is shown in Table 3-2. These dose levels represent the radiological data base that exists for the LCPL crews and can be used for dose determination of crews engaged in lagoon surveys.

Table 3-2 Dosimetry Summary for LCPL Crews

	JULY 1946										
LCPL	1	2	3	25	26	27	28	29	30	31	OTHER
A 1	70(70)	0	-	85(100)	0	62(80)	-	110(110)	113(130)	0	200(200) (7/31-8/26)
A 2	0	0	-	0	0	0	72(80)	-	-	-	-
A 3	0	0	0	70(70)	-	100(100)	-	-	188(270)	-	-
A 4	0	0	-	0	0	8(40)	-	34(50)	-	-	-
A 5	0	0	0	0	28(40)	28(30)	-	50(50)	-	-	-
A 6	-	-	-	0	0	110(120)	152(180)	-	-	-	-
A 7	-	-	-	-	-	80(80)	-	-	-	-	-
A 8	-	-	-	-	0	-	-	-	-	-	-
B 6	0	0	-	-	-	-	-	-	-	-	-
B 7	0	0	-	0	0	-	108(140)	-	-	-	-
B 8	0	0	-	0	52(60)	84(90)	124(150)	100(100)	-	-	-
B 9	100(120)	0	-	0	0	62(70)	-	-	-	94(100)	-
B 10	50(60)	0	-	0	0	0	-	-	-	-	-
B 11	8(40)	10(50)	0	0	0	26(50)	-	-	-	-	80(100) (7/28-8/03)
B 12	64(70)	0	-	0	0	66(80)	126(150)	-	-	-	-
B 13	0	12(60)	-	106(120)	0	78(90)	0	-	-	-	-
B 14	0	0	-	14(70)	0	80(90)	78(90)	-	-	-	-
B 15	0	0	-	0	54(60)	8(40)	-	-	-	-	-
B 16	0	0	-	0	58(70)	48(60)	-	-	-	-	-
B 17	0	0	-	72(74)	60(60)	15(30)	-	40(60)	-	-	-
B 18	0	0	10(50)	198(240)	40(80)	0	-	-	-	-	-
B 19	40(50)	0	-	130(140)	30(30)	102(120)	-	60(80)	-	-	-
B 20	0	32(50)	-	36(60)	44(50)	0	-	-	-	-	-
NO. OF BADGES ISSUED (579)	98	92	20	97	96	97	35	27	5	6	6
NO. OF ZERO EXPOSURES (329)	69	82	18	65	56	33	4	2	0	0	0

Table gives average dose in mrem, maximum dose in parentheses.

Dash indicates no data available.

The 10 salvage units led by the RECLAIMER were the first ships to follow the PGM radiological patrol. Each ARS except the RECLAIMER was accompanied by a rescue tug carrying a fire fighting officer and team. The movements of the RECLAIMER are well documented and are discussed at length in Section 5. Following Shot BAKER, most other units remained outside the lagoon and did not enter until after B+4, by which time the water intensity had greatly diminished. Units operating within the lagoon generally anchored for the night in the southeastern corner of the lagoon. However, on B+3 some ships were forced to shift their anchorages 4-5 miles to the west to avoid the advancing radioactive waters.

3.3 Boarding Party Operations

Boarding parties were established to board target ships for purposes of inspection, damage control, instrument retrieval, and reactivation of target ships. The organization and mission of the major boarding parties are discussed below.

1) Initial Boarding Teams

There were ten such teams, each composed of seven to eleven people. Key elements of each team included:

Representative, Director of Ship Material - In charge of team.

Assistant to Representative, Director of Ship Material - Deputy team leader.

Radiological Safety Monitor - Determined radiological conditions of all topside structures. Advised length of time personnel could remain onboard under existing conditions. Located and marked all unsafe spots.

Medical Safety Officer - Determined possible personnel hazards regarding air contamination; noted conditions of animals on topside structures, and served as Damage Control Safety Officer.

Bomb and Ammunition Safety Officer - Determined over-all condition of exposed ammunition and safety of ammunition in magazines as indicated by results of previous and existing fires.

Photographer - Obtained photographs of gross damage conditions as directed by DSM representative.

Six of the ten Initial Boarding Teams were located aboard salvage ships; four were aboard LCPLs and later transferred to other salvage units. The function of these teams was damage control, radiological monitoring and initial inspection and disposition of the target vessels. Boarding teams were kept together during the inspection of each ship insofar as practicable. The assignment of individuals to the various Initial Boarding Teams was made in accordance with the Initial Boarding Plan, Reference 30. However, the compositions of the teams were tailored to the nature of each day's operations.

In addition, salvage and firefighting teams from Task Unit 1.2.7 were embarked in vessels carrying Initial Boarding Teams.

2) Target Ship Crew Inspection Parties

The crew of each target ship was divided into four teams. Teams A, B, and C were headed by the commanding officer, engineering officer, and executive officer, respectively. Team A was to make a complete survey of the ship's superstructure. Team B would open the interior of the ship and make it habitable if possible. Team C would reactivate the administration functions, and team D, the remaining ship's personnel, would reman the ship. These parties included any Army personnel attached to the target ships.

3) Boarding Inspection Parties from the DSM Staff

These boarding parties were comprised of technical personnel on the DSM staff, many of whom were located on the USS WHARTON. These included Army, BuAir, BuShips, BuOrd, BuMed and BuShips electronics personnel.

Section 4
DOSE RECONSTRUCTION

Operations within Bikini Lagoon after the ABLE and BAKER shots were complicated not only by a complex radiological environment, but also because the unexpectedly high radiation levels from Shot BAKER necessitated revisions of the operation plans. The planned ship movements were revised on an ad hoc basis, and detailed reports are subsequently fragmentary. Central to the reconstruction of the dose to a crew is the knowledge of the vessel's path. This path must then be correlated with the radiological environment, which itself was changing with time due to radioactive decay and physical transport in the water.

Three sources of radiation are considered significant in this analysis. Each was present to various degrees after the ABLE and BAKER shots. Sources considered are:

1) Radioactivity in the lagoon water. Analysis of the radioactivity of neutron-activated seawater after Shot ABLE is described in Section 2.1. Estimation of the radiation intensities from water contaminated by weapon debris after Shot BAKER is described in detail in Section 2.3. Occasionally it was reported that various support ships passed through radioactive "hot" spots. Most of these hot spots were oil slicks encountered by destroyers on patrol north of the lagoon, and therefore not included in the water activity model. Doses from these sources are estimated from measured or assumed intensities and durations in these locations. In calculating shipboard doses, the water is treated as an infinite plane, and shielding by the ship structure is assumed negligible for topside exposures.

2) Radioactivity on target ships. Separate models are constructed for Shots ABLE and BAKER. Since there was essentially no local fallout for ABLE, only the neutron activation of the target ships is considered for this shot. The analysis of this radiation source is developed in Section 2.2. The residual activity of target ships is more complex for Shot BAKER, because of the radioactive weapon debris that was deposited on many of the target ships. Since there is an abundance of radiological data available for the BAKER target vessels, an empirical, vice

theoretical, approach is taken. From reported readings, time-dependent gamma intensity curves for target ships of interest are developed, as explained in Section 2.4. Three curves for each target vessel cover most operational situations regarding close encounters of non-target support ships and crews with target vessels. When available, the effects of target ship decontamination are shown on the gamma intensity curves. These curves apply to the following locations:

a) Topside on the target vessel. This curve describes the average topside intensity that was present on the upper exposed decks of a target vessel. This curve is applicable to boarding parties working topside on target ships.

b) Below decks on a target vessel. This curve is applicable whenever personnel were below decks. Its use requires a determination of the time spent below decks for parties operating aboard.

c) Moored alongside a target vessel while conducting reboarding, damage control or scientific operations. The amidships curve for the target ship describes the radiation intensity that existed near (6 feet) the side of a target vessel.

In addition to these encounters with target ships, there were occasional reports of various support ships passing near (within approximately 100 feet) radioactive target ships and measuring intensities. Doses accrued during such maneuvers are estimated from the reported intensities and an assumed exposure duration of three minutes.

3) Contamination buildup on ships operating in contaminated water. For target and non-target ships operating in the lagoon, radioactivity began to accumulate on those surfaces in contact with the contaminated water. The areas of greatest concern were the exterior hull at or below the water line, salt water piping, and the condensors/evaporators of the ships. The method developed to estimate dose contributions from these sources is described in Section 2.5.

The radiation environments described in Section 2 are free-field intensities. A conversion factor from free-field dose to film badge dose, 0.7 for a properly worn film badge (Reference 26), is applied to all free-field doses. It is also necessary to consider personnel activity aboard a ship. A typical sailor will not be fully exposed to all radiation sources at the same time. Specifically, the water intensity contributed to the dose of a sailor topside, but the self-shielding of the water and shielding by ship structural material greatly reduced this contribution below decks. Similarly, the ship contamination dose contributed significantly to doses accrued below decks, but probably contributed negligibly topside. In computing total doses, it is assumed that the average sailor spent 8 hours daily topside, and 16 hours below decks. Therefore, 24-hour water doses are multiplied by 1/3, and 24-hour ship contamination doses by 2/3, to determine the total dose for a typical sailor.

4.1 Computerized Methodology

The radiation environments described in Section 2 essentially define the gamma intensity in the lagoon as a function of position and time. The calculation of a ship's free-field dose can be obtained by correlating the unit's maneuver history with the radiation environment. A computerized methodology has been developed which allows input of ship path data and calculates the doses accrued by shipboard personnel from the previously described radiation sources. Figure 4-1 shows the reconstruction of a hypothetical ship's movement and the manner in which it is represented in this computer model. The lagoon is divided into 1000-yard grid squares, each assigned a unique number. Each grid square is subdivided into 200-yard squares. This coordinate system, used during the operation, allows the positioning of a unit to within 200 yards through the use of a five-digit alpha-numeric code. For example, the surface zeroes for Shots ABLE and BAKER were 2101L and 2201K, respectively. Figure 4-1 shows the input positions and four intermediate positions interpolated by computer on a three-minute basis. Straight-line interpolation between known position points is used, and incremental doses are calculated from the local radiation intensity and the size of the time step. The values of gamma intensity in the post-BAKER environment are stored for each grid square in the lagoon for each of six days (B+1 through B+5, and B+8) following the detonation. Linear interpolation in time between these data sets is employed. The post-ABLE water environment is described in the computer code by the mathematical expression developed in Section 2. A computer program calculates

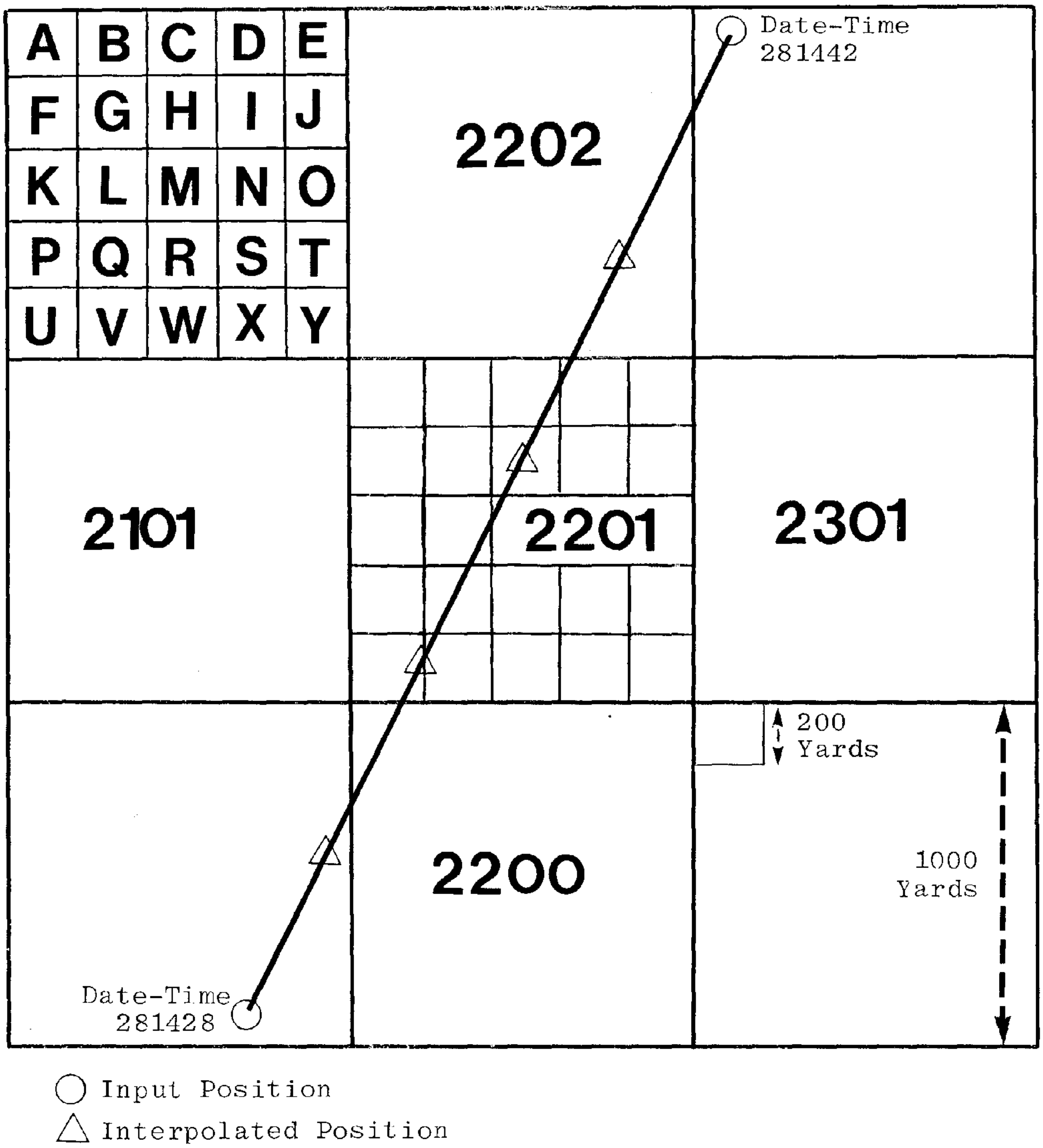


Figure 4-1 Ship Position Calculation

water doses through ABLE plus 3 days and BAKER plus 8 days. Doses from target ships and ship contamination are calculated on a daily basis until departure from the lagoon.

4.2 Program Descriptions/Listings

A series of programs has been developed to perform these calculations and to provide various bookkeeping functions. A description of each program and its listing are included in this section. The following programs are included:

- INPUT PATH
- INPUT PASSING SHIP DOSE
- WATER INTENSITY
- LATE WATER
- TARGET INTENSITY
- SHIP CONTAMINATION
- RADIATION REPORT
- UPDATE
- UPDATE TARGET SHIPS
- UPDATE PASSING SHIP DOSE
- PATH REPORT
- UPDATE SHIP CONTAMINATION

Program: INPUT PATH

Program Objective: To create files that define a ship's location in Bikini Lagoon as a function of time.

Description: The path is input as a set of discrete data points. Each data point includes a time, a place, and an indicator of the ship's proximity to any target ships. The time is input in days, hours, and minutes, e.g., 031650 is the 3rd of July at 1650. The place is input using the coordinate system described in Figure 4-1. The target ship proximity is indicated by the letters P, A, L, or N, where P = passing, A = alongside, L = leaving, and N = not near a target ship. All codes except N are then followed by the name of the target ship. This information is stored in a file created for each ship.

After this information is input, there is the option of supplying the doses received when passing radioactive target ships. This option need not be selected - a separate program can be used to input the passing numbers at a later time. See INPUT PASSING SHIP DOSE.

Input: Terminal input of a sequence of values for time, place and target ship proximity.

Output: File "ship" PATH containing path information
File "ship" PASSES with passing dose information

Table 4-1 Input Path

```
10      HOME
20      DIM PLACE$(300),TIME$(300),SHIP$(300)
30      PRINT :
        PRINT
40      PRINT "THIS PROGRAM CREATES A FILE WHICH"
50      PRINT "CONTAINS THE HISTORY OF THE PATH"
60      PRINT "OF A SHIP"
70      PRINT
80      INPUT "NAME OF SHIP ?";X$
90      Z$ = X$ + " PATH"
100     PRINT
110     PRINT "EACH DATA POINT CONSISTS OF A TIME"
120     PRINT "IN THE FORM DDHHMM AND THEN A"
130     PRINT "POSITION LIKE 2591M"
140     PRINT "AND THEN A SHIP CODE BEGINNING"
150     PRINT "WITH N,L,A OR P.  WITH ALL BUT N A SHIP NAME FOLLOWS"
160     PRINT :
        PRINT "HIT RETURN WHEN DONE":
        PRINT
170     FOR I = 0 TO 300
180         GOSUB 3500
190         IF A1$ = CHR$ (13) THEN 290
200         GOSUB 4000:
            GOSUB 4500
250         IF SHIP$(I) = CHR$ (13) THEN
                SHIP$(I) = "N"
260         NEXT I
270     PRINT "ONLY FIRST 300 POINTS USED"
280     PRINT CHR$ (7); CHR$ (7); CHR$ (7)
290     N = I - 1
300     D$ = CHR$ (4)
310     PRINT D$;"OPEN   ";Z$;",D2"
320     PRINT D$;"DELETE ";Z$
330     PRINT D$;"OPEN   ";Z$
340     PRINT D$;"WRITE  ";Z$
350     PRINT N + 1
360     FOR I = 0 TO N
370         PRINT TIME$(I)
380         PRINT PLACE$(I)
390         PRINT SHIP$(I)
400         NEXT I
410     PRINT D$;"CLOSE  ";Z$
420     PRINT "CREATE PASSING SHIP DOSE FILE NOW?";
```

```
430    GET A$:
       PRINT A$
440    IF A$ < > "Y" THEN 570
450    DIM PTIME$(300),PNAME$(300),PDOSE(300)
460    FOR I = 0 TO NTIMES - 1
470        T$ = LEFT$ (SHIP$(I),1)
480        IF T$ = "A" THEN
               GOTO 560
490        IF T$ = "N" THEN
               GOTO 560
500        IF T$ = "L" THEN
               GOTO 560
510        L = LEN (SHIP$(I)) - 1
520        SHIP$(I) = RIGHT$ (SHIP$(I),L)
530        IF T$ = "P" THEN
               GOSUB 730
540        IF TEST = 0 THEN
               GOSUB 820
550        TEST = 0
560        NEXT I
570    Z$ = X$ + " PASSES"
580    PRINT D$;"OPEN  ";Z$;",D2"
590    PRINT D$;"DELETE";Z$
600    PRINT D$;"OPEN  ";Z$
610    PRINT D$;"WRITE ";Z$
620    PRINT PASSES
630    IF PASSES = 0 THEN 690
640    FOR I = 1 TO PASSES
650        PRINT PTIME$(I)
660        PRINT PNAME$(I)
670        PRINT PDOSE(I)
680        NEXT I
690    PRINT D$;"CLOSE ";Z$
700    PRINT D$;"NOMON,C"
710    PRINT D$;"PR#0"
720    PRINT D$;"RUN MENU,D1"
730    PRINT TIME$(I);"  PASSING ";SHIP$(I);
740    INPUT "  DOSE = ? ";D
750    PRINT
760    PASSES = PASSES + 1
770    PTIME$(PASSES) = TIME$(I)
780    PNAME$(PASSES) = SHIP$(I)
790    PDOSE(PASSES) = D
800    TEST = 1:
       RETURN
810    RETURN
820    PRINT "ERROR IN PATH FILE(NOT N,L,P,A)"
830    PRINT TIME$(I),PLACE$(I),SHIP$(I)
840    PRINT "DO YOU WANT TO CONTINUE? ";
850    GET A$:
       PRINT A$:
       IF A$ = "Y" THEN
           RETURN
860    INPUT "WANT TO GO TO MENU ?";A$
```

```
870    IF LEFT$ (A$,1) = "Y" THEN
            PRINT D$;"RUN MENU,D1"
880    PRINT "ERROR TERMINATION, RETURNING TO BASIC"
890    PRINT "TYPE CONT TO RESTART PROGRAM"
900    END
910    POKE 51,128:
       GOTO 450
3500   PRINT "TIME ";:
       GET A1$:
       PRINT A1$;:

3600   IF A1$ = CHR$ (13) THEN
            RETURN
3710   GET A2$:
       PRINT A2$;:
       IF A2$ = CHR$ (8) THEN
            GET A1$:
            PRINT A1$;:
            GOTO 3600
3720   GET A3$:
       PRINT A3$;:
       IF A3$ = CHR$ (8) THEN 3710
3730   GET A4$:
       PRINT A4$;:
       IF A4$ = CHR$ (8) THEN 3720
3740   GET A5$:
       PRINT A5$;:
       IF A5$ = CHR$ (8) THEN 3730
3750   GET A6$:
       PRINT A6$;:
       IF A6$ = CHR$ (8) THEN 3740
3800   TIME$(I) = A1$ + A2$ + A3$ + A4$ + A5$ + A6$
3900   RETURN
4000   PRINT "   PLACE ";:
       GET A1$:
       PRINT A1$;
4010   GET A2$:
       PRINT A2$;:
       IF A2$ = CHR$ (8) THEN
            GET A1$:
            PRINT A1$;:
            GOTO 4010
4020   GET A3$:
       PRINT A3$;:
       IF A3$ = CHR$ (8) THEN 4010
4030   GET A4$:
       PRINT A4$;:
       IF A4$ = CHR$ (8) THEN 4020
4040   GET A5$:
       PRINT A5$;:
       IF A5$ = CHR$ (8) THEN 4030
4100   PLACE$(I) = A1$ + A2$ + A3$ + A4$ + A5$
4200   RETURN
4500   PRINT "  SHIP ";:
```

```
4501   GET T1$:
       PRINT T1$;
4502   IF T1$ = CHR$ (13) THEN
            T1$ = "N":
            GOTO 4504
4503   INPUT "";T2$
4504   T2$ = T1$ + T2$
4510   L = LEN (T2$)
4520   T1$ = LEFT$ (T2$,1)
4530   IF T1$ = "N" THEN 4600
4540   IF L > 1 THEN 4560
4550   FLASH :
       PRINT "BAD INPUT, TRY AGAIN":
       NORMAL :
       GOTO 4500
4560   IF T1$ = "L" THEN 4600
4570   IF T1$ = "P" THEN 4600
4580   IF T1$ = "A" THEN 4600
4590   GOTO 4550
4600   SHIP$(I) = T2$
4700   RETURN
```

Program: INPUT PASSING SHIP DOSE

Program Objective: To create a file containing information on the radiation dose received while "passing" radioactive ships.

Description: Program cycles through the PATH file to locate passing code "P". For each occurence as noted below, the dose received from passing a target ship is calculated. This dose, along with the time of occurence and the name of the radioactive ship, is then inputed and saved in a new data file. This file is subsequently used as input for the Radiation Report.

Input: File "ship" PATH from INPUT PATH.
Terminal input for dose received from passing ships (in mR).

Output: File "ship" PASSES containing passing ship dose information.

Note: This program is used only to create a new file. It need not be used if a file was created while running INPUT PATH. UPDATE should be used to modify an existing file. This file is created for every situation where a time and intensity are reported for a ship passing a radiation source.

Table 4-2 Input Passing Ship Dose

```
10      D$ = CHR$ (4)
20      PRINT D$;"MON,C"
30      DIM PDOSE(300),PNAME$(300),PTIME$(300)
40      DIM PLACE$(300),TIME$(300),SHIP$(300)
50      INPUT "NAME OF SHIP ";X$:
        Z$ = X$ + " PATH"
60      PRINT D$;"OPEN ";Z$;",D2"
70      PRINT D$;"READ ";Z$
80      INPUT NTIMES
90      FOR I = 0 TO NTIMES - 1
100         INPUT TIME$(I),PLACE$(I),SHIP$(I)
110         NEXT
120     PRINT D$;"CLOSE ";Z$
130     IF NTIMES < 2 THEN 9000
140     FOR I = 0 TO NTIMES - 1
150         T$ = LEFT$ (SHIP$(I),1)
160         IF T$ = "A" THEN
                GOTO 240
170         IF T$ = "N" THEN
                GOTO 240
180         IF T$ = "L" THEN
                GOTO 240
190         L = LEN (SHIP$(I)) - 1
200         SHIP$(I) = RIGHT$ (SHIP$(I),L)
210         IF T$ = "P" THEN
                GOSUB 410
220         IF TEST = 0 THEN
                GOSUB 500
230         TEST = 0
240         NEXT I
250     Z$ = X$ + " PASSES"
260     PRINT D$;"OPEN  ";Z$;",D2"
270     PRINT D$;"DELETE";Z$
280     PRINT D$;"OPEN  ";Z$
290     PRINT D$;"WRITE ";Z$
300     PRINT PASSES
310     IF PASSES = 0 THEN 370
320     FOR I = 1 TO PASSES
330         PRINT PTIME$(I)
340         PRINT PNAME$(I)
350         PRINT PROSE(I)
360         NEXT I
370     PRINT D$;"CLOSE ";Z$
```

```
380    PRINT D$;"NOMON,C"
390    PRINT D$;"PR#0"
400    PRINT D$;"RUN MENU,D1"
410    PRINT TIME$(I);"  PASSING ";SHIP$(I);
420    INPUT "  DOSE = ? ";D
430    PRINT
440    PASSES = PASSES + 1
450    PTIME$(PASSES) = TIME$(I)
460    PNAME$(PASSES) = SHIP$(I)
470    PDOSE(PASSES) = D
480    TEST = 1:
       RETURN
490    RETURN
500    PRINT "ERROR IN PATH FILE(NOT N,L,P,A)"
510    PRINT TIME$(I),PLACE$(I),SHIP$(I)
520    PRINT "DO YOU WANT TO CONTINUE? ";
530    GET A$:
       PRINT A$:
       IF A$ = "Y" THEN
           RETURN
540    INPUT "WANT TO GO TO MENU ?";A$
550    IF LEFT$ (A$,1) = "Y" THEN
           PRINT D$;"RUN MENU,D1"
560    PRINT "ERROR TERMINATION, RETURNING TO BASIC"
570    PRINT "TYPE CONT TO RESTART PROGRAM"
580    END
590    POKE 51,128:
       GOTO 50
9000   PRINT "NOT ENOUGH DATA, ONLY ";NTIMES;" POINTS"
9010   GET A$:
       PRINT :
       PRINT D$;"RUN MENU,D1"
```

Program: WATER INTENSITY

Program Objective: To estimate the doses accrued by support ship personnel from radioactive water sources during post-ABLE and post-BAKER operations.

Description: The program first calculates doses from the Shot ABLE water environment, and then from the BAKER environment.

Shot ABLE

The intensity at time t after detonation and distance r from surface zero is determined from the equation

$$I(r,t) = t^{-3/2} \exp\left[-4.56\times10^{-6}\left(\frac{r^2}{t}\right) - .0462\,t + 0.503\right],$$

where t is in hours, r in meters, and I in R/hr. This pattern drifts 900 meters per 24 hours on an azimuth of 10° east of north. The derivation of this model is discussed in Section 2-1.

Dose increments are calculated every 3 minutes while the vessel was in water with intensity greater than 0.01 R/day, as predicted by the water intensity model. The 3-minute time step can be changed by a single line program change (change value of S1T in first line of program). To decrease the execution time, the radius at which the intensity mathematically becomes less than 0.01 R/day was calculated for each hour, and is input via data statements. If the ship's radius is greater than this radius, no calculation is required.

As the program executes, any time interval for which the intensity exceeds 0.1 R/day is printed out. The accumulated dose for each hour is calculated and the first 72 hourly doses stored in the file "ship" WATER.

Shot BAKER

For Shot BAKER, the water intensity data base consists of the intensities at six different times (28, 50, 78, 100, 120, and 200 hours after detonation) for each of the thousand-yard grid squares in the lagoon. The values of intensity in the data base are in arbitrary units. To convert to R/hr, these values are divided by the following scale factors, which were derived from the contours in Reference 12 and the red-blue line data (see Section 2.3).

Time	Scale factor
28 hrs	10
50	15
78	100
100	50
120	100

Linear interpolation in time is used to estimate intensities at other times.

Spatial and time interpolation along a ship path is performed in three-minute time steps (this can be changed by changing the value of SBT in the second line of the program). First, the position of the ship is determined by linear interpolation between two data points in the ship's PATH file. Then the intensity at the ship's position is determined by linear interpolation in time of the intensities of the appropriate grid square appearing in the BAKER data base.

Any calculated intensities above 0.1 R/day are printed out. The dose increments are added to determine hourly totals, and the hourly dose for each of the first 200 hours is written to the file "ship" WATER.

Note that this program does not include water dose contributions from BAKER day operations. These must be calculated and input separately.

Input: File "ship" PATH

Output: File "ship" WATER

Intensities greater than 0.1 R/day, and the dose for each hour for both ABLE and BAKER (excluding BAKER day).

Table 4-3 Water Intensity

```
60 S1T = 3
70 SBT = 3
80  HOME : VTAB 8
100  PRINT "DO YOU WANT TO USE THE PRINTER?";
110  GET A$: PRINT A$
111  IF A$ = "Y" THEN  PRINT "WHAT SLOT IS THE PRINTER IN?";
: GET P$: PRINT P$
112  IF A$ = "Y" AND P$ > "3" OR A$ = "Y" AND P$ < "1" THEN
80
120 PR = 0: IF A$ = "Y" THEN PR = 1
130 D$ =  CHR$ (13) +  CHR$ (4): REM  CTRL-M + CTRL-D
400  DIM X2(24),Y2(24),RO(72)
410  DIM PLACE$(300),TIME$(300)
415  DIM SHIP$(300)
420  DIM DOSE(300)
450  INPUT "NAME OF SHIP ";X$:Z$ = X$ + " PATH"
460  PRINT D$;"OPEN ";Z$;",D2"
470  PRINT D$;"READ ";Z$
480  INPUT NTIMES
490  FOR I = 0 TO NTIMES - 1
500  INPUT TIME$(I),PLACE$(I),SHIP$(I)
510  NEXT
520  PRINT D$;"CLOSE ";Z$
530  IF NTIMES < 2 THEN  PRINT " NOT ENOUGH DATA, ONLY ";NTI
MES;" POINTS": END
1000  REM  ***********************
1005  REM  *                     *
1010  REM  * ABLE ACTIVATION     *
1015  REM  *                     *
1020  REM  ***********************
1025 CS = .98481
1026 SI = .17365
1027 DRFT = 1000 / 24
1030 TZERO = 51
1040 A1 =  - 4.56 * 10 ^  - 6
1050 A2 =  - .0462
1060 A3 = 0.503
1070  DEF  FN ACT(T) =  EXP (A1 * R * R / T + A2 * T + A3) /
 (T *  SQR (T))
1080 ST = S1T
1085  REM   READ IN GROUND ZERO & TIME FOR ABLE
1090  READ X0,Y0,T0
1100  DATA    21200,0400,33
1105  REM   READ IN CODES FOR GRID SQUARES
1110  REM  READ IN WHAT CODES STAND FOR IN RECTANGLES
1120  FOR I = 0 TO 24: READ X2(I),Y2(I): NEXT
1130  DATA  0,0,200,0,400,0,600,0,800,0
1140  DATA  0,200,200,200,400,200,600,200,800,200
```

```
1150  DATA  0,400,200,400,400,400,600,400,800,400
1160  DATA  0,600,200,600,400,600,600,600,800,600
1170  DATA  0,800,200,800,400,800,600,800,800,800
1175  REM   READ IN DISTANCE TO ZERO RADIATION
1180  FOR I = 0 TO TZERO: READ RO(I): NEXT I
1190  DATA  1344,1771,2067,2298,2487,2646
1200  DATA  2783,2901,3004,3095,3176,3246
1210  DATA  3308,3362,3408,3448,3481,3509
1220  DATA  3531,3547,3558,3564,3565,3565,3562
1230  DATA  3553,3540,3522,3499,3472,3440
1240  DATA  3403,3360,3313,3261,3202,3139
1250  DATA  3069,2992,2908,2817,2718,2610
1260  DATA  2491,2360,2215,2054,1871,1660
1270  DATA  1409,1089,601
1290  GOTO 1530
1295  REM   SUBROUTINE TO GET TIME
1300 DAY =  VAL ( LEFT$ (TIME$(I),2))
1310 HOUR =  VAL ( MID$ (TIME$(I),3,2))
1320 MINUTE =  VAL ( RIGHT$ (TIME$(I),2))
1330 MINUTE = ST *  INT ((MINUTE + ST / 2) / ST)
1340 T = (24 * DAY + HOUR + MINUTE / 60) - TO
1350  RETURN
1355  REM   SUBROUTINE TO GET POSITION FOR ABLE
1360 CODE =  ASC ( RIGHT$ (PLACE$(I),1)) - 65
1370  IF CODE > 24 THEN  PRINT CODE
1380 X = 1000 *  VAL ( LEFT$ (PLACE$(I),2)) + X2(CODE) - XO
1390 Y =  VAL ( MID$ (PLACE$(I),3,2))
1400  IF Y > 50 THEN Y = Y - 100
1410 Y = 1000 * Y - Y2(CODE) - YO
1412  REM  INCORPORATE DRIFT
1415 X9 = X - SI * DRFT * T
1416 Y9 = Y - CS * DRFT * T
1420 R =  SQR (X9 * X9 + Y9 * Y9)
1430 R = R * .9144
1440  RETURN
1530  IF PR = 1 THEN  PRINT D$;"PR#";P$
1535  PRINT : PRINT
1540  IF PR <  > 1 THEN  HOME
1550  PRINT "RUNNING ABLE WATER ACTIVATION"
1560  PRINT "            FOR"
1570  PRINT "          ";: FLASH : PRINT X$: NORMAL
1580  PRINT : POKE 34,4
1590 I = 0
1600  GOSUB 1300
1605  IF T < 0 THEN I = I + 1: GOTO 1600
1610  IF T > TZERO THEN  GOTO 1980
1614  PRINT "TIME","PLACE"
1615  PRINT "HOURS AFTER","X-GRID(YD)","Y-GRID(YD)","RADIUS(
M)","DOSE RATE(R/HR)"
1620  GOSUB 1360
```

```
1630 X1 = X:Y1 = Y:R1 = R:T1 = T
1640 I = I + 1
1650  GOSUB 1300: GOSUB 1360
1660  PRINT TIME$(I - 1),PLACE$(I - 1)
1665  REM  INTERPOLATE BETWEEN DATA POINTS
1670 N = (T - T1) / (ST / 60): IF N < 1 THEN N = 1
1690 I1 =  INT (T1):I2 =  INT (T)
1740 TX = (X - X1) / N:TY = (Y - Y1) / N
1750  FOR J = 1 TO N
1760 X = X1 + J * TX
1770 Y = Y1 + J * TY
1772 T = T1 + J * ST / 60
1773  REM  INCORPORATE DRIFT
1775 X9 = X - SI * DRFT * T
1776 Y9 = Y - CS * DRFT * T
1780 R =  SQR (X9 * X9 + Y9 * Y9)
1785  REM  CONVERT TO YARDS
1790 R = R * .9144
1810 TI =  INT (T)
1815  IF TI > TZERO THEN 1980
1820  IF R > RO(TI) THEN 1860
1830 D =  FN ACT(T)
1840 DOSE(TI) = DOSE(TI) + D
1850  IF D > .004 THEN  PRINT T,X,Y,R,D
1860  NEXT
1870  IF I = 72 OR I = NTIMES - 1 OR T > TZERO THEN 1980
1880  GOTO 1630
1980  PRINT TIME$(I),PLACE$(I)
1987  IF I = 0 THEN 2020
1989  REM  ABLE 0-72 ALWAYS
1990  FOR L = 0 TO 72
1995 DOSE(L) = DOSE(L) / (60 / ST)
2000  IF PR <  > 0 THEN  PRINT L,DOSE(L)
2010  NEXT
2020  PRINT "DONE WITH ABLE ACTIVATION"
4900  REM  ************************
4910  REM  *                      *
4920  REM  * BAKER CONTAMINATION *
4930  REM  *                      *
4940  REM  ************************
5000 ST = SBT
5020  REM  BAKER AT 830 JULY 25
5025  REM  TSTART IS MIDNIGHT, THE BEGINNING OF THE 26TH OF
JULY
5030 TO = 608.5
5040 TSTART = 624 - TO
5070 TLAST = 208
5075  REM  H IS HOURS TO DATA FOR BAKER
5076  REM   F IS SCALE FACTOR FOR DATA SET AT TIME H
5080 H(0) = 28:F(0) = 10
```

```
5090 H(1) = 50:F(1) = 15
5100 H(2) = 78:F(2) = 100
5110 H(3) = 100:F(3) = 50
5120 H(4) = 120:F(4) = 100
5130 H(5) = 216:F(5) = 0
5140 H8 = H(0):H1 = H8:H9 = H(1)
5150  PRINT D$;"OPEN BAKER,L3,D1"
5155  REM   READ IN SURFACE ZERO
5160  READ X0,Y0
5170  DATA  22,1
5180  GOTO 5300
5240  REM  SUBROUTINE TO GET PLACE FOR BAKER
5250 X =  VAL ( LEFT$ (PLACE$(I),2))
5260  IF X > 50 THEN X = X - 100
5270 Y =  VAL ( MID$ (PLACE$(I),3,2))
5280  IF Y > 50 THEN Y = Y - 100
5281 CODE =  ASC ( RIGHT$ (PLACE$(I),1)) - 65
5282 X = X + X2(CODE) / 1000.
5283 Y = Y + Y2(CODE) / 1000.
5290  RETURN
5300  IF PR = 0 THEN  HOME
5310  VTAB 1
5320  PRINT "RUNNING BAKER WATER CONTAMINATION"
5321  PRINT "             FOR"
5322  PRINT "         ";: FLASH : PRINT X$: NORMAL
5330  VTAB 5
5334  PRINT "TIME","PLACE"
5335  PRINT "HOURS AFTER","X-GRID","Y-GRID","DOSE RATE(R/DAY
)"
5340  IF I > NTIMES - 1 THEN 5910
5350  GOSUB 1300
5360  IF T > TLAST THEN  GOTO 5910
5370  IF T < TSTART THEN I = I + 1: GOTO 5350
5380  GOSUB 5250
5390 X1 = X:Y1 = Y:T1 = T
5400 I = I + 1
5410  IF I > NTIMES - 1 THEN 5910
5420  GOSUB 1300: GOSUB 5250
5430  PRINT TIME$(I - 1),PLACE$(I - 1)
5440 N = (T - T1) / (ST / 60): IF N < 1 THEN N = 1
5470  IF PLACE$(I) = PLACE$(I - 1) THEN 5580
5480 TX = (X - X1) / N:TY = (Y - Y1) / N
5490  FOR J = 1 TO N
5500 X = X1 + J * TX
5510 Y = Y1 + J * TY
5520 T = T1 + J * ST / 60
5530  IF T > TLAST THEN 5910
5550  GOSUB 5650
5560  NEXT
5570  GOTO 5390
```

```
5580  FOR J = 1 TO N
5590 T = T1 + J * ST / 60
5600  IF T > TLAST THEN 5910
5620  GOSUB 5650
5630 'NEXT
5640  GOTO 5390
5645  REM  SUBROUTINE TO GET DATA BETWEEN POINTS
5650 X9 = 29 -  INT (X)
5660 Y9 =  INT (Y + 10)
5670 R = 45 * Y9 + X9
5680  IF T > H8 THEN 5720
5690  IF R = R1 AND K = K1 THEN 5820
5700  GOSUB 5880
5705 D8 = D9
5710  GOTO 5820
5720  IF T <  = H9 THEN 5740
5730 H1 = H9:K = K + 1:H9 = H(K + 1)
5740 R = R + K * 1125
5745  IF T = H8 + ST / 60 THEN R1 = 0
5750  IF R = R1 AND K = K1 THEN 5810
5760  GOSUB 5880
5770 D1 = D9
5775 R = R + 1125:K = K + 1
5780  GOSUB 5880
5785 R = R - 1125:K = K - 1
5790 A = (D9 - D1) / (H9 - H1)
5800 B = D9 - A * H9
5810 D8 = A * T + B
5820 D6 = D8
5830  IF D6 > .0999 THEN  PRINT T,X,Y,D6
5840 D7 = D6 / 24
5845 TI = 73 +  INT (T)
5850 DOSE(TI) = DOSE(TI) + D7
5860 R1 = R:K1 = K
5870  RETURN
5875  REM  SUBROUTINE TO READ DOSE FOR POSITION FROM RANDOM
ACCESS FILES
5880  IF F(K) <  > 0 THEN 5885
5882  IF  SQR ((X - X0) ^ 2 + (Y - Y0) ^ 2) > 5.58 THEN D9 =
 0: RETURN
5883 D9 = .069
5884  RETURN
5885  PRINT D$;"READ BAKER,R";R
5890  INPUT D9
5895 D9 = D9 / F(K)
5900  RETURN
5910  PRINT D$;"CLOSE BAKER"
5915  PRINT TIME$(I);PLACE$(I)
5920 Z$ = X$ + " WATER"
5930  FOR I = 73 TO TLAST + 73
```

```
5940 DOSE(I) = DOSE(I) / (60 / ST)
5950  NEXT
5960  PRINT D$;"OPEN   ";Z$;",D2"
5970  PRINT D$;"DELETE ";Z$
5980  PRINT D$;"OPEN   ";Z$
5990  PRINT D$;"WRITE  ";Z$
6000  PRINT TLAST + 72
6005  REM  0-72 ARE FOR BAKER
6006  REM  73 TO TLAST ARE FOR BAKER
6010  FOR I = 0 TO TLAST + 72
6020  PRINT DOSE(I)
6030  NEXT
6040  PRINT D$;"CLOSE  ";Z$
6050  POKE 34,0
6060  IF PR = 0 THEN 6110
6070  FOR I = 73 TO TLAST + 72
6080  PRINT I - 73,DOSE(I)
6090  NEXT
6100  PRINT D$;"PR#0"
6110  PRINT D$;"RUN MENU,D1"

]
```

Program:	LATE WATER
Program Objective:	To allow input of manually obtained ship's late lagoon water dose; late water dose is that dose received after BAKER + 8.
Description:	This program accepts inputs from the keyboard to daily lagoon water dose received after BAKER + 8. The daily doses, having been determined in a separate analysis, are input and edited by this program. The "late water" file created is a continuation of the "water" file created by program WATER INTENSITY. Both the WATER and LATE WATER files are read by program SHIP CONTAMINATION.
Input:	From keyboard, daily doses
Output:	File "ship" LATE WATER

Table 4-4 Late Water

```
100  REM  THIS PROGRAM CREATES OR EDITS
110  REM  THE LATE WATER DOSE FILE
120 D$ =  CHR$ (4)
125  DIM H30(100)
130  HOME
140  INPUT "EDIT(E) OR CREATE(C) WATER DOSE FILE?";A$
150  IF A$ = "E" THEN  GOTO 400
160  IF A$ = "C" THEN  GOTO 190
170  PRINT "ENTER "E" FOR EDIT OR "C" FOR CREATE"
180  PRINT
185  GOTO 140
190  REM  BEGIN CREATE SECTION
200  HOME : INPUT "NAME OF SHIP?  ";X$
210  INPUT "HOW MANY DAYS TO INPUT? ";NDAYS
230  FOR I = 1 TO NDAYS
240  PRINT "ENTRY # ";I;"   B+";I + 8;" = "
250  HTAB 13
260  INPUT H30(I)
300  NEXT
310  HOME : VTAB 5: HTAB 5
320  INPUT "DO YOU WANT TO CHANGE ANY VALUES? (Y/N)";A$
330  IF A$ = "Y" THEN  GOTO 600
340  GOTO 800: REM  WRITE OUTPUT FILE
400  REM  INPUT DATA FOR EDITING
405  INPUT "NAME OF SHIP?;  ";X$
410  PRINT D$;"PR#0"
420 Z$ = X$ + " LATE WATER"
430  PRINT D$;"OPEN ";Z$;",D2"
440  PRINT D$;"READ ";Z$
450  INPUT NDAYS
460  FOR I = 1 TO NDAYS
470  INPUT H30(I)
480  NEXT
490  PRINT D$;"CLOSE ";Z$
600  REM
610  REM  EDIT PORTION OF PROGRAM
611  HOME : PRINT "CHANGE OR ADD VALUES?": INPUT "C OR A  ";
A$
612  IF A$ = "A" THEN  GOTO 1400
613  IF A$ = "C" THEN  GOTO 620
614  PRINT "ENTER C OR A": GOTO 611
620  HOME : REM  FIRST LIST THE VALUES
625  PRINT "ENTRY"; TAB( 12);"VALUE    (MREM/DAY)"
630  FOR I = 1 TO NDAYS
640  PRINT I; TAB( 5);"B+";I + 8; TAB( 12);"= ";H30(I)
650  NEXT
660  PRINT : PRINT "ENTER 0 TO QUIT"
670  INPUT "WHICH ENTRY TO CHANGE? ";E1
```

```
675  IF E1 = 0 THEN  GOTO 1400
680  PRINT "OLD VALUE FOR ENTRY ";E1;" = ";H30(E1)
690  PRINT
700  INPUT "INPUT NEW VALUE ";H30(E1)
710  HOME : INPUT "ANOTHER CHANGE? (Y/N)";A$
720  IF A$ = "N" THEN  GOTO 1400
730  IF A$ = "Y" THEN  GOTO 620
740  PRINT : PRINT "ANSWER Y OR N": GOTO 710
800  REM  WRITING THE OUTPUT FILE TO DISK
810 Z$ = X$ + " LATE WATER"
820  PRINT D$;"PR#0"
830  PRINT D$;"OPEN ";Z$;",D2"
840  PRINT D$;"DELETE";Z$
850  PRINT D$;"OPEN ";Z$
860  PRINT D$;"WRITE ";Z$
870  PRINT NDAYS
880  FOR I = 1 TO NDAYS
890  PRINT H30(I)
900  NEXT
910  PRINT D$;"CLOSE ";Z$
915  PRINT D$;"RUN MENU,D1"
920  END
1000  REM  ROUTINE TO ADD ADDITIONAL DATA ENTRIES I.E. MORE
DAYS
1010  REM
1020  HOME : INPUT "HOW MANY ADDITIONAL DAYS TO BE ENTERED?
";N2
1030 N3 = NDAYS + N2
1080  FOR I = NDAYS + 1 TO N3
1090  PRINT "ENTRY #  ";I;"  B+";I + 8;" = "
1100  INPUT H30(I)
1110  NEXT
1120  REM  LIST THE INPUTED DATA
1130  HOME
1140  VTAB 3: HTAB 10
1150  PRINT "THE NEW VALUES ARE"
1160  PRINT
1200  PRINT "ENTRY"; TAB( 12);"VALUE (MR/DAY)"
1210  FOR I = NDAYS + 1 TO N3
1220  PRINT I; TAB( 5);"B+";I + 8;" = "; TAB( 12);H30(I)
1225  PRINT
1230  NEXT : PRINT "ENTER 0 TO QUIT"
1240  INPUT "WHICH ENTRY TO CHANGE?";E1
1250  IF E1 = 0 THEN  GOTO 800
1260  PRINT "OLD VALUE FOR ENTRY";E1;" = ";H30(E1)
1270  PRINT
1280  INPUT "INPUT NEW VALUE ";H30(E1)
1290  HOME : INPUT "ANOTHER CHANGE? (Y/N)";A$
1294  IF A$ = "Y" THEN  GOTO 1120
1295 NDAYS = N3
```

```
1300  IF A$ = "N" THEN  GOTO 800
1320  PRINT : PRINT "ANSWER Y OR N ": GOTO 1290
1400  HOME
1410  INPUT "WANT TO ADD ANY ENTRIES? (Y/N)";A$
1420  IF A$ = "Y" THEN  GOTO 1000
1430  IF A$ = "N" THEN  GOTO 800
1440  PRINT "ENTER Y OR N": GOTO 1410
```

Program: TARGET INTENSITY

Program Objective: To estimate the radiation dose received by support ship personnel while alongside or passing radioactive target ships--Shot BAKER only.

Description: As this program progresses through a ship path, two things are accomplished:

1. If the file indicates the support ship is alongside a target ship, the program calculates the radiation dose based upon the length of time alongside, the time after detonation, and the intensity of the particular target ship. The alongside target ship intensity I at one hour after the shot is obtained from the file TARGET SHIPS. The dose is calculated from:

$$D = \frac{I}{.3} \left[\frac{1}{t_1^{.3}} - \frac{1}{t_2^{.3}} \right] ,$$

where t_1 is the time the ship came alongside, and t_2 the time it departed; both times are measured in hours after detonation.

2. If the file indicates the support ship is passing a target ship, the dose for this pass from "ship" PASSES is added to the dose received in that hour.

The output is a file indicating dose for each hour attributable to contact with radioactive target ships.

Input: File TARGET SHIPS with alongside one-hour intensity for each target ship.
File "ship" PASSES with dose from passing target ships.
File "ship" PATH with the path of the ship.

Output: File "ship" TARGETS with hourly dose from all target ships.

Table 4-5   Target Intensity

```
1       REM  ADOSE  = ABLE TARGET INTENSITY
2       REM  BDOSE  = BAKER TARGET INTENSITY
3       REM  PDOSE  = PASSING SHIP DOSE
4       REM  NTIMES = LENGTH OF PATH
5       REM  PTIME  = TIME PASSED TARGET SHIP
6       REM  PNAME  = TARGET SHIP PASSED AT PTIME
7       REM  NAME   = NAME OF A TARGET SHIP FROM TARGET SHIP FILE
8       REM  D0     = INITIAL RADIATION FROM TARGET SHIP
19      HOME :
        VTAB 8
20      D$ = CHR$ (4)
30      PRINT D$;"MON,C"
40      C = 0
50      PRINT "TARGET INTENSITY PROGRAM":
        PRINT
60      PRINT "SEND TO PRINTER ";:
        GET A$
70      PRINT A$
80      IF A$ = "Y" THEN
            PRINT "WHAT SLOT IS THE PRINTER IN?";:
            GET P$:
            PRINT P$
90      IF A$ = "Y" AND P$ > "3" OR A$ = "Y" AND P$ < "1" THEN
            HOME :
            VTAB 8:
            GOTO 50
100     DIM ADOSE(25),BDOSE(300)
110     DIM PDOSE(300),PNAME$(300)
120     DIM PLACE$(300),TIME$(300),SHIP$(300)
130     DIM NAME$(90),D0(90)
140     INPUT "NAME OF SHIP ";X$
150     PRINT D$;"OPEN TARGET SHIPS,D1"
160     PRINT D$;"READ TARGET SHIPS"
170     INPUT NSHIPS
180     FOR I = 1 TO NSHIPS
            INPUT NAME$(I),D0(I)
200         NEXT I
210     PRINT D$;"CLOSE TARGET SHIPS"
220     Z$ = X$ + " PATH"
230     PRINT D$;"OPEN ";Z$;",D2"
240     PRINT D$;"READ ";Z$
250     INPUT NTIMES
```

```
260     FOR I = 0 TO NTIMES - 1
270         INPUT TIME$(I),PLACE$(I),SHIP$(I)
280         NEXT
290     PRINT D$;"CLOSE ";Z$
300     IF NTIMES < 2 THEN 9000
310     Z$ = X$ + " PASSES"
320     PRINT D$;"OPEN ";Z$;",D2"
330     PRINT D$;"READ ";Z$
340     INPUT PASSES
350     IF PASSES = 0 THEN 390
360     FOR I = 1 TO PASSES
370         INPUT PTIME$,PNAME$(I),PDOSE(I)
380         NEXT I
390     PRINT D$;"CLOSE ";Z$
400     IF A$ = "Y" THEN
            PRINT D$;"PR#";P$
401     REM
402     REM  N = NOT NEAR TARGET SHIP
403     REM  L = LEAVING PROXIMITY OF TARGET SHIP
404     REM  P = PASSING A TARGET SHIP
405     REM  A = COMING ALONGSIDE A TARGET SHIP
406     REM
410     FOR I = 0 TO NTIMES - 1
420         T$ = LEFT$ (SHIP$(I),1)
430         IF T$ = "N" THEN
                GOTO 520
440         IF T$ = "L" THEN
                GOTO 520
450         L = LEN (SHIP$(I)) - 1
460         SHIP$(I) = RIGHT$ (SHIP$(I),L)
470         GOSUB 3000
480         IF T$ = "P" THEN
                GOSUB 1000
490         IF T$ = "A" THEN
                GOSUB 2000
500         IF TEST = 0 THEN
                GOSUB 4000
510         TEST = 0
520         NEXT I
524     REM
525     REM   FIND LAST TIME RECEIVED DOSE FROM A TARGET SHIP
526     REM
530     FOR I = 300 TO 0 STEP - 1
540         IF BDOSE(I) < > 0 THEN 570
550         NEXT I
560     PRINT "NO DATA FOUND FOR BAKER"
570     Z$ = X$ + " TARGETS"
580     PRINT D$;"OPEN  ";Z$;",D2"
590     PRINT D$;"DELETE ";Z$
600     PRINT D$;"OPEN  ";Z$
610     PRINT D$;"WRITE ";Z$
620     FOR J = 0 TO 24
630         PRINT ADOSE(J)
640         NEXT J
```

```
650     PRINT I + 1
660     FOR J = 0 TO I
            PRINT BDOSE(J)
680         NEXT J
690     PRINT D$;"CLOSE ";Z$
700     PRINT D$;"NOMON,C"
710     PRINT D$;"PR#0"
720     PRINT D$;"RUN MENU,D1"
730     REM
740     REM  SUBROUTINE TO GET DOSE FROM PASSING TARGET SHIPS
750     REM
1000    PRINT TIME$(I);"  PASSING ";SHIP$(I);
1010    C = C + 1
1014    REM
1015    REM  MATCH PATH AND PASSES FILES
1016    REM
1020    IF PNAME$(C) = SHIP$(I) THEN 1500
1030    PRINT "FILES DO NOT MATCH, NAMES ARE"
1040    PRINT C - 1,PNAME$(C - 1),PDOSE(C - 1)
1050    PRINT C,PNAME$(C),PDOSE(C)
1060    PRINT C + 1,PNAME$(C + 1),PDOSE(C + 1)
1070    PRINT
1080    PRINT "RUN PROGRAM TO UPDATE SHIPS PASSED"
1100    GET A$:
        PRINT :
        PRINT D$;"RUN MENU,D1"
1490    REM
1491    REM  D IS DOSE FROM PASSES FILE
1492    REM  ADD DOSE TO THE DOSE FOR THE PROPER DAY FOR ABLE OR BAK
ER
1493    REM
1500    D = PDOSE(C)
1510    POKE 36,32:
        PRINT D
1530    IF DAY < 25 THEN
            ADOSE(DAY - 1) = ADOSE(DAY - 1) + D:
            GOTO 1550
1540    BDOSE(DAY - 25) = BDOSE(DAY - 25) + D
1550    TEST = 1:
        RETURN
1600    REM
1610    REM  SUBROUTINE TO GET DOSE FROM BEING ALONGSIDE TARGET SHIP
S
1620    REM
2000    IF DAY < 25 THEN
            TEST = 1:
            PRINT "NO ACTIVATION FROM ABLE YET":
            RETURN
2010    PRINT TIME$(I);"  ALONGSIDE ";SHIP$(I);
2020    D = 0:
        T1 = 0:
        T2 = 0
2025    REM  MATCH SHIPS
2030    FOR J = 1 TO NSHIPS
```

```
2040        IF SHIP$(I) < > NAME$(J) THEN
                GOTO 2060
2050        D = DO(J):
            J = NSHIPS
2060        NEXT J
2065    IF D = 0 THEN
            PRINT :
            PRINT SHIP$(I);" NOT FOUND";:
            TEST = 1:
            RETURN
2067    REM   FIND OUT HOW LONG WAS ALONGSIDE
2070    T1 = TIME - 608.5
2080    FOR M = I + 1 TO NTIMES - 1
2090        IF LEFT$ (SHIP$(M),1) < > "L" THEN 2120
2100        IF SHIP$(I) < > RIGHT$ (SHIP$(M),L) THEN 2120
2110        GOSUB 3500:
            M = NTIMES - 1
2120        NEXT M
2124    IF DAY > D1Y THEN
            PRINT D1Y;H1R;M1N;:
            GOSUB 4000
2125    REM  IF SPANS TWO DAYS CALCULATE PART
2126    IF DAY < > D1Y THEN
            GOSUB 2500
2129    REM   GET DOSE FROM THIS CONTACT
2130    DOSE = (1 / T1) ^ .3 - (1 / T2) ^ .3
2140    DOSE = DOSE * D / .3
2145    DOSE = DOSE * 1000:
        REM  R TO MR
2146    DOSE = INT (DOSE)
2150    POKE 36,32:
        PRINT DOSE
2155    REM  ADD TO DOSE FOR DAY
2160    BDOSE(DAY - 25) = BDOSE(DAY - 25) + DOSE
2170    TEST = 1:
        RETURN
2400    REM
2410    REM   SUBROUTINE WHEN CONTACT OVER MULTIPLE DAYS
2420    REM
2500    T3 = T2
2510    ND = D1Y - DAY
2520    FOR J = 1 TO ND
2530        T2 = 24 * (DAY + 1) - 608.5
2540        GOSUB 2130
2550        T1 = T2:
            DAY = DAY + 1
2560        NEXT J
2570    T2 = T3
2580    IF DAY < > D1Y THEN
            PRINT D1Y,H1R,MIN:
            GOSUB 4000
2590    RETURN
2900    REM
2910    REM   SUBROUTINE TO GET TIME WHEN CONTACT TARGET SHIP
```

```
2920    REM
3000    DAY = VAL ( LEFT$ (TIME$(I),2))
3010    HOUR = VAL ( MID$ (TIME$(I),3,2))
3020    MINUTE = VAL ( RIGHT$ (TIME$(I),2))
3030    TIME = 24 * DAY + HOUR + MINUTE / 60
3040    RETURN
3400    REM
3410    REM   SUBROUTINE TO GET LEAVING TIME
3420    REM
3500    D1Y = VAL ( LEFT$ (TIME$(M),2))
3510    H1R = VAL ( MID$ (TIME$(M),3,2))
3520    M1N = VAL ( RIGHT$ (TIME$(M),2))
3530    T2 = 24 * D1Y + H1R + M1N / 60 - 608.5
3540    RETURN
4000    PRINT 'ERROR IN PATH FILE(NOT N,L,P,A)'
4010    PRINT TIME$(I),PLACE$(I),SHIP$(I)
4020    PRINT 'DO YOU WANT TO CONTINUE';
4030    GET A$:
        PRINT A$:
        IF A$ = 'Y' THEN
            RETURN
4040    INPUT 'WANT TO GO TO MENU ?';A$
4050    IF LEFT$ (A$,1) = 'Y' THEN
            PRINT D$;'RUN MENU,D1'
4060    PRINT 'ERROR TERMINATION, RETURNING TO BASIC'
4080    END
9000    PRINT 'NOT ENOUGH DATA, ONLY ';NTIMES;' POINTS'
9010    GET A$:
        PRINT :
        PRINT D$;'RUN MENU,D1'
```

Program: SHIP CONTAMINATION

Program Objective: To calculate doses to support ship personnel due to ship contamination.

Description: This program provides daily estimates of doses accrued by support ship personnel due to ship contamination for the duration of post-BAKER operations in the lagoon. Contamination intensities are calculated numerically from the integral formulation developed in Section 2.5:

$$I_c(t_n) = 3.53\, t_n^{-1.3} \sum_{i=0}^{n} t_i^{1.3}\, I_w(t_i),$$

where $I_w(t)$ is the lagoon water intensity at time t after the BAKER detonation. The dose accrued between times t_1 and t_2 is then calculated from the equation

$$D(t_1 \text{ to } t_2) = \frac{1}{.3}\, t_1^{1.3}\, I_c(t_1) \left[t_1^{-.3} - t_2^{-.3} \right]$$

Output file contains the contamination dose accrued each day the ship was in the lagoon. In addition, the last element in the file is the ship contamination factor at the time the ship departed the lagoon.

Input: File "ship" WATER
File "ship" PATH
File "ship" LATE WATER

Output: File "ship" SELF

Table 4-6 Ship Contamination

```
1  REM  I=DOSE # WHICH STARTS AT 89 TO GO WITH WHERE CREATED
2  REM  H1=STARTING HOUR FOR CURRENT DAY
3  REM  H2=HOUR AFTER BAKER WHEN FIRST TOUCH HOT WATER ON A
DAY
4  REM  H3=ENDING HOUR FOR DAY IN HOURS AFTER BAKER
5  REM  H20=TOTAL DOSE FROM WATER FOR A DAY
6  REM  TD=SUM OF DOSE TIMES TIME TO 1.3 POWER
7  REM  ITEN=INTENSITY
8  REM  SELF=SHIP CONTAMINATION FOR DAY
9  REM  HR=ARRAY STORING VALUES OF H2
10  HOME : VTAB 8
11 T$ = " ":T1 =  PEEK ( - 15382):T2 =  PEEK ( - 15380):T3 =
  PEEK ( - 15378)
12  IF T1 <  > 8 OR T2 <  > 4 OR T3 <  > 2 THEN 20
13  PRINT  CHR$ (4);"IN#3"
14  PRINT  CHR$ (4);"PR#3"
15  PRINT  CHR$ (23);"C"
16  INPUT T$
18  PRINT  CHR$ (4);"PR#0"
19  PRINT  CHR$ (4);"IN#0"
20 ABLE = 3
30 BAKER = 100
35  DIM H30(100)
40  DIM DOSE(300),H20(300)
50  DIM HR(300),TD(300)
60  DIM SELF(300),ITEN(300)
70 D$ =  CHR$ (4): REM  CTRL-D
80  INPUT "NAME OF SHIP IS ? ";X$
90  PRINT
100  INPUT "SEND OUTPUT TO PRINTER?";ANS$
110  PRINT
120  IF  LEFT$ (ANS$,1) <  > "Y" THEN 160
130  INPUT "WHAT SLOT IS THE PRINTER IN?";P$
140  IF P$ > "3" OR P$ < "1" THEN  HOME : VTAB 6: PRINT X$:
GOTO 100
150  PRINT
160  INPUT "ENTER TOTAL DOSE ON BAKER DAY (MR) ";BDAY
170  PRINT
180  INPUT "HOW MANY HOURS AFTER BAKER DID IT FIRST ENTER TH
E LAGOON? ";HR(0)
184  PRINT
185  INPUT "WHAT IS THE BUILDUP FACTOR FOR THIS RUN?";B9
186  REM  B9 IS THE BUILDUP FACTOR "C" WHICH APPEARS IN THE
EQUATIONS IN THE TEXT
187  REM  I9 = SATURATION FACTOR
188  INPUT " WHAT IS THE SATURATION FACTOR FOR THIS RUN? ";I
9
189 B9 = B9 / 24: REM  CONVERT UNITS
```

```
190 Z$ = X$ + " WATER"
200  PRINT
201 I9 = I9 * 24 ^ .3: REM  CONVERT UNITS
210  PRINT "READING ";Z$
220  PRINT  CHR$ (7)
230  PRINT D$;"OPEN ";Z$;",D2"
240  PRINT D$;"READ ";Z$
250  INPUT N
260  FOR I = 0 TO N
270  INPUT DOSE(I)
280 DOSE(I) = 1000 * DOSE(I)
290  NEXT
300  PRINT D$;"CLOSE ";Z$
302  REM  CALCULATE VALUES FOR BAKER DAY
305 H2O(0) = BDAY
310 TD(0) = H2O(0) * HR(0) ^ 1.3
311  REM  X7 = EXPONENT IN INTENSITY EQUATION
312 X7 = B9 / I9 * TD(0)
313  REM  B9=BUILDUP FACTOR "C"
314  REM  I9=SATURATION FACTOR
315 ITEN(0) = I9 * HR(0) ^ ( - 1.3) * (1 -  EXP ( - X7))
320 SELF(0) = (1 / .3) * (HR(0) ^ 1.3) * ITEN(0) * (HR(0) ^
( - .3) - 15 ^ ( - .3))
325 H3 = 15
330  FOR J = 1 TO 8
335 ZR = 0:S1 = 0:S2 = 0
340 H1 = H3 + 1:H2 = H1:H3 = H3 + 24
345  FOR K = 1 TO 24
350 I = 73 + 24 * (J - 1) + 15 + K
355  IF DOSE(I) = 0 THEN 395
360  IF ZR = 1 THEN H2O(J) = H2O(J) + DOSE(I): GOTO 395
365 ZR = 1:H2O(J) = DOSE(I):H2 = H1 + K - 1
370  IF H2 = H1 THEN 395
372  REM  CALCULATE FOR PORTION OF DAY PRIOR TO HOT WATER CO
NTACT
374 X7 = B9 / I9 * TD(J - 1)
375 IO = I9 * H1 ^ ( - 1.3) * (1 -  EXP ( - X7))
380 S1 = (1 / .3) * (H1 ^ 1.3) * IO * (H1 ^ ( - .3) - (H2 -
1) ^ ( - .3))
395  IF I = N THEN 405
400  NEXT K
405  IF ZR = 1 THEN 425
406  REM  CASE WHEN HAD NO HOT WATER CONTACT FOR WHOLE DAY
407 TD(J) = TD(J - 1)
409 X7 = B9 / I9 * TD(J - 1)
410 IO = I9 * H1 ^ ( - 1.3) * (1 -  EXP ( - X7))
415 S1 = (1 / .3) * (H1 ^ 1.3) * IO * (H1 ^ ( - .3) - H3 ^ (
 - .3))
417 ITEN(J) = IO
420  GOTO 440
```

```
422  REM  CALCULATE FOR PORTION OF DAY AFTER CONTACT WITH HO
T WATER
425 TD(J) = TD(J - 1) + H2O(J) * H2 ^ 1.3
426 X7 = B9 / I9 * TD(J)
430 ITEN(J) = I9 * H2 ^ ( - 1.3) * (1 -  EXP ( - X7))
435 S2 = (1 / .3) * (H2 ^ 1.3) * ITEN(J) * (H2 ^ ( - .3) - H
3 ^ ( - .3))
440 SELF(J) = S1 + S2
445 HR(J) = H2
450  NEXT J
500 B8 = B9 * 24: REM  CONVERT BACK TO ORIGINAL UNITS
501 I8 = I9 / 24 ^ .3: REM  CONVERT BACK TO ORIGINAL UNITS
540  PRINT D$;"PR#";P$
542  PRINT : PRINT T$
545  PRINT
546  PRINT " ","SHIP CONTAMINATION FOR THE USS ";X$
547  PRINT : PRINT "C FACTOR = ";B8
551  PRINT : PRINT "SATURATION FACTOR = ";I8
555  PRINT
560  PRINT "DAY","HOUR","WATER","RATE","DOSE"
570  PRINT "---","----","-----","----","----"
580  FOR J = 0 TO 7
590  PRINT J,HR(J),H2O(J),ITEN(J),SELF(J)
620  NEXT J
625  REM   CALCULATIONS WHEN NOT IN HOT WATER
630 Z$ = X$ + " PATH"
640  PRINT D$;"PR#0"
650  PRINT "READING ";Z$
660  PRINT  CHR$ (7)
670  PRINT D$;"OPEN ";Z$;",D2"
680  PRINT D$;"READ ";Z$
690  INPUT NTIMES
700  FOR I = 0 TO NTIMES - 1
710  INPUT TIME$,PLACE$,SHIP$
720  NEXT
730  PRINT D$;"CLOSE ";Z$
740  PRINT D$;"PR#";P$
750 DAY =  VAL ( LEFT$ (TIME$,2))
760 HOUR =  VAL ( MID$ (TIME$,3,2))
770 MINUTE =  VAL ( RIGHT$ (TIME$,2))
780 T = 24 * DAY + HOUR + MINUTE / 60 - 608.5
790 T =  INT ((T + 8.5) / 24)
810  IF T < 8 THEN 990
860 HR(9) = 208
870 J = 8
890  PRINT J,HR(J),H2O(J),ITEN(J),
900 SELF(J) = (1 / .3) * (HR(J) ^ 1.3) * ITEN(J) * (HR(J) ^
( - .3) - HR(J + 1) ^ ( - .3))
910  PRINT SELF(J)
915  IF T = 8 THEN 990
```

```
916  REM  READ LATE WATER DOSES
917  GOSUB 1300
920  FOR J = 9 TO T
940 HR(J + 1) = HR(J) + 24
949 TD(J) = TD(J - 1) + H30(J) * HR(J) ^ 1.3
950 X7 = B9 / I9 * TD(J)
951 ITEN(J) = I9 * HR(J) ^ ( - 1.3) * (1 -  EXP ( - X7))
955  PRINT J,HR(J),H30(J),ITEN(J),
960 SELF(J) = (1 / .3) * (HR(J) ^ 1.3) * ITEN(J) * (HR(J) ^
( - .3) - HR(J + 1) ^ ( - .3))
970  PRINT SELF(J)
980  NEXT J
981 T8 = 0
982  FOR I = 0 TO T
983 T8 = T8 + SELF(I)
984  NEXT I
985  PRINT : PRINT "TOTAL SELF DOSE = ";T8
990 Z$ = X$ + " SELF"
1000  PRINT D$;"PR#0"
1010  PRINT "WRITING ";Z$
1020  PRINT  CHR$ (7)
1030  PRINT D$;"OPEN ";Z$;",D2"
1040  PRINT D$;"DELETE";Z$
1050  PRINT D$;"OPEN ";Z$
1060  PRINT D$;"WRITE ";Z$
1070  PRINT BDAY
1080  PRINT T
1090  FOR I = 0 TO T
1100  PRINT SELF(I)
1110  NEXT I
1115  PRINT ITEN(T)
1120  PRINT D$;"CLOSE ";Z$
1130  PRINT D$;"PR#0"
1140  HOME
1141  PRINT D$;"RUN MENU,D1"
1150  END
1300  REM      SUBROUTINE TO INPUT SHIP'S
1310  REM      LATE DAILY WATER DOSE
1320  REM      (I.E. GREATER THAN B+8)
1330  REM
1340 Z$ = X$ + " LATE WATER"
1350  PRINT D$;"PR#0"
1360  PRINT D$;"OPEN";Z$;",D2"
1370  PRINT D$;"READ";Z$
1380  INPUT NTIMES
1390  FOR I = 1 TO NTIMES
1400  INPUT H30(I + 8)
1410  NEXT
1420  PRINT D$;"CLOSE ";Z$
1430  PRINT D$;"PR#";P$
```

```
1440  RETURN

]
```

Program: RADIATION REPORT

Program Objective: To provide a written report of the radiation dose accrued by support ship personnel.

Description: This program reads files "ship" TARGETS, "ship" WATER, and "ship" SELF and prints a radiation summary report. This report contains a tabulation of daily film badge dose contributions from radioactive water and target ship sources for Shots ABLE and BAKER, and from ship contamination during the post-BAKER period. The free-field doses from the WATER, TARGETS and SELF files are converted to film badge doses via a conversion factor of 0.7. The water and ship contamination doses are multiplied by factors (1/3 and 2/3, respectively) to account for shielding afforded personnel above and below decks, as discussed in Section 4.

Input: File "ship" WATER
File "ship" TARGETS
File "ship" SELF
Date ship leaves lagoon for the last time.
Ship Apportionment Factor (see Table 2-7).

Output: Written report on daily dose contributions.

Table 4-7 Radiation Report

```
1  REM  DOSE  = HOURLY WATER ACTIVATION
2  REM   H2O  = DAILY WATER DOSE
3  REM   SHIP = DAILY TARGET SHIP DOSE
4  REM   SELF = DAILY SHIP CONTAMINATION DOSE
5  REM   ALL  = DAILY TOTAL DOSE
6  REM   ABLE = NUMBER OF DAYS FOR ABLE
7  REM   BAKER= NUMBER OF DAYS AFTER BAKER ALLOWED
8  REM   ITEN = DEPARTING LAGOON INTENSITY
9  REM   FRAC = APPORTIONMENT FACTOR
10  REM    BDAY= BAKER DAY DOSE
11  REM    NDAY= NUMBER OF DAYS OF DATA FROM SHIP CONTAMINAT
ION PROGRAM
19  HOME : VTAB 8
20 ABLE = 4
30 BAKER = 150
40  DIM DOSE(300),H2O(300),SHIP(300),ALL(300),SELF(300)
50 D$ =  CHR$ (4): REM  CTRL-D
60  INPUT "NAME OF SHIP IS ? ";X$
70  PRINT : PRINT
79  INPUT "WHAT SLOT IS THE PRINTER IN?";P$
80  IF P$ > "3" OR P$ < "1" THEN  HOME : VTAB 6: PRINT X$: G
OTO 70
81  PRINT
82  INPUT "USE PREVIOUSLY CREATED REPORT FILE?";PREP$: IF  L
EN (PREP$) = 0 THEN PREP$ = "Y"
83  IF  LEN (PREP$) > 1 THEN PREP$ =  LEFT$ (PREP$,1)
84  IF PREP$ <  > "Y" AND PREP$ <  > "N" THEN  PRINT  CHR$ (
7): HOME : GOTO 82
85  IF PREP$ = "N" THEN 109
86 Z$ = X$ + " REPORT"
87  PRINT D$;"OPEN ";Z$;",D2"
88  PRINT D$;"READ ";Z$
89  INPUT X2$: INPUT ITEN: INPUT N: INPUT FRAC
90  PRINT D$;"CLOSE";Z$
91  HOME : IF X$ <  > X2$ THEN  PRINT " SHIP NAMES DO NOT MA
TCH": PRINT "FILE NAME WAS ";X2$
92  PRINT "SHIP NAME IS ";X$: PRINT "DEPARTING INTENSITY WAS
 ";ITEN: PRINT "APPORTIONMENT FACTOR WAS ";FRAC
93  IF N < 7 THEN MM$ = "JUL ":MD = N + 25
94  IF N > 6 AND N < 38 THEN MM$ = "AUG ":MD = N - 6
95  IF N > 37 THEN MM$ = "SEP ":MD = N - 37
96  PRINT "LEFT LAGOON ";MM$;" ";MD
97  PRINT : PRINT
98  INPUT "WANT TO USE THESE INPUTS?";AN$: IF  LEN (AN$) = 0
 THEN AN$ = "N"
99  IF  LEN (AN$) > 1 THEN AN$ =  LEFT$ (AN$,1)
100  IF AN$ = "Y" THEN 181
109  PRINT
```

```
110  INPUT "MONTH OF LAST DATA POINT?";MM$
120  PRINT
130 MM$ =  LEFT$ (MM$,3)
140 MM$ = MM$ + " "
150  INPUT "DAY OF MONTH OF LAST POINT?";MD
160  IF MD < 1 OR MD > 31 THEN  PRINT : GOTO 150
170  PRINT
180  INPUT "HOW IS THE SHIP CONTAMINATION FOR THIS SHIP TO B
E APPORTIONED?(0-1.0)";FRAC
181  PRINT
185  INPUT "PRINT APPORTIONMENT FACTOR?";PFRAC$: IF  LEN (PF
RAC$) = 0 THEN PFRAC$ = "Y"
186  IF  LEN (PFRAC$) > 1 THEN PFRAC$ =  LEFT$ (PFRAC$,1)
187  IF PFRAC$ <  > "Y" AND PFRAC$ <  > "N" THEN  PRINT  CHR
$ (7): HOME : GOTO 185
188  PRINT
189  INPUT "PRINT DEPARTING INTENSITY?";PITEN$: IF  LEN (PIT
EN$) = 0 THEN PITEN$ = "Y"
190  IF  LEN (PITEN$) > 1 THEN PITEN$ =  LEFT$ (PITEN$,1)
191  IF PITEN$ <  > "Y" AND PITEN$ <  > "N" THEN  PRINT  CHR
$ (7): HOME : GOTO 189
194  PRINT
195  INPUT "WANT TO CREATE A NEW REPORT FILE?";AN$: IF  LEN
(AN$) = 0 THEN AN$ = "N"
196  IF  LEN (AN$) > 1 THEN AN$ =  LEFT$ (AN$,1)
199  REM
200  REM   READ IN DAILY SHIP CONTAMINATION
201  REM
209 Z$ = X$ + " SELF"
210  PRINT D$;"OPEN ";Z$;",D2"
220  PRINT D$;"READ ";Z$
230  INPUT BDAY
240  INPUT NDAY
250  FOR I = 0 TO NDAY
260  INPUT SELF(I + ABLE + 1)
270  NEXT I
280  INPUT ITEN
290  PRINT D$;"CLOSE ";Z$
294  REM
295  REM  READ IN DAILY TARGET ACTIVATION
296  REM
300 Z$ = X$ + " TARGETS"
310  PRINT D$;"OPEN ";Z$;",D2"
320  PRINT D$;"READ ";Z$
330  FOR J = 0 TO ABLE: INPUT SHIP(J): NEXT
340  FOR J = ABLE + 1 TO 24: INPUT DUMMY: NEXT
350  INPUT K: IF K > BAKER THEN K = BAKER
360  FOR J = ABLE + 1 TO ABLE + K: INPUT SHIP(J): NEXT
370  PRINT D$;"CLOSE ";Z$
374  REM
```

```
375  REM  READ IN HOURLY WATER ACTIVATION
376  REM
380 Z$ = X$ + " WATER"
390  PRINT D$;"OPEN ";Z$
400  PRINT D$;"READ ";Z$
410  INPUT N
420  FOR I = 0 TO N - 1
430  INPUT DOSE(I)
440  NEXT
450  PRINT D$;"CLOSE ";Z$
454  REM
455  REM  CALCULATE DAILY WATER ACTIVATION
456  REM
460  PRINT
470  PRINT D$;"PR#";P$
471  PRINT  CHR$ (9);"100N"
480  FOR I = 0 TO 15
490 H2O(0) = H2O(0) + DOSE(I)
500  NEXT
510  FOR J = 1 TO 3
520  FOR K = 1 TO 24
530 I = 24 * (J - 1) + 15 + K
540 H2O(J) = H2O(J) + DOSE(I)
550  NEXT
560  NEXT
570 W = ABLE + 1
580 H2O(W) = BDAY / 1000
590  FOR J = 1 TO 8
600  FOR K = 1 TO 24
610 I = 73 + 24 * (J - 1) + 15 + K
620 H2O(W + J) = H2O(W + J) + DOSE(I)
624 F1 = 1
630  IF I = N - 1 THEN 651
640  NEXT
650  NEXT
651  REM  READ IN LATE WATER DAILY DOSE
652 Z$ = X$ + " LATE WATER"
653  PRINT D$;"OPEN";Z$
654  PRINT D$;"READ";Z$
655  INPUT N9
656  FOR I = 14 TO N9 + 13
657  INPUT H2O(I):H2O(I) = H2O(I) / 1000: NEXT
658  PRINT D$;"CLOSE";Z$
660  PRINT  CHR$ (12)
670  FOR I = 0 TO 1 + ABLE + BAKER
672  REM              *****
673  REM  :  APPLY FILM BADGE CONVERSION FACTOR = .7
674  REM :  APPLY CREW ACTIVITY APPORTIONMENT FACTOR FOR WAT
ER DOSE = .333
675  REM : APPLY CREW ACTIVITY APPORTIONMENT FACTOR FOR SHIP
```

```
 CONTAMINATION = .667
676  REM              *****
680 H20(I) = H20(I) * 1000 * .7 * .333
690 H20(I) =  INT (H20(I))
700 SHIP(I) =  INT (.7 * SHIP(I) + .5)
710 SELF(I) = FRAC * SELF(I)
712 SELF(I) = SELF(I) * F1 * .667
720 SELF(I) =  INT (.7 * SELF(I) + .5)
727  REM
728  REM  SUM FOR TOTAL DAILY DOSE
729  REM
730 ALL(I) = H20(I) + SHIP(I) + SELF(I)
740  NEXT
750 CUM = 0
755  PRINT  CHR$ (27);"M"
760  PRINT : PRINT : PRINT : PRINT
770  PRINT " ","   USS ";X$;" CALCULATED FILM BADGE DOSE (IN
 MREM)"
780  PRINT
790  PRINT
791 Z6 = 14
792 Z7 = Z6 + 9
793 Z8 = Z7 + 8
794 Z9 = 11
800  POKE 36,Z6: PRINT "DATE";: POKE 36,Z7: PRINT "TIME";: P
OKE 36,Z8: PRINT "LAGOON";: POKE 36,Z8 + Z9: PRINT "
     TARGET";: POKE 36,Z8 + 2 * Z9: PRINT "SHIP";: POKE 36,Z
8 + 3 * Z9 + 5: PRINT "DAILY";: POKE 36,Z8 + 4 * Z9 +
     5: PRINT "CUM"
810  POKE 36,Z8: PRINT "WATER";: POKE 36,Z8 + Z9: PRINT "SHI
PS";: POKE 36,Z8 + 2 * Z9: PRINT "CONTAMINATION";: POKE
     36,Z8 + 3 * Z9 + 5: PRINT "TOTAL";: POKE 36,Z8 + 4 * Z9
 + 5: PRINT "TOTAL"
820  POKE 36,Z6: PRINT "-------------------------------------
-----------------------------------"
830 M$ = "JUL "
840 J = 0
850  FOR I = 0 TO ABLE - 1
860 J = J + 1
870 CUM = CUM + ALL(I)
880  POKE 36,Z6: PRINT M$;J;: POKE 36,Z7: PRINT "A+";I;: POK
E 36,Z8: PRINT H20(I);: POKE 36,Z8 + Z9: PRINT SHIP(
     I);: POKE 36,Z8 + 3 * Z9 + 5: PRINT ALL(I);: POKE 36,Z8
 + 4 * Z9 + 5: PRINT CUM
890  NEXT I
892 CUM = CUM + SHIP(ABLE)
895  POKE 36,Z6: PRINT "JUL 5 THRU 24";: POKE 36,Z8: PRINT H
20(ABLE);: POKE 36,Z8 + Z9: PRINT SHIP(ABLE);: POKE
     36,Z8 + 4 * Z9 + 5: PRINT CUM
900  PRINT
```

```
910 J = 24
920  FOR I = ABLE + 1 TO 1 + ABLE + BAKER
930 J = J + 1
940  IF J = 32 AND M$ = "JUL " THEN J = 1:M$ = "AUG "
950  IF J = 32 AND M$ = "AUG " THEN J = 1:M$ = "SEP "
960 CUM = CUM + ALL(I)
970  POKE 36,Z6: PRINT M$;J;: POKE 36,Z7: PRINT "B+";I - (1
+ ABLE);: POKE 36,Z8: PRINT H2O(I);: POKE 36,Z8 + Z9
     : PRINT SHIP(I);: POKE 36,Z8 + 2 * Z9: PRINT SELF(I);:
POKE 36,Z8 + 3 * Z9 + 5: PRINT ALL(I);: POKE 36,Z8 +
     4 * Z9 + 5: PRINT CUM
980  IF J = MD AND MM$ = M$ THEN 1000
990  NEXT I
995  REM
996  REM  SCALE DEPARTING INTENSITY
997  REM
1000  PRINT
1004 ITEN = ITEN * FRAC * .667
1005 ITEN =  INT (24 * ITEN + .5)
1010  IF PITEN$ = "Y" THEN  PRINT "SHIP CONTAMINATION DEPART
URE FACTOR = ";ITEN
1015  PRINT
1017  IF PFRAC$ = "Y" THEN  PRINT "APPORTIONMENT FACTOR IS "
;FRAC
1020  PRINT D$;"PR#0"
1037  IF AN$ <  > "Y" AND AN$ <  > "N" THEN  PRINT  CHR$ (7)
: GOTO 1030
1040  IF AN$ = "N" THEN 1200
1044  REM
1045  REM  PRINT FILE TO SAVE FINAL DOSE CALCULATIONS
1046  REM
1050 Z$ = X$ + " REPORT"
1060  PRINT D$;"OPEN   ";Z$;",D2"
1070  PRINT D$;"DELETE ";Z$
1080  PRINT D$;"OPEN   ";Z$
1090  PRINT D$;"WRITE  ";Z$
1100  PRINT X$
1110  PRINT ITEN
1120  PRINT I - (1 + ABLE)
1130  PRINT FRAC
1140  PRINT I + 1
1150  FOR J = 0 TO I
1160  PRINT ALL(J)
1170  NEXT J
1180  PRINT D$;"CLOSE ";Z$
1190  PRINT
1200  END
1210  REM  LATEST VERSION RAD REPORT 16 NOV 82 WITH MARGIN &
 POSITION CORRECTIONS
1220  REM  MODIFIED 6 FEB 84 FOR THE EPSON PRINTER
```

Program:	UPDATE
Program Objective:	To allow the modification of existing "ship" PATH and "ship" PASSES files.
Description:	This program performs edit functions on the PATH file and automatically updates the PASSES file if required. Edit functions are of three types: add, delete, or modify lines of data. Four types of modifications to a line of data are supported. The user may choose to modify date-time, location, or remarks data individually or as a group. As a screen of data is presented, the user is queried as to the accuracy of the data. A "yes" response proceeds to the next screen of data. A response of "no" will produce a question for the type of edit function: add (A), delete (D), modify (M). At the program prompt "ARE THESE OKAY?", three additional responses are supported. A return is interpreted as a yes (Y). Control-A is interpreted to mean the data are correct and there is no need to view the remainder of the file. An "R" response allows the starting of the next screen of data at any line desired. At the end of an edit session, the option is given to the user to save the modified file.
Input:	Existing files "ship" PATH "ship" PASSES
Output:	Updated files "ship" PATH "ship" PASSES

Table 4-8 Update

```
10 D$ =  CHR$ (4)
20  PRINT D$;"MON,C"
30  DIM PDOSE(300),PNAME$(300),PTIME$(300)
40  DIM TIME$(300),PLACE$(300),SHIP$(300)
50  HOME : VTAB 6
60  INPUT "NAME OF SHIP ";X$:Z$ = X$ + " PATH"
70  PRINT
80  PRINT D$;"OPEN ";Z$;",D2"
90  PRINT D$;"READ ";Z$
100  INPUT NTIMES
110  FOR I = 0 TO NTIMES - 1
120  INPUT TIME$(I),PLACE$(I),SHIP$(I)
130  NEXT
140  PRINT D$;"CLOSE ";Z$
150 Y$ = X$ + " PASSES"
160  PRINT D$;"OPEN  ";Y$
170  PRINT D$;"READ  ";Y$
180  INPUT PASSES
190  IF PASSES = 0 THEN 230
200  FOR I = 1 TO PASSES
210  INPUT PTIME$(I),PNAME$(I),PDOSE(I)
220  NEXT I
230  PRINT D$;"CLOSE ";Y$
240 I1 = 0:I2 = I1 + 19
250  POKE 34,0
260  IF I1 + 1 > NTIMES THEN 460
270  IF I2 > NTIMES - 1 THEN I2 = NTIMES - 1
280  HOME : PRINT " I    TIME    PLACE    SHIP"
290  FOR I = I1 TO I2
300  IF I < 10 THEN  PRINT " ";
310  PRINT I;"  ";TIME$(I);"  ";PLACE$(I);"   ";SHIP$(I)
320  NEXT I
330  VTAB 23: POKE 34,21
340  PRINT "ARE THESE OK SO FAR?";: GET A$: PRINT A$
350  IF A$ = "Y" THEN I1 = I2 + 1:I2 = I1 + 19: GOTO 250
360  IF A$ = "F" THEN 460
370  IF A$ = "N" THEN  PRINT "TYPE OF UPDATE(A,D,M,T,P,S)?";: GET
 A$: PRINT A$
380  IF A$ = "D" THEN 1000
390  IF A$ = "A" THEN 1100
400  IF A$ = "M" THEN 1200
410  IF A$ = "T" THEN 1300
420  IF A$ = "P" THEN 1400
430  IF A$ = "S" THEN 1500
440  IF A$ = "R" THEN 1600
450  GOSUB 2000: GOTO 250
460  POKE 34,0: HOME : VTAB 8
470  PRINT "DO YOU WANT TO SAVE THIS AS THE DATA FOR THIS SHIP?";
: GET A$: PRINT A$
471  IF A$ <  > "Y" THEN 720
480  IF C1 = 0 THEN 600
490  PRINT D$;"OPEN   ";Z$;",D2"
```

```
500  PRINT D$;"DELETE ";Z$
510  PRINT D$;"OPEN   ";Z$
520  PRINT D$;"WRITE  ";Z$
530  PRINT NTIMES
540  FOR I = 0 TO NTIMES - 1
550  PRINT TIME$(I)
560  PRINT PLACE$(I)
570  PRINT SHIP$(I)
580  NEXT I
590  PRINT D$;"CLOSE ";Z$
600  IF C2 = 0 THEN 720
610  PRINT D$;"OPEN  ";Y$;",D2"
620  PRINT D$;"DELETE";Y$
630  PRINT D$;"OPEN  ";Y$
640  PRINT D$;"WRITE ";Y$
650  PRINT PASSES
660  FOR I = 1 TO PASSES
670  PRINT PTIME$(I)
680  PRINT PNAME$(I)
690  PRINT PDOSE(I)
700  NEXT I
710  PRINT D$;"CLOSE ";Y$
720  PRINT D$;"NOMON,C"
730  PRINT D$;"RUN MENU,D1"
1000  HOME : INPUT "FIRST LINE TO DELETE=";A$:D1 =  VAL (A$)
1010  IF D1 < 0 THEN  PRINT  CHR$ (7);"TOO SMALL": GOTO 1000
1015  IF D1 >  = NTIMES THEN  PRINT  CHR$ (7);"TOO LARGE": GOTO 1
000
1017  IF D1 < I1 THEN I1 = D1 - 1: GOTO 1620
1018  IF D1 > I2 THEN  PRINT "CYCLE UNTIL COMES ON SCREEN": GET A
$: PRINT : GOTO 250
1020  INPUT "LAST  LINE TO DELETE=";A$:D2 =  VAL (A$)
1025  IF D2 < 0 THEN  PRINT  CHR$ (7);"TOO SMALL": GOTO 1020
1030  IF D2 >  = NTIMES THEN  PRINT  CHR$ (7);"TOO LARGE": GOTO 1
020
1035  IF D1 > D2 THEN  PRINT  CHR$ (7);"FIRST LARGER THAN LAST":
GOTO 370
1040  GOSUB 5000: IF C1 = 2 THEN  PRINT "ABORTED": GET A$: PRINT
: GOTO 250
1050  GOSUB 2500:C1 = 1
1055  IF D2 = NTIMES - 1 THEN NTIMES = D1: GOTO 250
1060 J = D2 - D1 + 1
1065  FOR I = D2 + 1 TO NTIMES - 1
1070 K = I - J
1075 TIME$(K) = TIME$(I)
1076 PLACE$(K) = PLACE$(I)
1077 SHIP$(K) = SHIP$(I)
1080  NEXT I
1090 NTIMES = NTIMES - J:S2 = 0: GOTO 250
1100 J = 300 - (NTIMES - 1):J1 =  - 1
1105 A$ = "N"
1110  IF I1 = 0 THEN  PRINT "ADD TO START OF FILE ?";: GET A$: PR
INT A$
1120  IF A$ <  > "Y" THEN  INPUT "LAST LINE BEFORE NEW DATA=";A$:
```

```
J1 =  VAL (A$)
1130  IF J1 = NTIMES - 1 THEN 1150
1140  FOR S1 = NTIMES - 1 TO J1 + 1 STEP  - 1
1142 TIME$(S1 + J) = TIME$(S1)
1144 PLACE$(S1 + J) = PLACE$(S1)
1146 SHIP$(S1 + J) = SHIP$(S1)
1148  NEXT S1
1150 A1 = 0:I = J1 + 1
1160  GOSUB 3500: IF A1$ =  CHR$ (13) THEN 1180
1162  GOSUB 4000: GOSUB 4500
1165 C1 = 1
1170  IF A$ =  CHR$ (13) THEN 1180
1175 I = I + 1:A1 = A1 + 1: GOTO 1160
1180  IF J1 = NTIMES - 1 THEN 1190
1181  FOR S1 = J1 + J + 1 TO 300
1182 TIME$(I) = TIME$(S1)
1184 PLACE$(I) = PLACE$(S1)
1186 SHIP$(I) = SHIP$(S1)
1188 I = I + 1: NEXT S1
1190 NTIMES = NTIMES + A1:S2 = 0:I2 = I1 + 19: GOTO 250
1200  INPUT "CHANGE ALL OF WHICH POINT?";A$:I =  VAL (A$)
1210  IF I < I1 OR I > I2 THEN  PRINT "OUTSIDE OF CURRENT DISPLAY
; ABORTED";: GET A$: PRINT : GOTO 250
1220  GOSUB 3500: GOSUB 4000: GOSUB 4500:C1 = 1
1230  GOTO 250
1300  INPUT " CHANGE TIME FOR WHICH POINT?";A$:I =  VAL (A$)
1310  IF I < I1 OR I > I2 THEN  PRINT "OUTSIDE OF CURRENT DISPLAY
; ABORTED";: GET A$: PRINT : GOTO 250
1320  GOSUB 3500:C1 = 1: GOTO 250
1400  INPUT " CHANGE PLACE FOR WHICH POINT?";A$:I =  VAL (A$)
1410  IF I < I1 OR I > I2 THEN  PRINT "OUTSIDE OF CURRENT DISPLAY
; ABORTED";: GET A$: PRINT : GOTO 250
1420  GOSUB 4000:C1 = 1: GOTO 250
1500  INPUT " CHANGE SHIP FOR WHICH POINT?";A$:I =  VAL (A$)
1510  IF I < I1 OR I > I2 THEN  PRINT "OUTSIDE OF CURRENT DISPLAY
; ABORTED";: GET A$: PRINT : GOTO 250
1520  GOSUB 4500:C1 = 1: GOTO 250
1600  POKE 34,0: HOME : VTAB 8
1605  PRINT "LAST LINE IS #";NTIMES - 1
1610  INPUT "START NEXT SCREEN AT LINE #";I1
1620 I2 = I1 + 19
1630  GOTO 250
2000  POKE 34,0: HOME : VTAB 2
2002  PRINT "POSSILE UPDATE RESPONSES"
2004  PRINT : PRINT
2010  PRINT "  A = ADD POINTS TO PATH"
2015  PRINT
2020  PRINT "  D = DELETE POINTS FROM PATH"
2025  PRINT
2030  PRINT "  M = MODIFY ALL PARTS OF A POINT"
2035  PRINT
2040  PRINT "  T = CHANGE TIME OF A POINT"
2045  PRINT
2050  PRINT "  P = CHANGE PLACE OF A POINT"
```

```
2055  PRINT
2060  PRINT "  S = CHANGE SHIP OF A POINT"
2063  PRINT
2065  PRINT "  R = RECYCLE UPDATE TO A LINE NUMBER"
2066  PRINT
2067  PRINT "  F = FINISHED WITH ALL CHANGES"
2070  VTAB 23: INVERSE : PRINT "HIT ANY KEY TO CONTINUE"; NORMAL
2080  GET A$: PRINT
2090  RETURN
2500 T1$ = TIME$(D1):T2$ = TIME$(D2)
2510  FOR S1 = 0 TO PASSES
2520  IF T1$ > PTIME$(S1) THEN  NEXT S1: RETURN
2530  IF T1$ <  > PTIME$(S1) THEN S1 = S1 + 1: GOTO 2600
2540 D3 = D1
2550  IF  LEFT$ (SHIP$(D3),1) = "P" THEN 2590
2560 D3 = D3 + 1:T3$ = TIME$(D3)
2570  IF T3$ <  > T1$ THEN S1 = S1 + 1: GOTO 2600
2580  IF  LEFT$ (SHIP$(D3),1) <  > "P" THEN 2560
2590  IF  RIGHT$ (SHIP$(D3), LEN (SHIP$(D3)) - 1) <  > PNAME$(S1)
 THEN 2560
2600  IF T2$ < PTIME$(S1) THEN S1 = PASSES: NEXT S1: RETURN
2610  FOR S2 = S1 TO PASSES
2620  IF PTIME$(S2) < T2$ THEN  NEXT S2: GOTO 2700
2630  IF PTIME$(S2) > T2$ THEN S2 = S2 - 1: GOTO 2700
2640 D3 = D2
2650  IF PNAME$(S2) =  RIGHT$ (SHIP$(D3), LEN (SHIP$(D3)) - 1) TH
EN 2700
2660 D3 = D3 - 1
2670  IF TIME$(D3) = T2$ THEN 2650
2680 S2 = S2 - 1
2700 J = S2 - S1 + 1
2710  FOR K = S2 + 1 TO PASSES
2720 PTIME$(K - J) = PTIME$(K)
2722 PNAME$(K - J) = PNAME$(K)
2724 PDOSE(K - J) = PDOSE(K)
2730  NEXT K
2740 PASSES = PASSES - J
2745 C2 = 1
2750  RETURN
3000  FOR S1 = S2 TO PASSES
3010  IF PTIME$(S1) < TIME$(I) THEN  NEXT S1:S1 = PASSES + 1: GOT
O 3060
3020  IF PTIME$(S1) = TIME$(I) AND PNAME$(S1) = T2$ THEN 3080
3030  FOR S3 = PASSES TO S1 STEP  - 1
3040 PTIME$(S3 + 1) = PTIME$(S3)
3042 PNAME$(S3 + 1) = PNAME$(S3)
3044 PDOSE(S3 + 1) = PDOSE(S3)
3050  NEXT S3
3060 PTIME$(S1) = TIME$(I)
3070 PNAME$(S1) =  RIGHT$ (T2$, LEN (T2$) - 1)
3080  INPUT "DOSE FROM THIS PASS=";PDOSE(S1)
3085  IF S1 < PASSES THEN S1 = PASSES: NEXT S1
3090 PASSES = PASSES + 1
3100  RETURN
```

```
3500  PRINT "TIME ";: GET A1$: PRINT A1$;:
3600  IF A1$ =  CHR$ (13) THEN  RETURN
3710  GET A2$: PRINT A2$;: IF A2$ =  CHR$ (8) THEN  GET A1$: PRINT A1
$;: GOTO 3600
3720  GET A3$: PRINT A3$;: IF A3$ =  CHR$ (8) THEN 3710
3730  GET A4$: PRINT A4$;: IF A4$ =  CHR$ (8) THEN 3720
3740  GET A5$: PRINT A5$;: IF A5$ =  CHR$ (8) THEN 3730
3750  GET A6$: PRINT A6$;: IF A6$ =  CHR$ (8) THEN 3740
3800 TIME$(I) = A1$ + A2$ + A3$ + A4$ + A5$ + A6$
3900  RETURN
4000  PRINT "   PLACE ";: GET A1$: PRINT A1$;
4010  GET A2$: PRINT A2$;: IF A2$ =  CHR$ (8) THEN  GET A1$: PRINT A1
$;: GOTO 4010
4020  GET A3$: PRINT A3$;: IF A3$ =  CHR$ (8) THEN 4010
4030  GET A4$: PRINT A4$;: IF A4$ =  CHR$ (8) THEN 4020
4040  GET A5$: PRINT A5$;: IF A5$ =  CHR$ (8) THEN 4030
4100 PLACE$(I) = A1$ + A2$ + A3$ + A4$ + A5$
4200  RETURN
4500  INPUT "  SHIP ";T2$
4510 L =  LEN (T2$)
4520 T1$ =  LEFT$ (T2$,1)
4530  IF T1$ = "N" THEN 4600
4540  IF L > 1 THEN 4560
4550  FLASH : PRINT "BAD INPUT, TRY AGAIN": NORMAL : GOTO 4500
4560  IF T1$ = "L" THEN 4600
4570  IF T1$ = "P" THEN  GOSUB 3000:C2 = 1: GOTO 4600
4580  IF T1$ = "A" THEN 4600
4590  GOTO 4550
4600 SHIP$(I) = T2$
4700  RETURN
5000 J1 = D1 - 1: IF J1 < 0 THEN J1 = 0
5010 J2 = D2 + 1: IF J2 = NTIMES THEN J2 = J2 - 1
5020  POKE 34,0
5030  HOME : PRINT " I   TIME   PLACE   SHIP"
5040 J3 = J1 + 19
5045  IF J1 > NTIMES - 1 THEN 5140
5050  IF J3 > NTIMES - 1 THEN J3 = NTIMES - 1
5060  FOR J = J1 TO J3
5070  IF J >  = D1 THEN  INVERSE
5075  IF J > D2 THEN  NORMAL
5080  IF J < 10 THEN  PRINT " ";
5090  PRINT J;"  ";TIME$(J);"  ";PLACE$(J);"   ";SHIP$(J)
5110  NEXT J
5120  NORMAL
5130  PRINT
5140  PRINT "OK?";: GET A$: PRINT A$
5150  IF A$ <  > "Y" THEN C1 = 2: RETURN
5160  IF D2 < J3 THEN  HOME : RETURN
5170 J1 = J1 + 20
5180  HOME : PRINT " I   TIME   PLACE   SHIP"
5190  IF D1 = 0 THEN 5040
5200 K = D1 - 1
5210  IF J < 10 THEN  PRINT " ";
5220  PRINT K;"  ";TIME$(K);"  ";PLACE$(K);"   ";SHIP$(K)
5230  GOTO 5040
```


]

Program:	UPDATE TARGET SHIPS
Program Objective:	To modify the file TARGET SHIPS by deletion, addition, or modification.
Description:	The file TARGET SHIPS contains the names of most target ships and their one-hour intensities after Shot BAKER. This program allows the intensities to be modified and ships to be added or deleted, as required.
Input:	Existing file TARGET SHIPS
Output:	Updated file TARGET SHIPS

Table 4-9 Update Target Ships

```
10      DIM NAME$(90)
15      DIM DOSE1(90)
20      D$ = CHR$ (4)
30      PRINT D$;"OPEN TARGET SHIPS,D1"
40      PRINT D$;"READ TARGET SHIPS"
50      INPUT NSHIPS
60      IF NSHIPS = 0 THEN 100
70      FOR I = 1 TO NSHIPS
80          INPUT NAME$(I),DOSE1(I)
85          DOSE1(I) = DOSE1(I) * 24
90          NEXT I
100     PRINT D$;"CLOSE TARGET SHIPS"
110     ADDED = 0
115     PRINT "WANT TO ADD TARGET SHIPS? ";:
        GET A$:
        PRINT A$:
        IF A$ < > "Y" THEN 200
120     PRINT "NEW TARGET SHIP NAME ";
121     GET A$:
        PRINT A$;:
        IF A$ = CHR$ (13) THEN
            GOTO 200
122     INPUT "";N$
123     N$ = A$ + N$
130     IF LEFT$ (N$,1) = CHR$ (13) THEN 200
135     CHECK = 0
140     INPUT "INTENSITY AT 1 HOUR(R/DAY) ";D
150     IF D > 0 THEN 190
155     CHECK = CHECK + 1:
        IF CHECK > 1 THEN 120
160     PRINT "BAD INPUT,TRY AGAIN":
        GOTO 140
190     ADDED = ADDED + 1
191     NAME$(NSHIPS + ADDED) = N$
192     DOSE1(NSHIPS + ADDED) = D
193     GOTO 120
200     PRINT
201     PRINT "I";:
        POKE 36,5:
        PRINT "NAME";:
        POKE 36,23:
        PRINT "DOSE RATE (R/DAY)"
```

```
202     PRINT "----------------------------------------"
205     FOR I = 1 TO NSHIPS + ADDED
210         PRINT I;
211         POKE 36,5:
            PRINT NAME$(I);
212         POKE 36,25:
            PRINT DOSE1(I)
220         NEXT I
230     PRINT
231     PRINT "ARE THESE OKAY ? ";
232     GET A$:
        PRINT A$
240     IF A$ = "Y" THEN
            GOTO 500
250     INPUT "WHICH IS WRONG(I)?";J
260     PRINT NAME$(J),DOSE1(J)
270     PRINT "NEW NAME = ";NAME$(J)
272     CV = PEEK (37):
        VTAB CV:
        HTAB 12
274     INPUT "";A$
276     IF LEN (A$) > 0 THEN
            NAME$(J) = A$
280     PRINT "NEW INTENSITY = ";DOSE1(J)
282     CV = PEEK (37):
        VTAB CV:
        HTAB 17
284     INPUT "";A$
286     IF LEN (A$) > 0 THEN
            DOSE1(J) = VAL (A$)
290     GOTO 200
500     PRINT "WANT TO DELETE A SHIP ? ";
510     GET A$:
        PRINT A$
520     IF A$ = "N" THEN 1000
530     INPUT "WHICH ONE? ";J
540     FOR K = J TO NSHIPS + ADDED - 1
550         NAME$(K) = NAME$(K + 1)
560         DOSE1(K) = DOSE1(K + 1)
570         NEXT
580     NSHIPS = NSHIPS - 1
590     GOTO 200
1000    NSHIPS = NSHIPS + ADDED
1010    FOR I = 1 TO NSHIPS
1020        DOSE1(I) = DOSE1(I) / 24
1030        NEXT I
2000    PRINT D$;"OPEN TARGET SHIPS,D1"
2010    PRINT D$;"DELETE TARGET SHIPS"
2020    PRINT D$;"OPEN TARGET SHIPS"
2030    PRINT D$;"WRITE TARGET SHIPS"
2040    PRINT NSHIPS
2050    FOR I = 1 TO NSHIPS
2060        PRINT NAME$(I)
```

```
2070        PRINT DOSE1(I)
2080        NEXT I
2090    PRINT D$;"CLOSE TARGET SHIPS"
2100    PRINT D$;"RUN MENU,D1"
```

Program:	UPDATE PASSING SHIP DOSE
Program Objective:	To modify doses in PASSES file, and to modify any entry in the PATH file that relates to a "passing" encounter with a target ship.
Description:	This program reads "ship" PASSES file and allows modification of dose. Input and output are displayed on the screen only.
Input:	Existing file "ship" PASSES
Output:	Updated file "ship" PASSES

Table 4-10 Update Passing Ship Dose

```
10      D$ = CHR$ (4)
20      DIM PDOSE(300),PNAME$(300),PTIME$(300)
30      INPUT "NAME OF SHIP ";X$
40      Z$ = X$ + " PASSES"
50      PRINT D$;"OPEN  ";Z$;",D2"
60      PRINT D$;"READ  ";Z$
70      INPUT PASSES
80      IF PASSES = 0 THEN 140
90      FOR I = 1 TO PASSES
100         INPUT PTIME$(I)
110         INPUT PNAME$(I)
120         INPUT PDOSE(I)
130         NEXT I
140     PRINT D$;"CLOSE ";Z$
150     IF PASSES > 0 THEN 200
160     PRINT "USE UPDATE"
170     PRINT "TO ADD PASSING SHIP MEETINGS"
180     FOR I = 1 TO 3000:
            NEXT I
190     PRINT D$;"RUN MENU,D1"
200     ISTART = 1
210     NTILL = ISTART + 19
220     IF NTILL > PASSES THEN
            NTILL = PASSES
230     HOME :
        PRINT "#  ";"TIME","SHIP","DOSE"
240     FOR I = ISTART TO NTILL
250         PRINT I;" ";PTIME$(I),PNAME$(I);:
            POKE 36,32:
            PRINT PDOSE(I)
260         NEXT I
270     PRINT
280     PRINT "WANT TO CHANGE ANY ? ";
290     GET A$:
        PRINT A$
300     IF A$ = "N" THEN 470
310     INPUT "WHICH ONE ? ";A$
320     J = VAL (A$)
330     IF J < ISTART THEN
            PRINT "BAD INPUT":
            FOR J = 0 TO 500:
                NEXT :
```

```
        GOTO 230
340     IF J > NTILL THEN
            PRINT "BAD INPUT":
            FOR J = 0 TO 500:
                NEXT :
            GOTO 230
350     PRINT "DELETE?";:
        GET A$:
        PRINT A$
360     IF A$ = "Y" THEN 390
370     INPUT "NEW DOSE = ";PDOSE(J)
380     GOTO 230
390     IF J = PASSES THEN 450
400     FOR I = J TO PASSES - 1
410         PTIME$(I) = PTIME$(I + 1)
420         PNAME$(I) = PNAME$(I + 1)
430         PDOSE(I) = PDOSE(I + 1)
440         NEXT I
450     PASSES = PASSES - 1
460     GOTO 220
470     IF NTILL = PASSES THEN 490
480     ISTART = NTILL + 1:
        GOTO 210
490     HOME :
        VTAB 10
500     PRINT "SAVE THIS VERSION OF FILE ? ";
510     GET A$:
        PRINT A$
520     PRINT :
        PRINT
530     IF A$ < > "Y" THEN 650
540     PRINT D$;"OPEN  ";Z$;",D2"
550     PRINT D$;"DELETE";Z$
560     PRINT D$;"OPEN  ";Z$
570     PRINT D$;"WRITE ";Z$
580     PRINT PASSES
590     FOR I = 1 TO PASSES
600         PRINT PTIME$(I)
610         PRINT PNAME$(I)
620         PRINT PDOSE(I)
630         NEXT I
640     PRINT D$;"CLOSE ";Z$
650     PRINT D$;"RUN MENU,D1"
```

Program:	PATH REPORT
Program Objective:	To print out path data for ships in Bikini Lagoon.
Description:	This program reads "ship" PATH and PASSES files and print information, either on screen or on printer. The dose for a passing ship is printed immediately after the target ship name.
Input:	File "ship" PATH File "ship" PASSES
Output:	A complete report on the input data for a ship, displayed either on the screen or on the printer.

Table 4-11 Path Report

```
1       HOME :
        VTAB 4
10      D$ = CHR$ (4)
20      DIM PTIME$(300),PNAME$(300),PDOSE(300)
30      DIM PLACE$(300),TIME$(300),SHIP$(300)
40      INPUT "NAME OF SHIP ";X$:
        Z$ = X$ + " PATH"
50      Y$ = X$ + " PASSES"
60      PRINT "SEND TO PRINTER ";:
        GET A$:
        PRINT A$
61      IF A$ = "Y" THEN
            PRINT "WHAT SLOT IS THE PRINTER IN?";:
            GET P$:
            PRINT P$
62      IF A$ = "Y" AND P$ > "3" OR A$ = "Y" AND P$ < "1" THEN
            HOME :
            VTAB 8:
            PRINT X$:
            PRINT :
            GOTO 60
70      PRINT
80      PRINT D$;"OPEN ";Y$;",D2"
90      PRINT D$;"READ ";Y$
100     INPUT PASSES:
        IF PASSES = 0 THEN 140
110     FOR I = 1 TO PASSES
120         INPUT PTIME$(I),PNAME$(I),PDOSE(I)
130         NEXT
140     PRINT D$;"CLOSE ";Y$
150     PRINT D$;"OPEN ";Z$;",D2"
160     PRINT D$;"READ ";Z$
170     INPUT NTIMES
180     FOR I = 0 TO NTIMES - 1
190         INPUT TIME$(I),PLACE$(I),SHIP$(I)
200         NEXT
210     PRINT D$;"CLOSE ";Z$
220     IF NTIMES < 2 THEN 9000
230     IF A$ = "Y" THEN
            PRINT D$;"PR#";P$
240     PRINT :
        PRINT :
```

```
       PRINT
250    IF A$ < > "Y" THEN
           HOME :
           PRINT :
           SPEED= 200
255    PRINT " ","PATH REPORT FOR THE USS ";X$:
       PRINT
260    PRINT "TIME";:
       POKE 36,8:
       PRINT "PLACE";:
       POKE 36,15:
       PRINT "REMARKS"
270    PRINT "------  -----  --------------------------"
280    POKE 34,3:
       VTAB 4
285    POKE 1786,106
290    K = 1
300    FOR I = 0 TO NTIMES - 1
310        PRINT TIME$(I);
320        POKE 36,8
330        PRINT PLACE$(I);
340        L$ = LEFT$ (SHIP$(I),1)
350        IF L$ = "N" AND LEN (SHIP$(I)) = 1 THEN
               PRINT :
               GOTO 440
360        POKE 36,15
370        L = LEN (SHIP$(I)):
           SHP$ = RIGHT$ (SHIP$(I),L - 1)
375        IF L$ = "N" THEN
               PRINT SHP$:
               GOTO 440
380        IF L$ = "A" THEN
               PRINT "ALONGSIDE ";SHP$:
               GOTO 440
390        IF L$ = "L" THEN
               PRINT "LEAVING   ";SHP$:
               GOTO 440
400        IF L$ = "P" THEN
               PRINT "PASSING   ";SHP$;:
               GOSUB 490:
               GOTO 440
410        PRINT L$
420        PRINT SHIP$(I),SHP$
430        STOP
440        NEXT
450    IF A$ = "Y" THEN
           PRINT D$;"PR#0":
           HOME
460    IF A$ < > "Y" THEN
           SPEED= 255
470    POKE 34,0
480    PRINT D$;"RUN MENU,D1"
490    IF C9 < > 0 THEN
```

```
          RETURN
500     IF TIME$(I) < > PTIME$(K) THEN 550
510     IF SHP$ < > PNAME$(K) THEN 550
520     PRINT " ";PDOSE(K)
530     K = K + 1
540     RETURN
550     PRINT "WHAT SLOT IS THE PRINTER IN?";:
        GET P$:
        PRINT P$
551     IF P$ > "3" OR P$ < "1" THEN 550
555     A$ = "Y":
        SPEED= 255:
        PRINT :
        PRINT :
        PRINT
560     PRINT D$;"PR#";P$
570     FOR J = 1 TO PASSES
580         PRINT PTIME$(J),PNAME$(J),PDOSE(J)
590         NEXT
600     PRINT "ERROR IN FILE"
610     C9 = 1:
        RETURN
9000    PRINT "NOT ENOUGH DATA , ONLY ";NTIMES;" POINTS"
9010    GET A$:
        PRINT :
        PRINT D$;"RUN MENU,D1"
```

Program:	UPDATE SHIP CONTAMINATION
Program Objective:	To allow manual changes to the doses contained in the SHIP CONTAMINATION file to account for special circumstances.
Description:	This program reads in "ship" SELF file, displays values on screen, allows the input of new values for any day, and outputs a revised file. This program is not intended for use when the path of a ship has been changed - SHIP CONTAMINATION should be re-executed in that case. This program only allows the modification of specific values, as might be appropriate when sailing through a radioactive oil slick.
Input:	Existing file "ship" SELF
Output:	Updated file "ship" SELF

Table 4-12 Update Ship Contamination

```
10      D$ = CHR$ (4)
20      HOME :
        VTAB 8
30      DIM SELF(100)
40      INPUT "NAME OF SHIP IS ? ";X$
50      Z$ = X$ + " SELF"
60      PRINT D$;"OPEN ";Z$;",D2"
70      PRINT D$;"READ ";Z$
80      INPUT BDAY
90      INPUT NDAY
100     FOR I = 0 TO NDAY
110         INPUT SELF(I)
120         NEXT I
125     INPUT ITEN
130     PRINT D$;"CLOSE ";Z$
140     I1 = 0:
        I2 = I1 + 19
150     IF I2 > NDAY THEN
            I2 = NDAY
160     IF I1 > NDAY THEN
            HOME :
            VTAB 10:
            GOTO 300
170     HOME
180     PRINT "DAY","SHIP-CONTAMINATION"
190     FOR I = I1 TO I2
200         PRINT I,SELF(I)
210         NEXT I
220     PRINT "ARE THESE OK?";
230     GET A$:
        PRINT A$
240     IF A$ = "Y" THEN
            I1 = I2 + 1:
            I2 = I1 + 19:
            GOTO 150
250     IF A$ < > "N" THEN 170
260     INPUT "WHICH DAY NEEDS CHANGING?";K
270     INPUT "NEW VALUE = ";SELF(K)
280     GOTO 150
290     STOP
300     PRINT
310     INPUT "DO YOU WANT TO SAVE THESE CHANGES IN A  NEW FILE?";AN$
```

```
320    IF AN$ < > "Y" THEN 430
330    PRINT D$;"OPEN ";Z$;",D2"
340    PRINT D$;"DELETE";Z$
350    PRINT D$;"OPEN ";Z$
360    PRINT D$;"WRITE ";Z$
370    PRINT BDAY
380    PRINT NDAY
390    FOR I = 0 TO NDAY
400        PRINT SELF(I)
410        NEXT I
415    PRINT ITEN
420    PRINT D$;"CLOSE ";Z$
430    PRINT D$;"PR#0"
440    PRINT D$;"RUN MENU,D1"
```

Section 5
USS RECLAIMER OPERATIONS

To demonstrate the application of the dose reconstruction methodology, a detailed examination is made of the operations of the USS RECLAIMER (ARS-42).

5.1 USS RECLAIMER Dose Reconstruction

As a salvage ship and the flagship of the Director of Ship Material (DSM), the RECLAIMER participated in nearly all radiologically significant operations, and her movements are well-documented. After each detonation, she followed the PGM/LCPL radiological monitors into the lagoon; onboard, the DSM made the first inspections of the target array and supervised the conduct of salvage operations. Data sources on ship operations include deck logs, salvage ship summaries (Reference 22), operation summaries (Reference 21), and reports of the Director of Ship Material activities (Reference 32). Additionally, operational data are obtained from original message traffic and Director of Ship Material target ship inspection reports.

An Information Summary for the RECLAIMER is contained in Table 5-1, and a Path Report in Table 5-2. The information recorded in the Path Report includes time, location, and ship activity (such as passing close to or moored alongside a target ship). The time is given as a six-digit date-time group, the first two digits of which is the day, with 1 July 1946 as day 01 and numbered consecutively thereafter (e.g., 1 August 1946 = day 32). The remaining four digits is the military time. The date-time group of each change of status of the RECLAIMER is recorded through 39 days after Shot BAKER, after which she departed Bikini Lagoon for Kwajalein. The location is given using a grid coordinate system, described in Section 4.1, which is based on Navy Hydrographic Office Misc. Chart Number 11854. Portions of this chart are reproduced in Figures B-1, 2, 3, and 4 of Appendix B. The results of the analysis of the RECLAIMER are contained in Table 5-3, the Radiation Report. This report is a day-by-day compilation of the reconstructed film badge doses from the various radiation sources that this ship encountered while in Bikini Lagoon. Daily and cumulative totals are also included until departure from Bikini. A detailed explanation of each source is found in Section 2 of this volume.

Table 5-1

Support Ship Information Summary

SHIP: USS RECLAIMER (ARS-42)

CREW SIZE: 73

GROUP: SALVAGE

MISSION: RECLAIMER arrived at Bikini on June 1, 1946 and began to prepare for the operation. As a member of the Salvage Unit, RECLAIMER's duties included salvaging the damaged target vessels after the tests, performing emergency repairs, and fighting fires. In addition, the Director of Ship Material (DSM) was embarked aboard the RECLAIMER from where he coordinated all salvage operations. The DSM, in RECLAIMER, made the first inspection of the target array, operating on numerous occasions between the Red and Blue lines.

SHOT DATA:	TEST	DATE (TIME)	YIELD	TYPE DETONATION
	ABLE	1 July 46 (0900)	23 KT	Air Burst (+520 feet)
	BAKER	25 July 46 (0835)	23 KT	Shallow Underwater (-90 feet)

PATH REPORT: This report contains the geographic locations of CTJF-1 support vessels within Bikini lagoon. The time is in Day-Hour-Minutes and begins 1 July 1946. All days are July (e.g., 1 Aug = 32 July, etc.). Place is the grid square within Bikini lagoon from Hydrographic Office Misc. Chart number 11854, portions of which are reproduced in Figures B-1, 2, 3, 4.

RADIATION REPORT: This report is a day-by-day compilation of the reconstructed film badge dose for this unit from the various sources which it encountered while at Bikini lagoon. A daily total and cumulative total are also included up to departure from Bikini. A detailed explanation of each source contribution is contained in the basic report, Section 2.

Total calculated dose received while at Bikini: 1.679 REM

Date unit departed Bikini: September 1, 1946 (BAKER + 38)

Ship contamination factor when departing Bikini: 4
(this value is for use with the nomograph in Figure B-5)

Table 5-2 RECLAIMER Path Report

PATH REPORT FOR THE USS RECLAIMER

TIME	PLACE	REMARKS
010900	2591M	OBSERVED SHOT ABLE FROM APPROXIMATELY 27 MILES
011219	2592M	ENTERED BIKINI LAGOON
011300	2592M	PROCEEDING TO VICINITY OF USS SARATOGA
011325	2399A	PASSING SARATOGA 0
011524	2399A	LEAVING USS SARATOGA
011525	2200U	PASSING PENNSYLVANIA 0
011600	2200U	LEAVING USS PENNSYLVANIA
011601	2301U	PASSING NEW YORK 0
011625	2301U	LEAVING USS NEW YORK
011733	2201P	PASSING NEVADA 0
011742	2201P	LEAVING USS NEVADA
011759	2001R	NEAR USS DAWSON
011812	1800W	NEAR USS COURTLAND
011820	2002V	NEAR PRINZ EUGEN
011828	2000J	MANEUVERING AS BEFORE
011839	2400J	ANCHORED IN VICINITY OF BERTH 190
020800	2400J	UNDERWAY
021131	2201P	PASSING NEVADA 0
021135	2201P	SECURED FROM FIGHTING FIRE ON USS NEVADA
021305	2102S	PASSING LAMSON 0
021620	2101S	NEAR SKATE
021733	2101X	PASSING INDEPENDENCE 0
021757	2101X	PROCEEDING AWAY FROM USS INDEPENDENCE
021848	2404C	ANCHORED IN BERTH #42
030757	2404C	UNDERWAY
031000	2100G	PASSING ARDC-13 0
031030	2100G	PROCEEDING TO USS NEVADA
031041	2201P	ALONGSIDE NEVADA
031210	2201P	LEAVING NEVADA
031220	2101E	ALONGSIDE ARKANSAS
031310	2101E	LEAVING ARKANSAS
031435	2795K	IN SALVAGE UNIT ANCHORAGE AREA
031500	2101O	ALONGSIDE YO-160
031505	2101O	LEAVING YO-160
031530	2001I	ALONGSIDE CRITTENDEN
031556	2001I	LEAVING CRITTENDEN
031645	2795K	ANCHORED IN BERTH "BAKER"
031700	2795K	PASSING SUMMARY 12
042400	2795K	ANCHORED IN BERTH "BAKER" AS BEFORE
250835	2591M	OBSERVED SHOT BAKER FROM A DISTANCE IN EXCESS OF 14 MI LES
251100	2592M	ENTERED BIKINI LAGOON
251250	2493M	APPROACHING TARGET ARRAY
251330	2297M	ESTIMATED POSITION
251405	2299A	ESTIMATED POINT OF CROSSING RED LINE
251530	2001N	ESTIMATED POSITION

```
251545 2000J  ESTIMATED POSITION
251555 2000X  ESTIMATED POSITION
251605 2100L  ESTIMATED POSITION
251737 2595M  ANCHORED IN BERTH #368
251900 2595M  PASSING   PARCHE 2
260001 2595M  ANCHORED AS BEFORE
261425 2595M  UNDERWAY
261450 2200G  PASSING   GASCONADE 15
261500 2201N  ALONGSIDE HUGHES
261518 2201N  LEAVING   HUGHES
261640 2793M  ALONGSIDE HUGHES
261648 2793M  LEAVING   HUGHES
261740 2793M  ALONGSIDE HUGHES
261749 2793M  LEAVING   HUGHES
261805 2101M  IN VICINITY OF USS FALLON
261815 2101M  LEAVING VICINITY OF USS FALLON
261822 2100I  SUB AREA
261854 2695M  ANCHORED IN BERTH #370
270815 2695M  UNDERWAY
270844 2201E  PASSING   SALT LAKE CITY 3
270855 2101I  PASSING   FALLON 6
270935 2200Q  PASSING   PENNSYLVANIA 9
270940 2200X  PASSING   BRACKEN 9
270946 2200S  PASSING   CATRON 6
271025 2595M  ANCHORED NEAR BERTH #368
271200 2595M  UNDERWAY
271210 2793M  PASSING   HUGHES 0
271220 2693M  ANCHORED NEAR ENYU ISLAND - "A" 128.5 DEG  "B" 27 DEG
271540 2693M  UNDERWAY
271608 2200Q  PASSING   PENNSYLVANIA 12
271610 2200G  PASSING   GASCONADE 3
271616 2201Y  PASSING   NEW YORK 4
271630 2202V  PASSING   NAGATO 4
271631 2202K  PASSING   NEVADA 6
271637 2100I  SUB AREA
271655 2000D  PASSING   INDEPENDENCE 4
271733 2695M  ANCHORED NEAR BERTH #370
271900 2695M  PASSING   LST-133 3
271901 2695M  PASSING   PARCHE 0
271902 2695M  PASSING   RALPH TALBOT 1
271903 2695M  PASSING   MUSTIN 3
280821 2695M  UNDERWAY FROM BERTH #370
280835 2100U  NEAR SUBMARINES IN TARGET ARRAY
280845 2199F  NEAR USS TUNA
280852 2200P  PASSING   PENNSYLVANIA 4
280900 2200H  PASSING   BRISCOE 4
280903 2201S  PASSING   NEW YORK 4
280923 2101Q  PASSING   PENSACOLA 4
280937 2201I  PASSING   LST-133 0
280940 2301A  PASSING   SALT LAKE CITY 4
```

```
280945 2202Q  PASSING   NAGATO 4
280950 2202K  PASSING   NEVADA 4
281000 1903O  NEAR LCT-1114
281009 2105I  NEAR LST-545
281017 2104E  PASSING   LST-220 4
281030 2202B  PASSING   LST-52 9
281050 2100C  PROCEEDING TO SUB AREA
281219 2201Y  PASSING   NEW YORK 5
281230 2200M  MANEUVERING AS BEFORE
281245 2695M  ANCHORED IN BERTH #370
281543 2695M  UNDERWAY
281555 2795M  STANDING BY BEACHING OF USS DENTUDA IN BEACHING AREA O
              FF ENYU ISLAND
281630 2200M  PROCEEDING TOWARD USS BRISCOE
281637 2200H  PASSING   BRISCOE 4
281652 2202Q  PASSING   NAGATO 4
281655 2002M  PASSING   NEVADA 4
281810 2100C  IN SUBMARINE AREA
281825 2094S  ANCHORED IN BERTH #380
281900 2094S  PASSING   LST-661 2
281901 2094S  PASSING   YOG-83 1
281902 2095P  PASSING   CONYNGHAM 1
281903 2094S  PASSING   MUGFORD 1
281904 2094S  PASSING   RALPH TALBOT 3
281905 2094S  PASSING   MAYRANT 3
281906 2094S  PASSING   TRIPPE 1
281907 2094S  PASSING   RHIND 2
281908 2094S  PASSING   STACK 5
281909 2094S  PASSING   WILSON 3
281910 2094S  PASSING   MUSTIN 1
281911 2094S  PASSING   WAINWRIGHT 1
290855 2094S  UNDERWAY FROM BERTH #380
290920 2200Q  PASSING   PENNSYLVANIA 4
290935 2201U  PASSING   SARATOGA 4
290939 2200G  PASSING   GASCONADE 9
290943 2200S  PASSING   CATRON 4
290952 2200H  PASSING   BRISCOE 9
291009 2201E  PASSING   SALT LAKE CITY 6
291015 2202V  PASSING   NAGATO 6
291020 2202K  PASSING   NEVADA 4
291032 2101G  PASSING   BRULE 9
291039 2101Q  PASSING   PENSACOLA 9
291058 2201Y  ALONGSIDE NEW YORK1
291105 2201Y  LEAVING   NEW YORK1
291120 2298S  ANCHORED IN BERTH #282
291429 2298S  UNDERWAY
291504 2793M  OFF ENYU ISLAND
291605 2793M  OFF ENYU ISLAND
291634 2201Y  ALONGSIDE NEW YORK1
291639 2201Y  LEAVING   NEW YORK1
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291648 2201E  PASSING   SALT LAKE CITY 4
291651 2202V  PASSING   NAGATO 6
291653 2202K  PASSING   NEVADA 12
291715 2101Q  PASSING   PENSACOLA 9
291740 2094S  ANCHORED IN VICINITY OF BERTH #380
291900 2094S  PASSING   YOG-83 8
301040 2094S  UNDERWAY FROM BERTH #380
301100 2201M  IN TARGET ARRAY
301140 2201M  LEAVING TARGET ARRAY
301157 2694M  ANCHORED OFF ENYU ISLAND - "A" 151 DEG  "B" 21 DEG
301200 2694M  PASSING   MAYRANT 4
301201 2694M  PASSING   TRIPPE 3
301202 2694M  PASSING   RHIND 3
301204 2694M  PASSING   WILSON 3
301430 2694M  UNDERWAY FROM ANCHORAGE
301535 2201Y  ALONGSIDE NEW YORK1
301545 2201Y  LEAVING   NEW YORK1
301600 2101Q  ALONGSIDE PENSACOLA
301605 2101Q  LEAVING   PENSACOLA
301718 2101Q  ALONGSIDE PENSACOLA
301725 2101Q  LEAVING   PENSACOLA
301825 2694M  ANCHORED OFF ENYU ISLAND - "A" 166 DEG  "B" 18 DEG
310802 2694M  UNDERWAY FROM ANCHORAGE NEAR BERTH #370
310830 2201M  INSPECTING TARGET ARRAY
311100 2201M  UNDERWAY TO ANCHORAGE
311110 2402W  ANCHORED IN BERTH #145
311345 2402W  UNDERWAY
311400 2201M  UNDERWAY AS BEFORE
311425 2201E  PASSING   SALT LAKE CITY 4
311505 1802D  ALONGSIDE CONYNGHAM1
311539 1802D  LEAVING   CONYNGHAM1
311551 1902C  ALONGSIDE WAINWRIGHT1
311615 1902C  LEAVING   WAINWRIGHT1
311621 1902E  ALONGSIDE MUGFORD1
311635 1902E  LEAVING   MUGFORD1
311705 2402W  ANCHORED IN VICINITY OF BERTH #145
330835 2402W  UNDERWAY FROM VICINITY OF BERTH #145
331002 2101Q  ALONGSIDE PENSACOLA
331028 2101Q  LEAVING   PENSACOLA
331030 2301A  LAYING TO IN VICINITY OF USS SALT LAKE CITY IN BERTH #
              188
331414 2301A  PROCEEDING TO USS PENSACOLA
331415 2101Q  ALONGSIDE PENSACOLA
331528 2101Q  LEAVING   PENSACOLA
331537 2100B  ANCHORED IN VICINITY OF BERTH #219
331745 2100B  UNDERWAY
331805 2101Q  ALONGSIDE PENSACOLA
331810 2101Q  LEAVING   PENSACOLA
331830 2195P  ANCHORED IN VICINITY OF BERTH #356 - "D" 14 DEG  "C" 3
              9 DEG  "B" 71.5 DEG
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341500 2195P  UNDERWAY FROM ANCHORAGE
341623 2000E  ANCHORED IN BERTH #219
341829 2000E  UNDERWAY PROCEEDING TO ANCHORAGE IN VICINITY OF USS FA
              LL RIVER
341850 2194B  ANCHORED IN BERTH #357
352400 2194B  ANCHORED AS BEFORE
361425 2101Q  ALONGSIDE PENSACOLA
361518 2101Q  LEAVING   PENSACOLA
370932 2101Q  ALONGSIDE PENSACOLA
370937 2101Q  LEAVING   PENSACOLA
371335 2101Q  ALONGSIDE PENSACOLA
371410 2101Q  LEAVING   PENSACOLA
381415 2101Q  ALONGSIDE PENSACOLA
381548 2101Q  LEAVING   PENSACOLA
391509 2101Q  ALONGSIDE PENSACOLA
391610 2101Q  LEAVING   PENSACOLA
400856 2102S  ALONGSIDE MAYRANT2
400946 2102S  LEAVING   MAYRANT2
411025 2101Q  ALONGSIDE PENSACOLA
411126 2101Q  LEAVING   PENSACOLA
441630 2101Q  ALONGSIDE PENSACOLA
441638 2101Q  LEAVING   PENSACOLA
470800 2201Y  ALONGSIDE NEW YORK2
471500 2201Y  LEAVING   NEW YORK2
480810 2201P  ALONGSIDE NEVADA2
481600 2201P  LEAVING   NEVADA2
500835 2200Q  ALONGSIDE PENNSYLVANIA
501622 2200Q  LEAVING   PENNSYLVANIA
510851 2200Q  ALONGSIDE PENNSYLVANIA
511745 2200Q  LEAVING   PENNSYLVANIA
520820 2201Y  ALONGSIDE NEW YORK2
521238 2201Y  LEAVING   NEW YORK2
521345 2200Q  ALONGSIDE PENNSYLVANIA
521412 2200Q  LEAVING   PENNSYLVANIA
531435 2102S  ALONGSIDE MAYRANT2
531505 2102S  LEAVING   MAYRANT2
571042 2591M  ALONGSIDE CRITTENDEN
571335 2591M  LEAVING   CRITTENDEN
581247 2101M  ALONGSIDE FALLON
581415 2101M  LEAVING   FALLON
581505 2101M  ALONGSIDE FALLON
581635 2101M  LEAVING   FALLON
610723 2101M  ALONGSIDE FALLON
611210 2101M  LEAVING   FALLON
631150 2101M  ALONGSIDE FALLON
631245 2101M  LEAVING   FALLON
631500 2592M  DEPARTED BIKINI LAGOON ON 1 SEPTEMBER 1946 - ENROUTE K
              WAJALEIN
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Table 5-3 RECLAIMER Radiation Report

USS RECLAIMER CALCULATED FILM BADGE DOSE (IN MREM)

DATE	TIME	LAGOON WATER	TARGET SHIPS	SHIP CONTAMINATION	DAILY TOTAL	CUM TOTAL
JUL 1	A+0	15	0		15	15
JUL 2	A+1	6	0		6	21
JUL 3	A+2	0	8		8	29
JUL 4	A+3	0	0		0	29
JUL 5 THRU 24		0	0			29
JUL 25	B+0	29	1	45	75	104
JUL 26	B+1	9	127	42	178	282
JUL 27	B+2	11	51	60	122	404
JUL 28	B+3	18	57	59	134	538
JUL 29	B+4	5	84	40	129	667
JUL 30	B+5	3	32	31	66	733
JUL 31	B+6	11	50	26	87	820
AUG 1	B+7	16	0	21	37	857
AUG 2	B+8	14	81	18	113	970
AUG 3	B+9	1	0	16	17	987
AUG 4	B+10	0	0	14	14	1001
AUG 5	B+11	1	27	12	40	1041
AUG 6	B+12	3	18	11	32	1073
AUG 7	B+13	4	39	10	53	1126
AUG 8	B+14	10	23	9	42	1168
AUG 9	B+15	9	15	8	32	1200
AUG 10	B+16	8	20	8	36	1236
AUG 11	B+17	7	0	7	14	1250
AUG 12	B+18	6	0	7	13	1263
AUG 13	B+19	6	1	6	13	1276
AUG 14	B+20	5	0	6	11	1287
AUG 15	B+21	5	0	5	10	1297
AUG 16	B+22	4	8	5	17	1314
AUG 17	B+23	4	30	5	39	1353
AUG 18	B+24	3	0	4	7	1360
AUG 19	B+25	3	62	4	69	1429
AUG 20	B+26	3	67	4	74	1503
AUG 21	B+27	3	6	4	13	1516
AUG 22	B+28	2	4	4	10	1526
AUG 23	B+29	2	0	4	6	1532
AUG 24	B+30	0	0	3	3	1535
AUG 25	B+31	0	0	3	3	1538
AUG 26	B+32	0	10	3	13	1551
AUG 27	B+33	0	39	3	42	1593
AUG 28	B+34	1	0	3	4	1597
AUG 29	B+35	1	0	3	4	1601
AUG 30	B+36	1	58	3	62	1663
AUG 31	B+37	1	0	3	4	1667
SEP 1	B+38	0	10	2	12	1679

Although the RECLAIMER operated on numerous occasions between the blue and red lines, the water activation model indicates that she operated within the red line (i.e., greater than 1 R/24 hr) only once. It appears that constant attention was paid to total daily accumulated dose, as the model predicts a daily dose of approximately 100 mrem for the first few days after Shot BAKER. The standard at Bikini was 100 mrem daily dose.

The Information Summary, Path Report, and Radiation Report for each support ship of CJTF-1 are presented in Appendix B: Support Ships, and constitute the final results for each vessel.

5.2 USS RECLAIMER Boarding Parties

The term "boarding party" is found throughout the deck logs of the RECLAIMER without differentiation as to type, as defined in Section 3.3. The relevant documented boardings and calculated doses of the various boarding parties from the RECLAIMER are presented in Table 5-4. While several instances of target vessel boarding are found in RECLAIMER's deck log, only those for which dosimetry is available are shown. The total boarding time in each case is assumed to have been topside in the absence of additional information. Intensities are taken from the target ship intensity graphs of Appendix A. The below-deck (interior) intensity is used only when appropriate, as on B+8 when personnel were installing a pump on the USS PENSACOLA for dewatering purposes. The times spent onboard the target vessels are not well documented beyond B+25; hence, no entries are included after that date.

To calculate the dose for a member of a boarding party, the daily dose appearing in the Radiation Report (which includes a dose contribution for alongside the target ship) is supplemented by the additional dose accrued during boarding operations. This is accomplished by calculating the dose accrued while aboard the target vessel and subtracting the dose that personnel remaining aboard the alongside support ship accrued during the same time period. Both the daily (24-hour) dose and the supplemental dose from boarding operations are shown in the table.

Table 5-4

Boarding Team Dose Reconstruction, USS RECLAIMER

Date	Ship Boarded or Alongside	Time (min) Alongside	Time (min) Aboard	Intensity (R/day)	Calculated Dose (mrem) Average Crew (daily)	Calculated Dose (mrem) Boarding Team (while aboard target ship)
31 July (B+6)	CONYNGHAM	34	34	0.5	116	8
	WAINWRIGHT	24	18	1.5		17
	MUGFORD	14	9	5.9		26
						51
2 Aug (B+8)	PENSACOLA	104	Topside 20	12.4	139	120
			Interior 69	0.9		29
						149
5 Aug (B+11)	PENSACOLA	53	53	8.2	65	210
7 Aug (B+13)	PENSACOLA	93	93	6.6	70	297
8 Aug (B+14)	PENSACOLA	61	60	6.0	51	174
13 Aug (B+19)	PENSACOLA	8	8	4.0	20	16
17 Aug (B+23)	PENSACOLA	-	45*	3.1	45	68
19 Aug (B+25)	PENSACOLA	-	92*	2.8	75	125

*4 five-minute boat trips subtracted.

5.3 Comparison With Film Badge Data

Analysis of the dosimetry and personnel rosters showed that most film badges were issued to members of boarding parties and the remainder to RECLAIMER crew members. To compare recorded dosimetry with a calculated dose, it is necessary to identify boarding events and recorded times with corresponding dosimetry. There are numerous records of target ship boardings in the deck log of the RECLAIMER, but most are unusable due to undetermined periods, unknown participants, and no corresponding dosimetry. Likewise, there is dosimetry for RECLAIMER, but some for periods in which RECLAIMER remained at anchor and did not participate in target ship boardings. In these cases, the film badge likely reflects an unrecorded activity for which no reconstruction or calculation is possible. Table 5-4 lists those target ship boardings reported in the deck logs of the RECLAIMER that are also supported by relevant dosimetry. It is assumed that film badges were issued for daily use to members of the boarding teams, and that the badges were exposed for an average 8-hour work day by a combination of support ship (i.e., RECLAIMER) and target ship boarding time.

Using the above assumption, the film badge dose for boarding parties is determined by adding the dose accrued on the support ship for the remainder of the 8-hour badge period to the dose accrued during actual boarding operations shown in Table 5-4. The total dose is shown in Table 5-5, as is the dosimetry for the same assumed badge period. Calculated values agree reasonably well with the film badge averages, except for 13 and 19 August. On 13 August, there were two additional reported boarding parties that left the RECLAIMER for a total of 3½ hours to service pumps aboard the PENSACOLA and MAYRANT. However, because the RECLAIMER was not reported alongside either ship during that time and because no realistic estimate of the time spent aboard those ships can be made, they are not included in this comparison. Inclusion would increase the calculated dose. For 19 August, film badge readings may be low due to time spent below. However, the calculated dose reflects only topside exposure and is thus high-sided in this instance.

Table 5-5

Comparison of RECLAIMER Calculated Doses with Dosimetry

Date	Number of Badges	Range (mrem)	Average (mrem)	Calculated Dose* (mrem)
31 July	5	50-50	50	85
2 Aug	6	50-380	187	185
5 Aug	1	--	300	229
7 Aug	1	--	370	316
8 Aug	3	100-230	147	187
13 Aug	6	60-210	95	23**
17 Aug	2	60-60	60	82
19 Aug	3	50-60	53	145

*Includes appropriate target ship and support ship doses for the assumed 8-hour badge period.

**Does not include all reported exposure (see text).

Section 6
UNCERTAINTY ANALYSIS

Two features of Operation CROSSROADS stand out in the dose reconstruction analysis: the radiation environment and ship operations were complex, and relevant data are not abundant. Therefore it is not unexpected that the uncertainties in calculated doses are rather large. In all calculations the quantity of interest is the film badge dose of an average sailor, defined as one who moved about a support ship subject to the constraint that he spent 1/3 time topside and 2/3 below decks (eating, sleeping, working or participating in other activities, but remaining outside the engine room) and who was exposed to the average dose of the appropriate location (topside, amidships, below decks) while on a target ship. Although some crewmembers probably spent more than eight hours per day topside, this constraint provides higher calculated doses for average crewmembers. Each dose contribution (ABLE water, ABLE target ship, BAKER water, BAKER target ship, and ship contamination) must be analyzed separately, and an uncertainty assigned to each. Since the environmental models developed in Section 2 are generally based on data sets of limited extent and accuracy, it is impractical to perform error analyses using standard techniques in all cases. Rather, best estimates of upper and lower bounds, expressed in terms of error factors, and a description of the methodology are provided. Wherever possible, these error factors are derived such that the bounds correspond approximately to 90-percent confidence limits. The upper confidence limit of a calculated dose is the product of that dose and the error factor; the lower confidence limit equals the dose divided by the error factor. It often occurs in the following analyses that the uncertainty in dose not symmetrical, so that the error factors used to determine the upper and lower confidence limits are not equal.

6.1 Uncertainty of Shot ABLE Water Doses

The uncertainty in the calculated water intensity for Shot ABLE is the major source of uncertainty in these doses. Except for the PGMs and LCPLs, the paths of support ships through the radioactive environment are known with a high degree of accuracy. Therefore, it is sufficient to concentrate on the water intensity, which is expressed in Section 2.1 as:

$$I(r,t) = t^{-3/2} \exp\left[-A\left(\frac{r^2}{t}\right) - \lambda t + B\right].$$

The value of B (0.503) is determined from the observation that the blue line vanished 25 hours after detonation. This is considered the most accurate data point in Table 2-1. The remaining data in this table are then used to determine a mean value of the constant A (4.56×10^{-6}). This is accomplished by calculating a value of A for each of the data points in this table (excluding the data corresponding to zero radius, for which a value of A cannot be determined) and deriving an average; this also provides a distribution in the quantity A on which to base an error analysis. From this distribution, which appears log-normal, 90-percent upper and lower bounds on A are derived. Since the intensity is inversely related to the magnitude of A, these values are used in the computerized methodology to determine lower and upper dose estimates, respectively, of the ABLE water doses for representative ships. The upper limit error factor (f_u) derived from these dose estimates is approximately 2.4; the lower limit error factor (f_l) approximately 3.1.

6.2 Uncertainty of Shot ABLE Target Ship Doses

The largest uncertainty in doses received from the activated target ships at Shot ABLE is due to uncertainty in target ship intensities. Times of boarding and stay times on target ships are relatively well known. Therefore, it is sufficient to examine the modeling of target ship intensity, which is developed in Section 2.2. The target ship intensity at time t is expressed as:

$$I(t) = CM\ f(t)\ R^{-2} e^{-R/\lambda}.$$

By fitting to the data of Table 2-3(a), the coefficient C is determined to be 1.1×10^7 yd^2-R/day. This value is used in ABLE target ship dose estimates. The distribution of the values of C derived from the data in Table 2-3(a) allows an estimation of 90-percent upper and lower limits on this quantity:

$$C \text{ (upper limit)} \approx 2.5 \times 10^7$$
$$C \text{ (lower limit)} \approx 3.1 \times 10^6.$$

Therefore upper and lower limit error factors may be calculated:

$$f_u = \frac{2.5x10^7}{1.1x10^7} = 2.3$$

$$f_l = \frac{1.1x10^7}{3.1x10^6} = 3.5.$$

6.3 Uncertainty of Shot BAKER Water Doses

As with Shot ABLE, the significant uncertainty for BAKER water doses is that of the water intensity. For most vessels (all except PGMs and LCPLs), the uncertainty in ship path is relatively small. As discussed in Section 2.3, the modeling of BAKER water intensities for BAKER Day through B+5 is accomplished primarily through analyses of reported red and blue line coordinates (e.g., Figure 2-3) and the water intensity contours of Reference 19 (Figure 2-5). The calibration of these contours (which were reported in arbitrary units) is accomplished so as to achieve maximum consistency with the red/blue line data for each day of interest. Upper and lower estimates of water intensities during this period are made by reviewing all relevant data, and determining maximum and minimum credible calibrations of the contours. The data base of the BAKER water intensity model is modified to incorporate these limiting calibration factors. The modeling of the water intensities after B+5 is based on a reported average intensity of 0.02 to 0.03 R per day on 15 August 1946 (a value of 0.025 R/day is used in the model), and on constraints imposed by the maximum initial inventory of radioactivity in the lagoon and subsequent decay and flushing rates. The size and location of the radioactive region, subject to these constraints, are chosen to maximize potential exposure to this environment. An upper estimate of the post-B+5 water environment is obtained by using the upper limit of the reported 15 August intensity range (0.03 R/day); the lower estimate is achieved by setting the water intensities to zero throughout the lagoon on B+8 (200 hours after detonation), as suggested by References 4 and 24.

Upper and lower limit BAKER water doses, calculated for nine representative ships, imply upper (f_u) and lower (f_l) error factors of approximately 1.7 and 5.8, respectively. The large asymmetry in these factors results from the conservative assumptions incorporated into the model.

6.4 Uncertainty of Shot BAKER Target Ship Doses

The major uncertainty is the average target ship intensity, which includes uncertainties in the intensity measurements themselves, the representativeness of these readings, and the techniques (see Section 2.4) used to interpolate/extrapolate from these measurements. Although this uncertainty is dependent on the amount of data available for a particular ship, it is estimated that for an average ship, and average times of boarding, the ship intensities can generally be predicted to within a factor of 1.5. Boarding times and stay times on target ships are usually known to a high degree of accuracy. Therefore the upper and lower error factors for this dose contribution are estimated to be 1.5.

6.5 Uncertainty of Ship Contamination Doses

The methodology for calculating doses accrued during lagoon operations due to the radioactive contamination of support ships is developed by first reconstructing exterior hull intensities at the time of lagoon departure for each of twelve ships having documented post-Bikini hull intensity readings. These reconstructed intensities are then used to fix parameters in a mathematical model which allows hull intensities to be calculated for all support ships at any time during lagoon operations. Geometric models of the support ships and sources of radiation (hull and pipe contamination) are then used to calculate the radiation intensity distribution inside the support ships, and hence the doses to shipboard personnel. The methodology is described in detail in Section 2.5.

The uncertainty associated with the ship contamination doses can be estimated by considering possible sources of error in each step outlined above. These errors, quantified in terms of 90 percent error factors, are presented in Table 6-1. The error factors associated with the variations in the values of the parameter S are derived from the distributions of S given in Table 2-6; the error factor given for "other" ships

Table 6-1

Sources of Uncertainty for Ship Contamination Doses

Uncertainty	Error Factor (90%)	Source
Post-Bikini hull intensity readings	1.2	Systematic errors in detectors and methods of measurement (random errors appear as variations in S).
Reconstruction of exterior hull intensity at lagoon departure	2.0	Systematic error in $t^{-1.3}$ hull decay factor, based on analysis of other reasonable decay rates. Error in steaming factor (½).
Modeling of exterior hull intensities during lagoon operations	1.5	Systematic errors in model.
Variations in S-values	1.7 for destroyers 2.1 for PGMs 2.0 for all others	Ship-to-ship variations in affinity for hull contamination. Random errors in post-Bikini hull readings.
Ship apportionment factors	1.5	Systematic errors in geometric modeling of radiation sources and ship interior. Errors in calculated intensity distribution.

(all ships except destroyers and PGMs) has been increased somewhat over that derived mathematically to reflect the additional uncertainty inherent in applying a single value of S (1570 mR-day$^{0.3}$) to a wide variety of ship types. The error factors assigned to other sources of uncertainty are based on semi-quantitative analyses and experience with radiation detection and modeling techniques. The combined error factor f is calculated by the relation (Reference 31)

$$f = \exp\left\{\left[\Sigma_i (\ln f_i)^2\right]^{1/2}\right\},$$

where f_i are the individual error factors. The following combined error factors are thus derived from the data in Table 6-1:

f = 2.9 for destroyers
3.3 for PGMs
3.2 for all other ships.

An additional uncertainty not addressed above is the possibility that an individual spent a significant amount of time in an engine room in the vicinity of radioactive sources such as evaporators and condensers. From the observation made in Section 2.5 that the engine room intensity was probably no greater than 1.5 times the exterior hull gamma intensity, it is possible to estimate the incremental dose received due to engine room duty. If a person spent eight hours per day in the engine room, eight hours topside, and eight hours below decks but outside the engine room, the contamination dose accrued by this individual is increased by a factor d:

$$d = \frac{F_a + 1.5}{2F_a},$$

where F_a is the apportionment factor (Table 2-7) for the appropriate ship type. For example, if F_a = .50, d = 2.0 and the contamination dose should be doubled to account for this hypothesized engine room duty.

This uncertainty analysis does not include operational constraints such as the 100 mR/day dose limit. For many ships, the calculated upper limit daily doses due to ship contamination exceed the 100 mR/day criterion by such an amount that it is extremely doubtful a ship contaminated to that degree would have been allowed to continue operations without decontamination of the ship or evacuation of personnel. Thus, while these upper limits are mathematically consistent, they may be operationally unrealistic and therefore in excess of the true 90-percent upper confidence limit for some ships.

6.6 Total Uncertainty

Summarized below are the upper and lower error factors for the various dose components.

Dose Component:

Error Factor	ABLE water	ABLE target ship	BAKER water	BAKER target ship	Ship contamination
f_u (upper)	2.4	2.3	1.7	1.5	2.9 for destroyers 3.3 for PGMs 3.2 for all other ship types
f_l (lower)	3.1	3.5	5.8	1.5	same

The confidence limits for a total dose are dependent on the magnitude of dose received from each dose component. The calculated film badge dose for the USS RECLAIMER, Table 5-3, serves as an example of how the approximate 90-percent upper and lower bounds of total dose may be determined from the component error factors developed in this section. From the data in this table and the component error factors, the dose in mrem from each component may be expressed as a best estimate plus and minus uncertainties in dose:

ABLE water	21^{+29}_{-14}
ABLE target ship	8^{+11}_{-6}
BAKER water	209^{+146}_{-173}

BAKER target ship	920^{+460}_{-310}
Contamination	521^{+1146}_{-358}

(Since the RECLAIMER is an ARS, an error factor of 3.2 is used for contamination.)

The best estimates are added to determine the best estimate of total dose, 1679 mrem. However, it is incorrect to add the individual upper (or lower) uncertainties to determine the composite 90-percent total dose upper (or lower) limit. It is approximately correct to combine uncertainties in a manner similar to that used when combining standard deviations for summed quantities, i.e., the square root of the sum of the squares. These uncertainties then combine as follows:

For upper dose: $\left[(29)^2 + (11)^2 + (146)^2 + (460)^2 + (1146)^2\right]^{1/2} = 1244$ mrem.

For lower dose: $\left[(14)^2 + (6)^2 + (173)^2 + (310)^2 + (358)^2\right]^{-1/2} = 504$ mrem.

The approximate 90-percent upper and lower bounds for the RECLAIMER total film badge dose are then:

Upper bound: 1679 + 1244 = 2923 mrem
Lower bound: 1679 - 504 = 1175 mrem.

The combined upper and lower uncertainties in dose may be calculated by this technique for each support ship, based on the dose components presented in Appendix B.

Section 7
CONCLUSIONS

A methodology is developed that allows calculation of external gamma doses accrued by personnel aboard target and support vessels operating in Bikini Lagoon during Operation CROSSROADS. The significant radiation sources (radioactive lagoon water, target ships, and support ship contamination) are identified, analyzed, and mathematically modeled. Doses to personnel are calculated by developing the path histories of support and target vessels, and numerically integrating the local radiation intensities along the ship paths, as determined by the radiation source models. Calculations are presented in detail for the USS RECLAIMER. Mean film badge doses calculated for personnel aboard the various support ships during operations within Bikini Lagoon are presented in Table 7-1. This compilation is a summary of more detailed information (Information Summary, Path Report, and Radiation Report for each support ship) appearing in Appendix B, Support Ships. Calculated mean film badge doses for the crews of the various target ships are presented in Table 7-2. These values represent doses accrued aboard the support ships on which the target ship crews were embarked during the operation, plus doses accrued aboard the target ships for those that were remanned. More detailed information on target ship crew doses is contained in Appendix A, Target Ships. Also included in this appendix are intensity curves for target ships, from which boarding team doses may be calculated.

This report also provides the means to determine additional doses to crews after each ship departed from Bikini, based upon departure date, debarkation date, and the level of hull contamination at the time of departure (calculated in the methodology). Thus, the total external dose from all contributing sources, excluding post-CROSSROADS operations at Kwajalein Atoll, can be determined, based upon the specific parameters associated with each ship and with the crew (or individual) debarkation date for a particular ship. See Appendix B.

Mean film badge doses are reconstructed for 93 percent of the 39,418 Naval participants at Operation CROSSROADS. Doses are not specifically reconstructed for staff and air units, but can be derived from the ships to which they were assigned. Only 7 percent of the doses exceed 0.5 rem and less than 2 percent exceed 1.0 rem. The maximum mean dose is calculated to be about 1.7 rem. A summary of calculated film badge doses is displayed graphically in Figure 7-1.

Table 7-1

Film Badge Dose Summary For Support Ship Crews

Support Ship	Crew Size	Total Film Badge Dose (mrem)
USS ACHOMAWI (ATF-148)	80	1245
USS AJAX (AR-6)	753	191
USS ALBEMARLE (AV-5)	569	0
USS ALLEN M. SUMNER (DD-692)	278	467
APL-27	23	131
USS APPLACHIAN (AGC-1)	614	1
USS APPLING (APA-58)	226	116
USS ARD-29	106	265
USS ARTEMIS (AKA-21)	160	216
USS ATA-124	44	359
USS ATA-180	45	547
USS ATA-185	43	593
USS ATA-187	33	347
USS ATA-192	15	547
USS ATR-40	68	903
USS ATR-87	69	485
USS AVERY ISLAND (AG-76)	483	147
USS BARTON (DD-722)	260	519
USS BAYFIELD (APA-33)	428	63
USS BEGOR (APD-127)	155	114
USS BENEVOLENCE (AH-13)	673	236
USS BEXAR (APA-237)	293	231
USS BLUE RIDGE (AGC-2)	534	1
USS BOTTINEAU (APA-235)	299	178
USS BOUNTIFUL (AH-9)	585	0
USS BOWDITCH (AGS-4)	296	143
USCG BRAMBLE (WAGL-392)	49	302
USS BURLESON (APA-67)	244	66
USS CEBU (ARG-6)	357	229
USS CHARLES P. CECIL (DD-835)	287	0
USS CHICKASAW (ATF-83)	78	400
USS CHIKASKIA (AO-54)	176	198
USS CHOWANOC (ATF-100)	88	401
USS CLAMP (ARS-33)	88	651
USS COASTERS HARBOR (AG-74)	195	195
USS CONSERVER (ARS-39)	86	919
USS COUCAL (ASR-8)	117	556
USS CREON (ARL-11)	144	284
USS CUMBERLAND SOUND (AV-17)	540	61
USS CURRENT (ARS-22)	94	885
USS DELIVER (ARS-23)	84	952
USS DIXIE (AD-14)	835	214

Table 7-1 (Continued)

Film Badge Dose Summary For Support Ship Crews

Support Ship	Crew Size	Total Film Badge Dose (mrem)
USS DUTTON (AGS-8)	60	306
USS ENOREE (AO-69)	152	198
USS ETLAH (AN-79)	36	689
USS FALL RIVER (CA-131)	817	204
USS FLUSSER (DD-368)	146	428
USS FULTON (AS-11)	733	267
USS FURSE (DD-882)	293	2
USS GEORGE CLYMER (APA-27)	270	248
USS GUNSTON HALL (LSD-5)	305	211
USS GYPSY (ARSD-1)	77	516
USS HAVEN (AH-12)	476	250
USS HENRICO (APA-45)	424	226
USS HESPERIA (AKS-13)	139	245
USS INGRAHAM (DD-694)	237	505
USS JAMES M. GILLISS (AGS-13)	40	202
USS JOHN BLISH (AGS-10)	48	335
USS KENNETH WHITING (AV-14)	539	195
USS LAFFEY (DD-724)	251	332
USS LCI-977	35	176
USS LCI(L)-1062	35	362
USS LCI-1067	34	93
USS LCI-1091	35	380
USS LOWRY (DD-770)	244	326
USS LST-388	80	277
USS LST-817	63	182
USS LST-861	80	326
USS LST-871	81	0
USS LST-881	71	193
USS LST-989	84	0
USS MENDER (ARSD-2)	49	307
USS MOALE (DD-693)	247	759
USS MOUNT McKINLEY (AGC-7)	824	193
USS MUNSEE (ATF-107)	63	368
USS NEWMAN K. PERRY (DD-883)	280	185
USS O'BRIEN (DD-725)	237	175
USS ONEOTA (AN-85)	45	582
USS ORCA (AVP-49)	215	262
USS OTTAWA (AKA-101)	67	63
USS PALMYRA (ARS(T)-3)	299	378
USS PANAMINT (AGC-13)	591	0
USS PGM-23	39	935
USS PGM-24	48	1293

Table 7-1 (Continued)

Film Badge Dose Summary For Support Ship Crews

Support Ship	Crew Size	Total Film Badge Dose (mrem)
USS PGM-25	53	1061
USS PGM-29	48	1087
USS PGM-31	55	812
USS PGM-32	27	1045
USS PHAON (ARB-3)	160	331
USS POLLUX (AKS-4)	154	117
USS PRESERVER (ARS-8)	85	1122
USS PRESQUE ISLE (APB-44)	194	280
USS QUARTZ (IX-150)	50	235
USS RECLAIMER (ARS-42)	73	1679
USS ROBERT K. HUNTINGTON (DD-781)	234	474
USS ROCKBRIDGE (APA-228)	206	334
USS ROCKINGHAM (APA-229)	297	241
USS ROCKWALL (APA-230)	288	208
USS ROLETTE (AKA-99)	151	241
USS SAIDOR (CVE-117)	854	68
USS SAINT CROIX (APA-231)	306	72
USS SAN MARCOS (LSD-25)	631	249
USS SEVERN (AO-(W)-61)	145	137
USS SHAKAMAXON (AN-88)	38	643
USS SHANGRI-LA (CV-38)	1935	.0
USS SIOUX (ATF-75)	66	301
USS SPHINX (ARL-24)	155	290
USS SUNCOCK (AN-80)	43	664
USS SYLVANIA (AKA-44)	208	238
USS TELAMON (ARB-8)	158	267
USS TOMBIGBEE (AOG-11)	86	273
USS TURNER (DD-834)	313	0
USS WALKE (DD-723)	242	210
USS WENATCHEE (ATF-118)	99	301
USS WHARTON (AP-7)	493	245
USS WIDGEON (ASR-1)	86	637
USS WILDCAT (AW-2)	128	172
USS YMS-354	28	457
USS YMS-358	31	468
USS YMS-413	32	444
USS YMS-463	17	441

Table 7-2

Summary of Calculated Doses for Target Ship Crews

REMANNED

	Crew Size	Total Film Badge Dose (mrem)
USS BLADEN (APA-63)	111	222
USS CONYNGHAM (DD-371)	109	495
USS CORTLAND (APA-75)	89	228
USS DENTUDA (SS-335)	58	693
USS FILLMORE (APA-83)	109	209
USS GENEVA (APA-86)	115	230
USS LCI(L)-329	16	208
USS LCI(L)-549	22	205
USS LCI(L)-615	16	644
USS NIAGARA (APA-87)	271	197
USS PARCHE (SS-384)	61	1097
USS SEARAVEN (SS-196)	58	896
USS TUNA (SS-203)	57	1489

NON-REMANNED

	Crew Size	Total Film Badge Dose (mrem)
USS ANDERSON (DD-411)	105	192
USS APOGON (SS-308)	54	248
USS ARDC-13	4	unk
USS ARKANSAS (BB-33)	441	178
USS BANNER (APA-60)	104	250
USS BARROW (APA-61)	114	206
USS BRACKEN (APA-64)	108	0
USS BRISCOE (APA-65)	112	202
USS BRULE (APA-66)	111	217
USS BUTTE (APA-68)	126	203
USS CARLISLE (APA-69)	104	5
USS CARTERET (APA-70)	119	219
USS CATRON (APA-71)	116	238
USS CRITTENDEN (APA-77)	112	258
USS DAWSON (APA-79)	110	270
USS FALLON (APA-81)	127	232
USS GASCONADE (APA-85)	105	224
USS GILLIAM (APA-57)	91	379
USS HUGHES (DD-410)	81	314
USS INDEPENDENCE (CVL-22)	343	200
USS LAMSON (DD-367)	119	2

Table 7-2 (continued)

Summary of Calculated Doses for Target Ship Crews

NON-REMANNED (continued)

	Crew Size	Total Film Badge Dose (mrem)
USS LCI-327	18	311
USS LCI-332	17	311
USS LCI-620 (officers)	2	274
USS LCI-620 (crew)	14	249
USS LSM-60	44	0
USS LST-52	63	240
USS LST-125	56	unk
USS LST-133	78	207
USS LST-220	59	226
USS LST-545	47	224
USS LST-661	62	229
USS LST MAYRANT (DD-402)	109	284
USS MUGFORD (DD-389)	126	255
USS MUSTIN (DD-413)	112	274
NAGATO (EX-JAP BB)	172	93
USS NEVADA (BB-36)	403	261
USS NEW YORK (BB-34)	536	331
USS PENSYLVANIA (BB-38)	484	255
USS PENSACOLA (CA-24)	354	231
USS PILOTFISH (SS-386)	52	209
PRINZ EUGEN (EX-GERMAN CA)	444	229
USS RALPH TALBOT (DD-390)	132	267
USS RHIND (DD-404)	104	266
SAKAWA (EX-JAP CL)	143	3
USS SALT LAKE CITY (CA-25)	335	330
USS SARATOGA (CV-3)	589	72
USS SKATE (SS-305)	53	508
USS SKIPJACK (SS-184)	78	230
USS STACK (DD-406)	102	223
USS TRIPPE (DD-403)	135	224
USS WAINWRIGHT (DD-419)	148	218
USS WILSON (DD-408)	115	222
USS YO-160	10	unk
USS YOG-83	10	unk

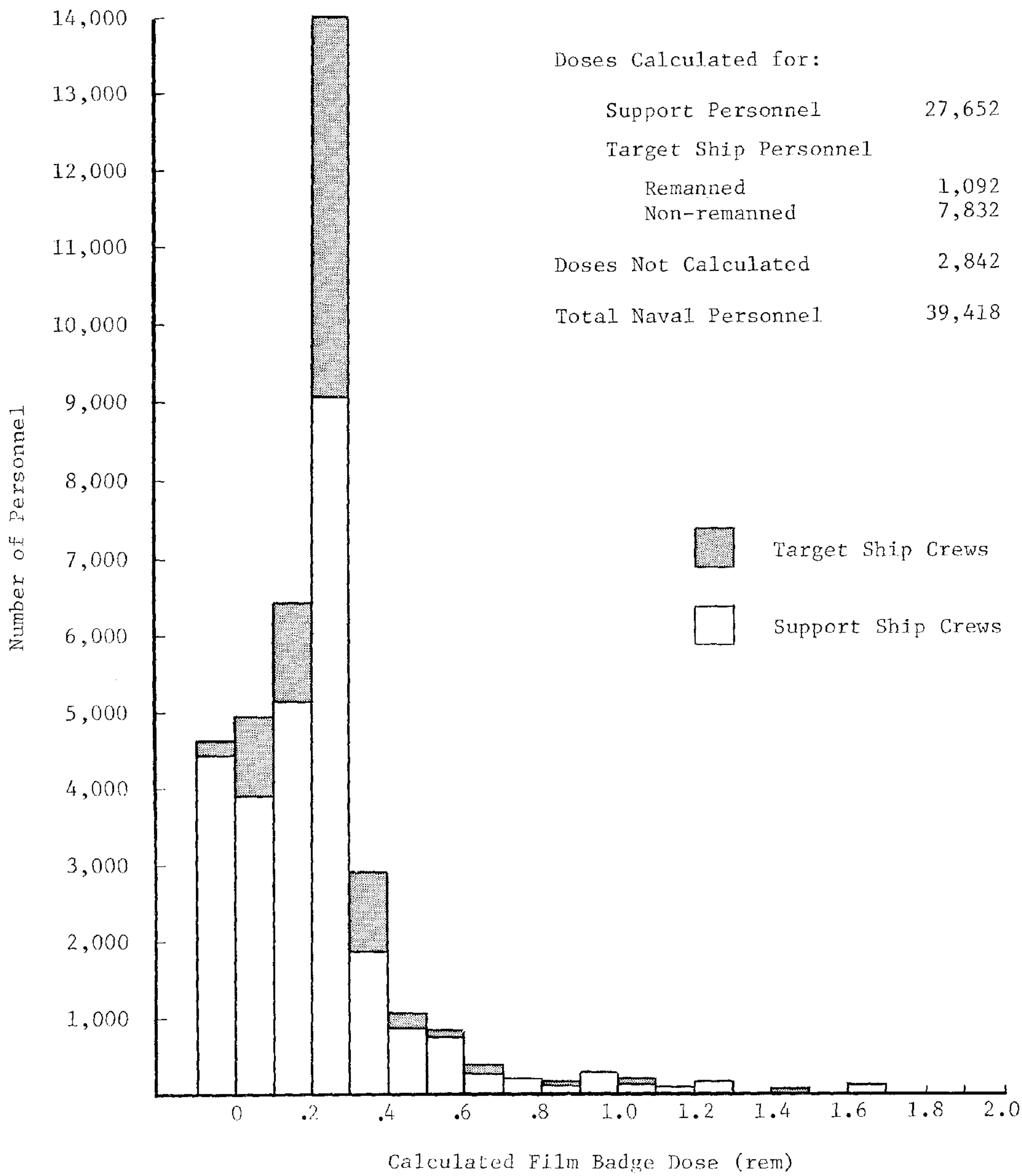

Figure 7-1 Distribution of Calculated Doses

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