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ASSESSMENT AND CONTROL OF THE TRANSOCEANIC FALLOUT THREAT

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Stanford Research Institute

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This report presents magnitude estimates of the transoceanic fallout threat to the United States from nuclear wars conducted by foreign opponents on the Asian Mainland. If precipitation occurs when the nuclear cloud from an Asian nuclear war passes over the United States, hazardous deposits of transoceanic fallout could result. The fallout threat from such an event is delineated in terms of external doses and internal organ doses that are derived from the inhalation of airborne activity and the ingestion of contaminated food and water, and in

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terms of the effect of these exposure doses on the health of the population. The exposure doses derived from transoceanic fallout are insufficient to cause early fatalities or sickness, but for large populations, the probable late deleterious health effects are very significant.

The report also covers feasible countermeasures for reducing the exposure doses and necessary preparations to cope with the possible hazards. These preparations include the establishment of a capability to recognize and evaluate the hazards and a capability to carry out the suitable countermeasures.

Final Report
Detachable Summary

August 1974

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By: H. LEE, and W. E. STROPE

For:

DEFENSE CIVIL PREPAREDNESS AGENCY
WASHINGTON, D.C. 20301

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R. M. RODDEN, *Director*
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Engineering Systems Division

DETACHABLE SUMMARY

A massive nuclear war in Asia will inject large quantities of nuclear debris into the atmosphere. Prevailing winds are likely to transport a significant part of this debris into the troposphere over the United States. It is also very likely that precipitation scavenging of the debris in the troposphere over substantial areas of the United States will occur. This sequence of events will probably produce transoceanic fallout deposits ranging from a few roentgen (R)/hr at 1 hour to several tens of R/hr at 1 hour. Although the dose rates at the time of arrival will be greatly reduced by radioactive decay, the possible accumulated exposure from external radiation sources and from ingested radiation sources would be sufficient to warrant countermeasures. External radiation sources are the principal contributors to whole-body doses. The I-131 in milk from cows grazing in transoceanic fallout contaminated pastures is a principal source of internal organ exposure. Infant and fetal thyroids are the organs most vulnerable to the dietary intake of radioactivity.

The exposure doses derived from transoceanic fallout are insufficient to cause early fatalities or sickness, but for large populations so exposed, the probable deleterious late effects are significant. Countermeasures can be taken to reduce the potential transoceanic fallout exposure and, thus, reduce the probable number of late effect incidents. For example, since the reduction of I-131 in pasturage from weathering and radioactive decay is relatively fast, the removal of dairy cows from pasture and placing them on uncontaminated feed and water for about two and a half weeks before returning them to pasture will reduce the maximum I-131 content in milk by a factor of 10. If the pasture denial

time is about five weeks, the maximum I-131 content in milk would be reduced by a factor of 100.

Certain preparations are necessary, however, to assure that the feasible countermeasures will be effectively executed in a transoceanic fallout emergency. Necessary is the capability to detect a probable transoceanic fallout event and the capability to monitor air contamination, external gamma dose rates, and food and water contamination at the local level. The existing monitoring capabilities, although substantial, are not organized to respond fully to a transoceanic fallout emergency. Even if all public and private facilities with radiological measurement capabilities are enlisted during a transoceanic emergency, increased food contamination monitoring capacity would still be needed. If monitors are organized and trained to use the Defense Civil Preparedness Agency (DCPA) V-700 instrument initially to screen the acceptability of food, existing monitoring capabilities and capacities would be adequate. The food producers, water suppliers, and the public must also be made knowledgeable of the hazards and the available countermeasures; they must be prepared to take the appropriate actions. The appropriate selection and timely execution of countermeasures could readily reduce external doses by an order of magnitude and internal organ doses by one to two orders of magnitude.

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Final Report *August 1974*

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SUMMARY

A massive nuclear war in Asia will inject large quantities of nuclear debris into the atmosphere. Prevailing winds are likely to transport a significant part of this debris into the troposphere over the United States. It is also very likely that precipitation scavenging of the debris in the troposphere over substantial areas of the United States will occur. This sequence of events will probably produce transoceanic fallout deposits ranging from a few roentgen (R)/hr at 1 hour to several tens of R/hr at 1 hour. Although the dose rates at the time of arrival will be greatly reduced by radioactive decay, the possible accumulated exposure from external radiation sources and from ingested radiation sources would be sufficient to warrant countermeasures. External radiation sources are the principal contributors to whole-body doses. The I-131 in milk from cows grazing in transoceanic fallout contaminated pastures is a principal source of internal organ exposure. Infant and fetal thyroids are the organs most vulnerable to the dietary intake of radioactivity.

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ABSTRACT

This report presents magnitude estimates of the transoceanic fallout threat to the United States from nuclear wars conducted by foreign opponents on the Asian Mainland. If precipitation occurs when the nuclear cloud from an Asian nuclear war passes over the United States, hazardous deposits of transoceanic fallout could result. The fallout threat from such an event is delineated in terms of external doses and internal organ doses that are derived from the inhalation of airborne activity and the ingestion of contaminated food and water, and in terms of the effect of these exposure doses on the health of the population. The exposure doses derived from transoceanic fallout are insufficient to cause early fatalities or sickness, but for large populations, the probable late deleterious health effects are very significant.

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I INTRODUCTION

The nuclear debris from nuclear weapons used by one or both foreign warring opponents that may become a health hazard to people in the United States is that carried into the lower atmosphere of the United States. This debris may be deposited in a dry state on various U.S. land areas through gravitational settling or downdrafts, or it may be scoured from the atmosphere by various forms of precipitation. The deposited nuclear debris, either in a dry or wet state, contaminates the landscape and cause external radiation exposure doses and internal radiation exposure doses if contaminated food and water are consumed. The inhalation of airborne nuclear debris, either nondeposited or resuspended, also leads to internal radiation exposures.

A. Objectives

The objectives of this research were

(1) To assess the short-term threat to the United States of fallout that might result from a nuclear war in other locations in the northern hemisphere.

(2) To develop a plan for radiological monitoring in the event of such a war.

(3) To recommend a set of actions that could be undertaken in areas where monitoring indicates protective actions are appropriate.

B. Method of Approach

The expected hazards to the United States from transoceanic fallout created by a nuclear war in other locations in the northern hemisphere were determined by the formulation of a calculation procedure and the comparison of the calculated results with reported data on activity concentrations in the air, on deposited activity, and on I-131 concentrations in milk after Chinese nuclear detonations. The procedure, thus substantiated, can be used as a basis for calculating the expected hazards from assumed nuclear war scenarios.

The transoceanic fallout contamination avenues were examined, and a set of radiological monitoring requirements were established that, if realized, will ensure the measurement of significant influxes of transoceanic fallout. Consideration was given to the feasibility of expanding existing monitoring networks to meet the established specifications on short notice and to methods that will provide timely warning in the event of an emergency. Consideration was also given to supplementing existing networks with resources that are currently available but not currently used. The various options were examined, and a suitable radiological monitoring plan is recommended.

There are several protective actions that can be taken in the affected areas. These protective actions are described and examined in relation to feasibility, cost, and effectiveness; suitable actions are recommended.

II TRANSOCEANIC FALLOUT THREAT

The large nuclear debris particles from surface bursts have sufficiently high falling speeds, and, thus, regardless of their altitude of origin (stabilization altitudes), they will deposit locally.* The very small particles from surface bursts and airburst particles originating from stratospheric altitudes, on the other hand, will fall so slowly that they will remain at high altitudes when they pass over the United States the first time around (worldwide fallout†). Therefore, the nuclear debris particles that presents a potential transoceanic radiation threat are the particles of intermediate sizes originating from the stratosphere and upper troposphere and the small-size particles originating from tropospheric altitudes. In the absence of precipitation scouring, only a small fraction of the nuclear debris that is carried into the U.S. atmosphere will deposit on the United States. With precipitation scouring, however, a substantial fraction of the nuclear debris in the troposphere below rain cloud altitudes can be expected to be deposited.

A. Air-Burst Fallout Particles

The fallout particle sizes associated with air bursts also include the multimicron sizes; however, the activity associated with these larger

*Local fallout has been variously defined, by particle size, distance, and deposition time. It is commonly defined as that which is deposited within 24 hours, and this is the definition that is used here.

†Defined as that which is deposited no earlier than three months.

particles is minimal, and for estimation purposes, all the activity can be assumed to be in the fine, worldwide fallout sizes.

B. Surface-Burst Fallout Particles

Surface bursts produce a wide range of fallout particle sizes. Those in the fine particle range can be treated like air burst particles. Those in the large particle range will deposit locally and will not be in the transoceanic fallout. Some intermediate sizes, depending on size, altitude of origin, and wind velocities, will remain in the atmosphere and reach the United States; some will not.

It has been estimated that about 60% of the total activity from surface bursts is deposited in local fallout.[1] It has also been estimated that about 20% of the activity is in the fine, "worldwide fallout," particle-size range.[2] Since the local fallout activity is estimated at 60% and the activity with the fine sizes is estimated at 20%, the remainder, about 20% of the activity, can be assigned to intermediate size particles. If the local fallout is defined as that which deposits within 24 hours, and worldwide fallout is defined as that which deposits after three months, then the activity associated with various particle sizes in the intermediate range can be estimated for various yields. Estimates of this activity distribution are shown in Figure 1.

C. Activity Concentrations over the United States

Having a rough estimate of the activity and particle size distribution, one can calculate and provide estimates of possible airborne concentrations over the United States. These estimates can then be extended to estimates of deposition, food and water contamination, and, finally, external dose rates, external doses, and internal doses.

If the particle's altitude of origin, falling speed, and time of travel are known, then, in the absence of updrafts and downdrafts, its

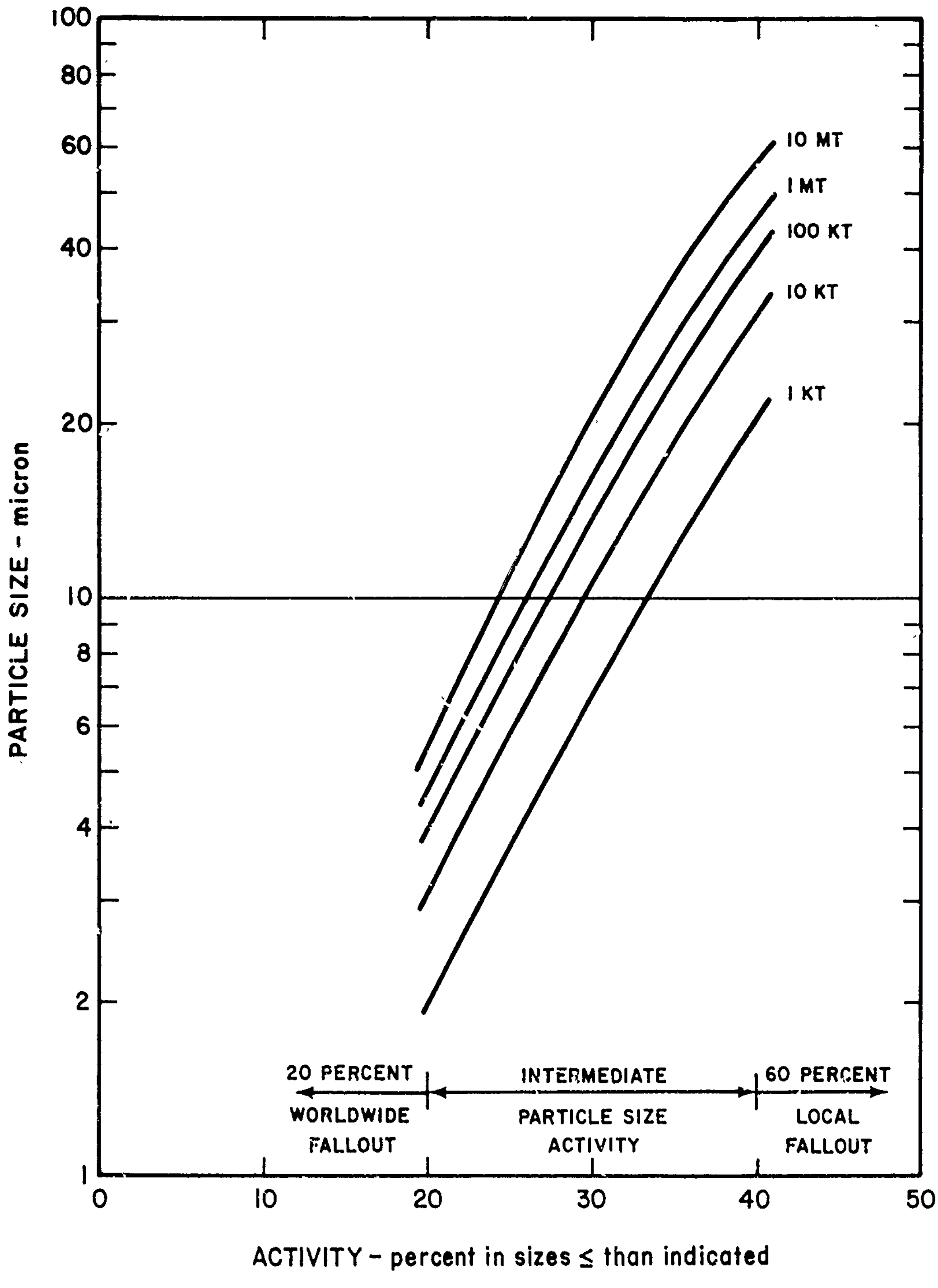

FIGURE 1 ACTIVITY DISTRIBUTION FOR INTERMEDIATE PARTICLE SIZES

altitude upon arrival over the U.S. can be determined. The travel time can be equated by

$$t_t = \frac{L}{\overline{V}} \qquad (1)$$

where L is the distance (i.e., the distance from the point of detonation to the United States) and $\overline{V}$ is the average resultant velocity of the winds acting on the particle. The particle fall time from an altitude of origin, on the other hand, can be equated by

$$t_f = \frac{H_o}{\overline{U}_\mu} \qquad (2)$$

where H_o is the altitude of origin and $\overline{U}_\mu$ is the average free-fall velocity for a specified particle size. For the particles to travel the distance L, it is necessary that $t_f \gtrsim t_t$. Also, the altitude of a particle at t_t can be determined by

$$H_{(t)} = H_o - \overline{U}_\mu t_t , \qquad (3)$$

and the limiting condition for fallout particles originating from H_o to be airborne in the troposphere at t_t is

$$\frac{H_o}{\overline{U}_\mu} > t_t > \frac{H_o - H_p}{\overline{U}_\mu} ,$$

where H_p is the altitude of the tropopause. The altitude of the tropopause, H_p, varies, but for the purpose to be applied here, it can be assumed to be 17 kilometers above sea level.

A set of calculated fallout free-fall velocities for various particle sizes at various altitudes is shown in Figure 2.* Figure 3 shows particle fall times from various altitudes and Figure 4 shows the particle fall times from various altitudes to the tropopause (17 km).

Nuclear cloud altitudes for any yield can vary over a relatively wide range[1†] depending on atmospheric conditions, but they can be estimated by

$$T = 762\ W^{0.234} + HOB \qquad 1\ \text{ton} \le W \le 10^3\ \text{tons} \qquad (4)$$

$$T = 335\ W^{0.353} + HOB \qquad 10^3\ \text{tons} < W \le 2 \times 10^4\ \text{tons} \qquad (5)$$

$$T = 2135\ W^{0.1661} + HOB \qquad W > 2 \times 10^4\ \text{tons} \qquad (6)$$

for the nuclear cloud top at cloud stabilization, and by

$$B = 433\ W^{0.22} + HOB \qquad 1\ \text{ton} \le W \le 10^3\ \text{tons} \qquad (7)$$

$$B = 100\ W^{0.432} + HOB \qquad 10^3\ \text{tons} < W \le 2 \times 10^4\ \text{tons} \qquad (8)$$

$$B = 1494\ W^{0.159} + HOB \qquad W > 2 \times 10^4\ \text{tons} \qquad (9)$$

for the stabilized nuclear cloud base where W is the weapon yield in tons and T and B and HOB are in meters. Also, the minimum HOB for air bursts can be estimated by

$$HOB\ (\text{air-min.}) = 3.5\ W^{0.4} \qquad (10)$$

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*Calculations are based on equations provided in Reference 3.
†References are on page 71.

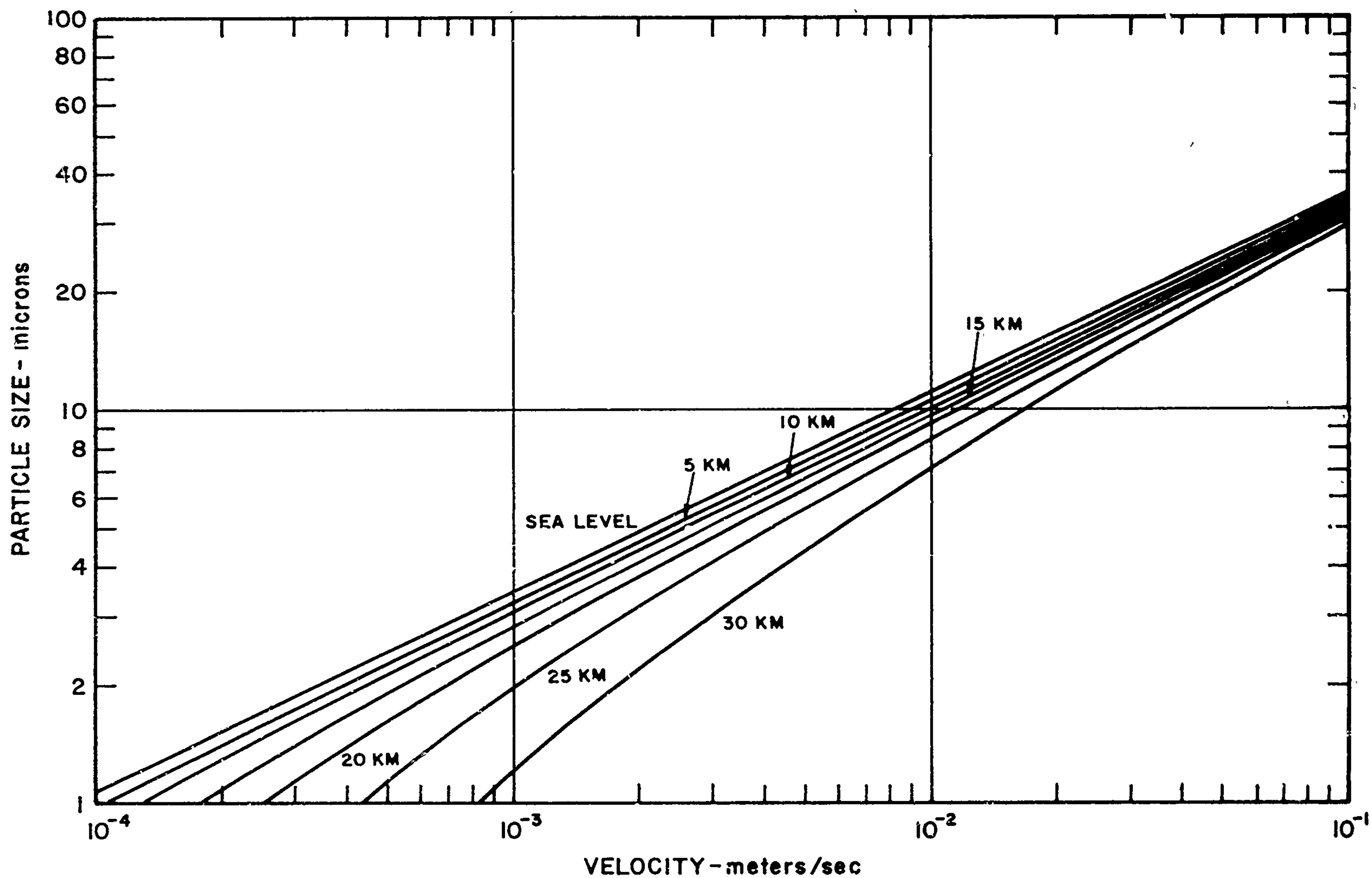

FIGURE 2 FALLOUT PARTICAL FREE-FALL VELOCITIES . VARIOUS ALTITUDES

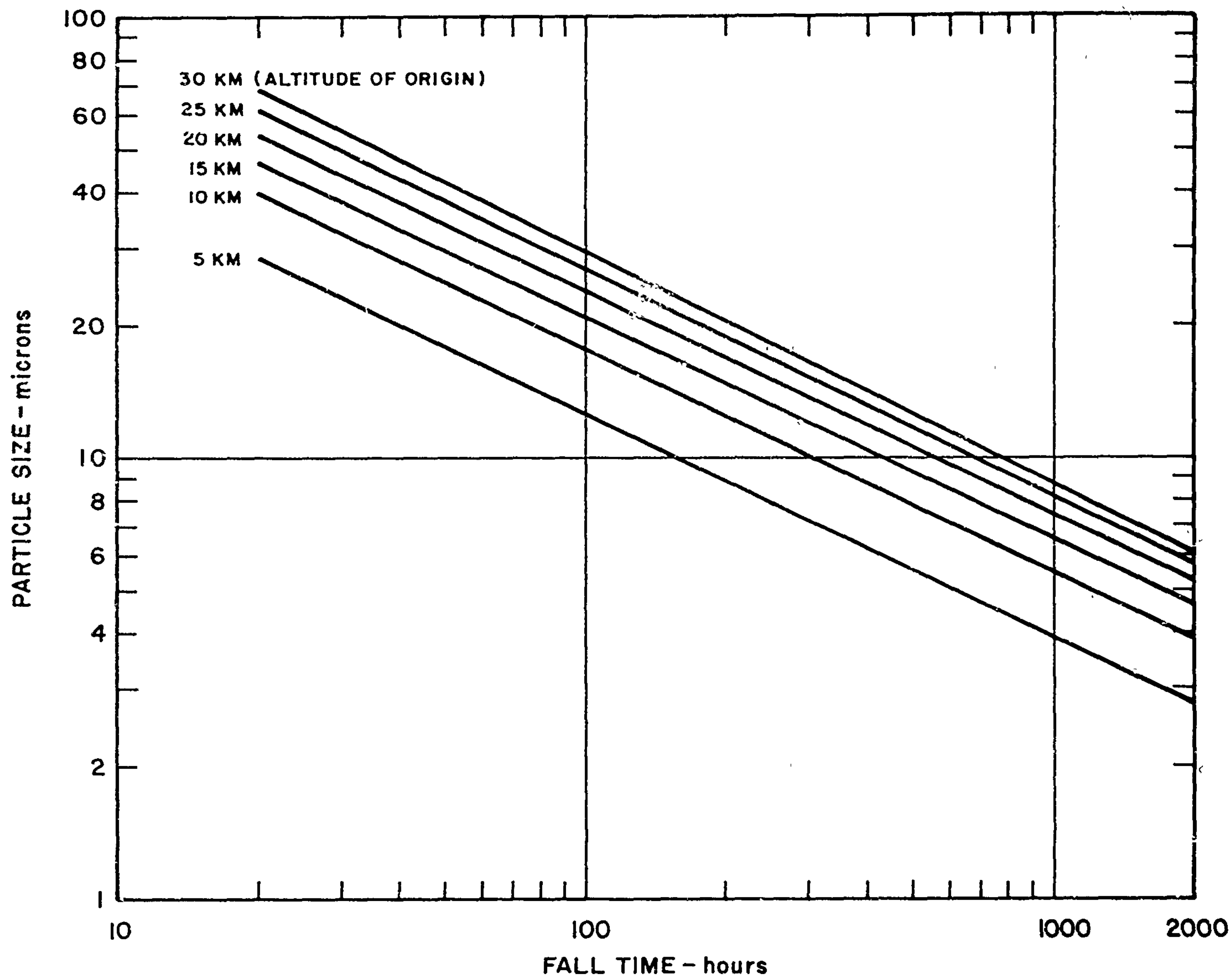

FIGURE 3 PARTICLE FALL TIMES FROM VARIOUS ALTITUDES

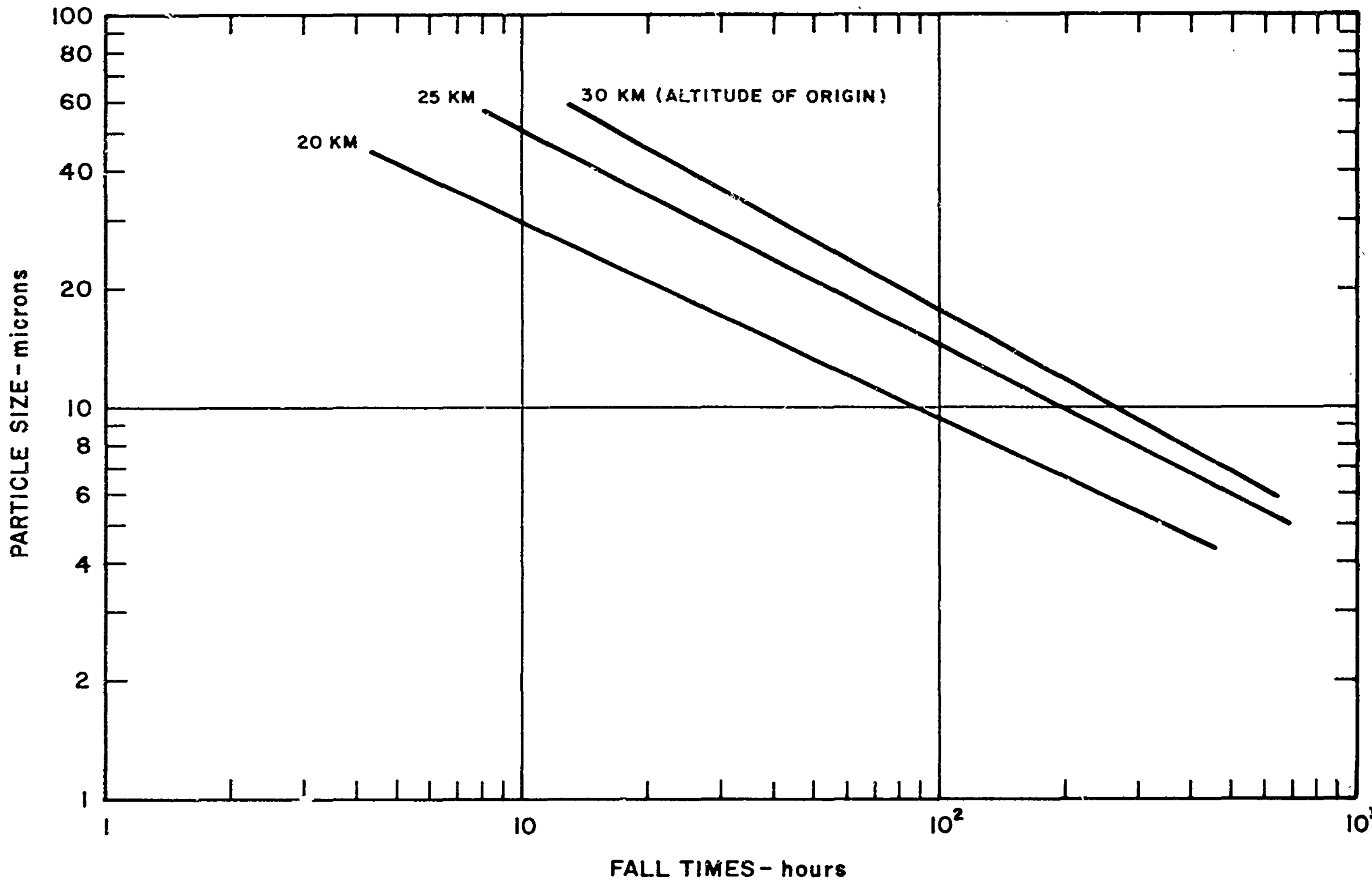

FIGURE 4 PARTICLE FALL TIMES TO 17 KM FROM VARIOUS ALTITUDES

Given the activity and particle size distribution in a nuclear cloud, the particle sizes from the nuclear cloud reaching L within the tropospheric layer can be calculated and the activity in the troposphere at L and available for rainout or washout deposition can be determined. To simplify the estimation process, it can be assumed that the activity associated with the worldwide-fallout particle sizes that are injected into the stratosphere (above 17 km) are not available for "first pass" transoceanic deposition on the United States. Also, for worst case calculations, the worldwide particle sizes originating from troposphere altitudes can be assumed to be totally available; that is, none are lost because of downdraft deposition or rainout deposition en route, and none are injected into the stratosphere en route.

For air bursts, the fraction of the total activity in the tropopause and available for transoceanic deposition can be estimated by

$$A_{fa} = \frac{H_p - B}{T - B} , \qquad H_p \leq T . \tag{11}$$

For surface bursts, the fraction of the total activity in the tropopause and available for transoceanic deposition can be estimated by

$$A_{fg} = 0.2 \frac{H_p - B}{T - B} + \Sigma A_\mu , \quad H_p \leq T \tag{12}$$

where ΣA_μ is the activity associated with the fallout particles in the intermediate-size range that are airborne in the troposphere at L.

As the particle cloud moves from its stabilization point through the atmosphere, the particle concentrations become increasingly diffused. For worst case estimates, little or no wind shear is assumed, and all the particle cloud reaching the United States is assumed to have diffused horizontally. According to Crawford[4], its center concentration can be estimated by

$$C_t = C_s t^{-3} \tag{13}$$

where C_s is the average concentration of activity in the nuclear cloud at the nuclear cloud stabilization time.

The gross fission product activity produced by a nuclear burst is estimated at 1.2 x 10^9 Ci per ton of fission yield. At one hour after burst (a convenient reference time for subsequent calculations), the activity is decayed to about 5 x 10^5 Ci (i.e., 5 x 10^5 Ci/ton at 1 hour). The activity concentration in the nuclear cloud at stabilization and referenced to 1 hour can be estimated from the stabilized cloud volume. The equations for estimating the stabilized cloud top and cloud base were previously provided. The diameter of the nuclear cloud at stabilization from data provided in Reference 1 can be estimated by the equation

$$D = 95\ W^{0.3806} \tag{14}$$

where D is in meters and W is in tons. If the nuclear cloud is modeled to resemble a vertical cylinder of diameter D with a height equal to T - B, the nuclear cloud activity concentration at stabilization and referenced to 1 hour after burst, can be equated by

$$C_{s(v)} = \frac{5 \times 10^5 F_y W^{0.2388}}{\pi \left(\frac{95}{2}\right)^2 \left(T - B\right)} \text{ Ci/m}^3 \text{ at 1 hour} \tag{15}$$

and

$$C_{s(A)} = \frac{5 \times 10^5 F_y W^{0.2388}}{\pi \left(\frac{95}{2}\right)^2} \text{ Ci/m}^2 \text{ at 1 hour} \qquad (16)$$

where $C_{s(v)}$ is the volumetric activity concentration, $C_{s(A)}$ is the horizontal activity concentration, and F_y is the fission yield fraction.

For hazard assessments, it is also desirable to estimate the deposited exposure rate per unit surface area. Thus, in terms of deposited exposure rates, one ton of fission yield is estimated to be equivalent to 3 R/hr per mi^2 at 1 hour after burst for deposition on an infinite smooth-plane surface.[2] If the deposition area is equivalent to the horizontal area of the stabilized cloud, i.e., $\pi D^2/4$, then the 1-hour concentration can also be equated in exposure rate units by

$$C_{s(A)} = \frac{3 \times 2.59 \times F_y W^{0.2388}}{\pi \left(\frac{95}{2}\right)^2 \times 10^{-6}} \text{ R/hr at 1 hour.} \qquad (17)$$

Equations (15), (16), and (17) can be reduced to the following:

$$C_{s(v)} = 70\ F_y W^{0.2388}/(T\text{-}B) \text{ Ci/m}^3 \text{ at 1 hour,} \qquad (18)$$

$$C_{s(A)} = 70\ F_y W^{0.2388} \text{ Ci/m}^2 \text{ at 1 hour, and} \qquad (19)$$

$$C_{s(A)} = 1100\ F_y W^{0.2388} \text{ R/hr at 1 hour.} \qquad (20)$$

If only horizontal diffusion of the worldwide-sized particles is assumed to occur (at t^{-3}), and if the decay rate is estimated by $t^{-1.2}$, the activity concentration per unit volume, that is in the atmosphere, after traveling the distance L, is represented by

$$C_{L(v)a} = C_{s(v)} t_t^{-4.2} \text{ Ci/m}^3 \tag{21}$$

for air bursts and

$$C_{L(v)g} = (0.2 + \Sigma A_\mu)\ C_{s(v)} t_t^{-4.2} \text{ Ci/m}^3 \tag{22}$$

for surface bursts. To check the validity of Equations (21) and (22), calculated values using these equations were compared to data report for two Chinese test detonations--the first was a tower mounted devi of approximately 20 kt on 18 November 1971[5] and the second with similar yield but unknown burst height on 7 January 1972.[6] The comparisons are as follows:

Date of Detonation	Reference Date	Maximum Measured Activity	Calculated Activity for 20 kt (worst case average)
18 Nov. 1971	25 Nov. 1971	51 pCi/m³	87 p Ci/m³ airburst 28 p Ci/m³ surface burst
7 Jan. 1972	13 Jan. 1972	91 p Ci/m³	167 p Ci/m³ airburst 53 p Ci/m³ surface burst

The peak air-activity concentration in the United States that was recorded for the 250 kt detonation on 27 December 1966 was obtained from an air sample filter that was collected six days after the burst and counted nine days after the burst. The reported gross beta air concentration was 127 p Ci/m^3 (this would be equivalent to about 207 p Ci/m^3 at the arrival time of six days). The calculated air activity concentrations, using Equations (21) and (22), for a 250 kt detonation and an arrival time of six days are 194 and 59 p Ci/m^3 for air and surface bursts respectively. It appears, therefore, that the calculated air activity concentrations are reasonable estimates of peak activity concentrations even though the available comparative data is extremely limited. It should be noted that, for a travel time of 144 hours, a 1% change in the diffusion exponent would alter the resulting air activity concentration by 16%.

In the absence of precipitation scavenging, virtually all of the activity would remain airborne, that is, transoceanic fallout deposition would be insignificant. If a precipitation event were to cause all the particles in the troposphere over a particular area at any time to be instantaneously deposited, however, the deposited activity concentration after traveling a distance, L, would be

$$C_{L(A)a} = C_{s(A)} A_{fa} t_t^{-4.2} \text{ Ci/m}^2 \text{ or R/hr at } t_t \qquad (23)$$

for air bursts and

$$C_{L(A)g} = C_{s(A)} A_{fg} t_t^{-4.2} \text{ Ci/m}^2 \text{ or R/hr at } t_t \qquad (24)$$

for surface bursts.

Because the deposited activity concentrations and exposure rates referenced to some time other than t_t may be desired, Equations (23) and (24) are rewritten as

$$C_{L(A)a} = C_{s(A)} A_{fa} t_t^{-3} t_r^{-1.2} \text{ Ci/m}^2 \text{ or R/hr at } t_r \quad (25)$$

and

$$C_{L(A)g} = C_{s(A)} A_{fg} t_t^{-3} t_r^{-1.2} \text{ Ci/m}^2 \text{ or R/hr at } t_r \ . \quad (26)$$

Depending on the scavenging event encountered, the concentration of deposited activity could be greater or less than that of instantaneous deposition. Most precipitation altitudes are well below the tropopause; nevertheless, if the scavenging location is stationary and of long duration, the concentration of deposited activity under the scavenging location will be increased. If the rate of scavenging is slow and the scavenging location moves with the nuclear debris, the concentration of deposited activity will be decreased and spread over a greater area. Calculated air activity for 100% fission-yield weapons are shown in Figure 5. Calculated activity concentrations and exposure rates for 100% fission-yield weapons and instantaneous deposition at 139 hours are shown in Figures 6 and 7 respectively. The standard intensities for these depositions are shown in Figure 8.

Data for checking the validity of Equations (25) and (26) are relatively scarce; however, a measured deposited activity exposure rate is available. It will also be shown, later, that these equations can be indirectly checked with measured milk contamination data. The Chinese detonated a tower-mounted device on 28 December 1966 with an estimated yield of 250 kt. Seven days later, the gamma radiation levels at Oak Ridge, Tennessee, increased from a normal of 0.018 mR/hr to 0.035 mR/hr.[7] The difference of 0.017 mR/hr for seven days of decay is equivalent to a standard intensity of about 8 mR/hr at 1 hour ($0.017 \times 168^{1.2} = 7.96$). The calculated standard intensity for a yield of 250 kt and $t_t = 168$ hours is 4.2 mR/hr at 1 hour for an air burst and 1.4 mR/hr for a surface burst.

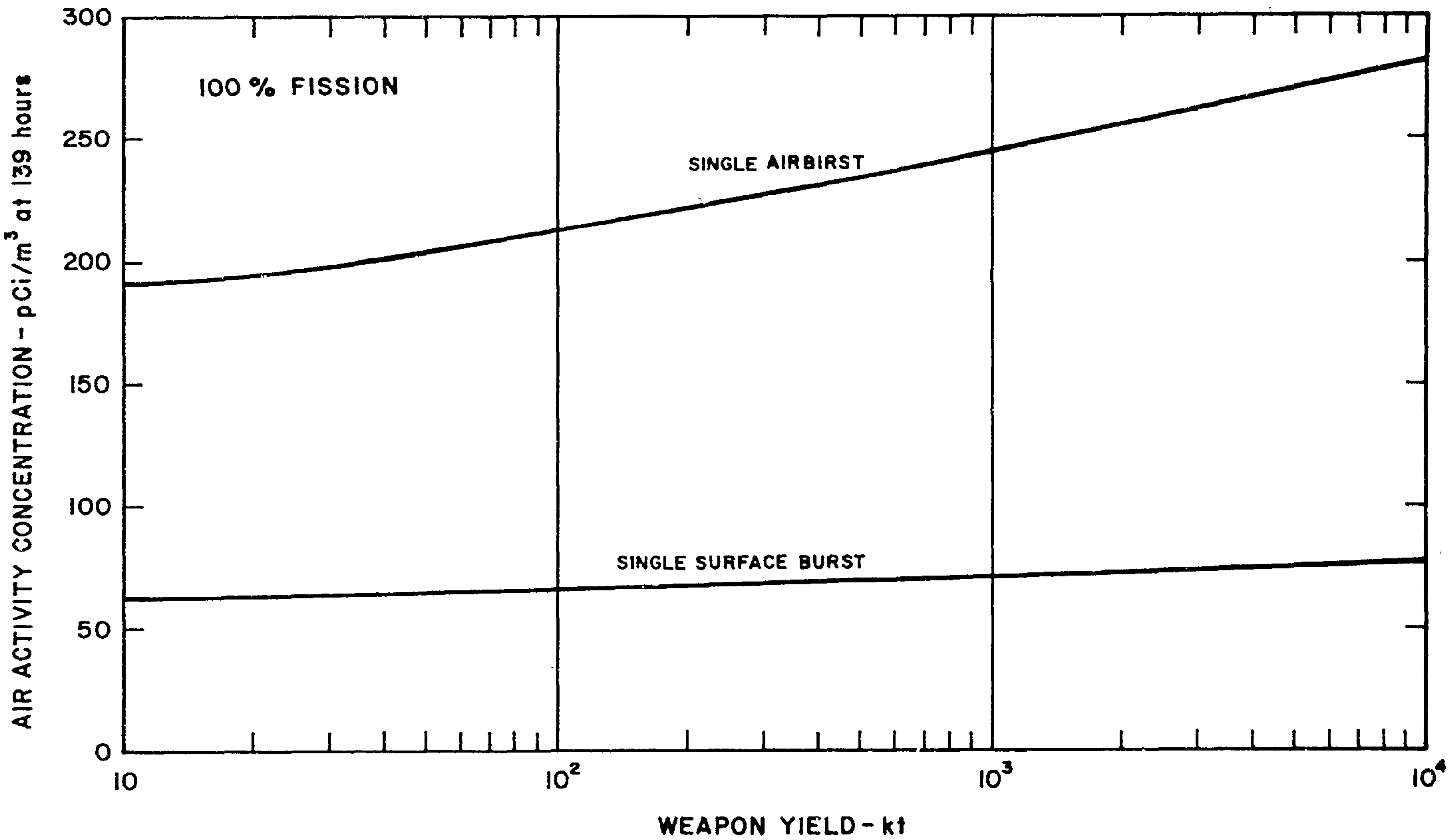

FIGURE 5 CALCULATED TRANSOCEANIC AIR ACTIVITY CONCENTRATIONS

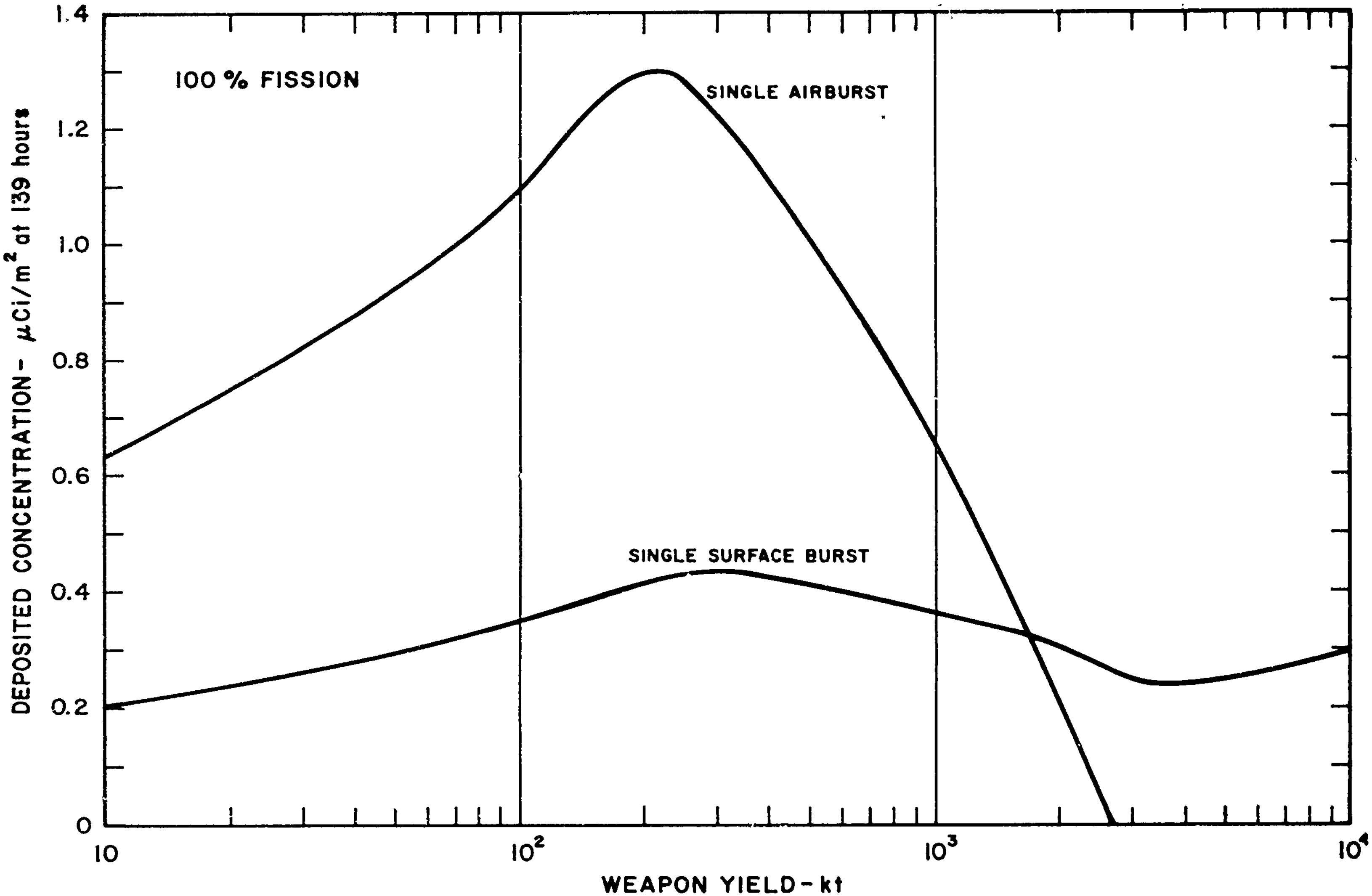

FIGURE 6 CALCULATED TRANSOCEANIC DEPOSITED ACTIVITY CONCENTRATIONS

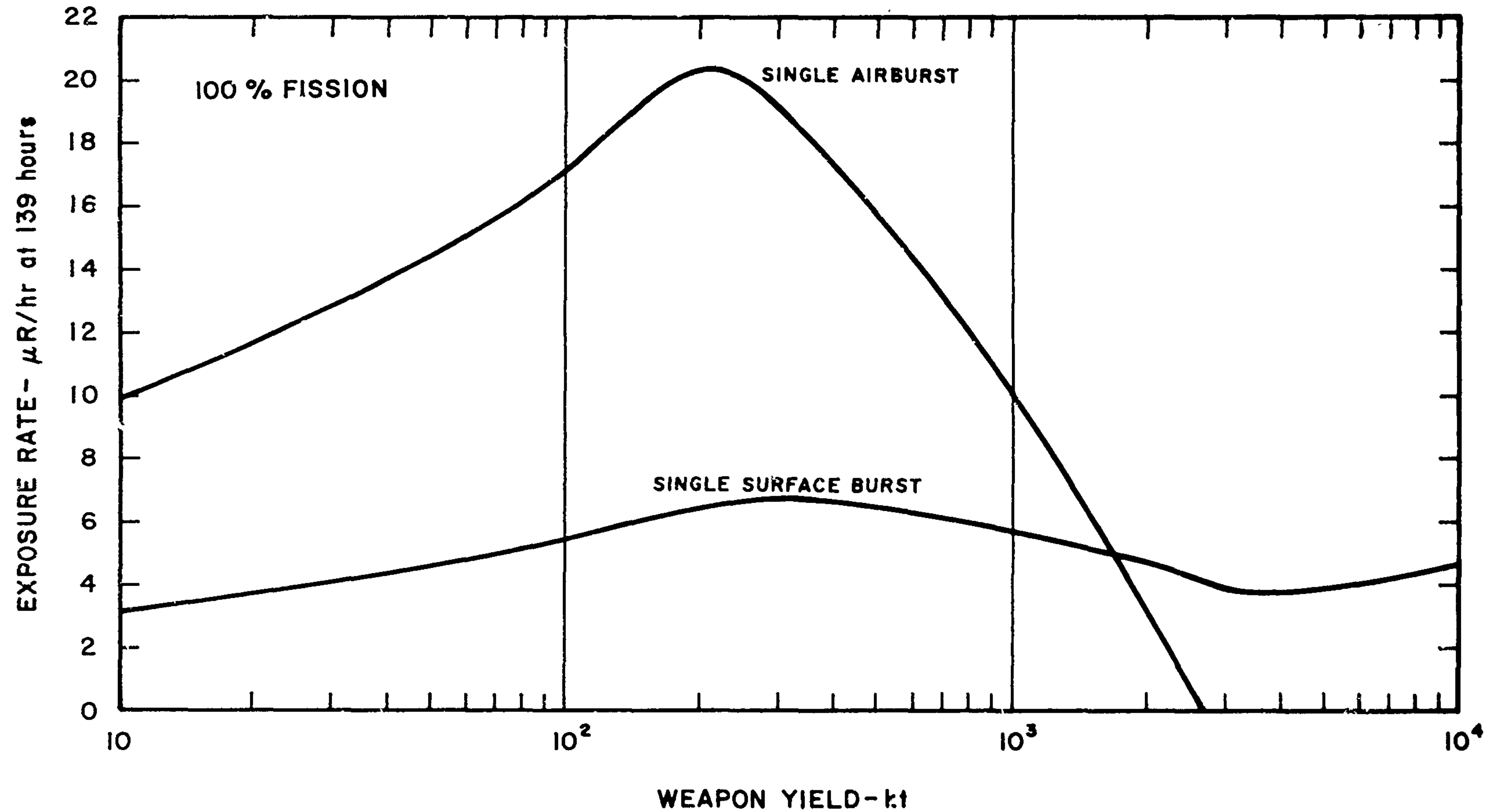

FIGURE 7 CALCULATED TRANSOCEANIC DEPOSITED ACTIVITY EXPOSURE RATES

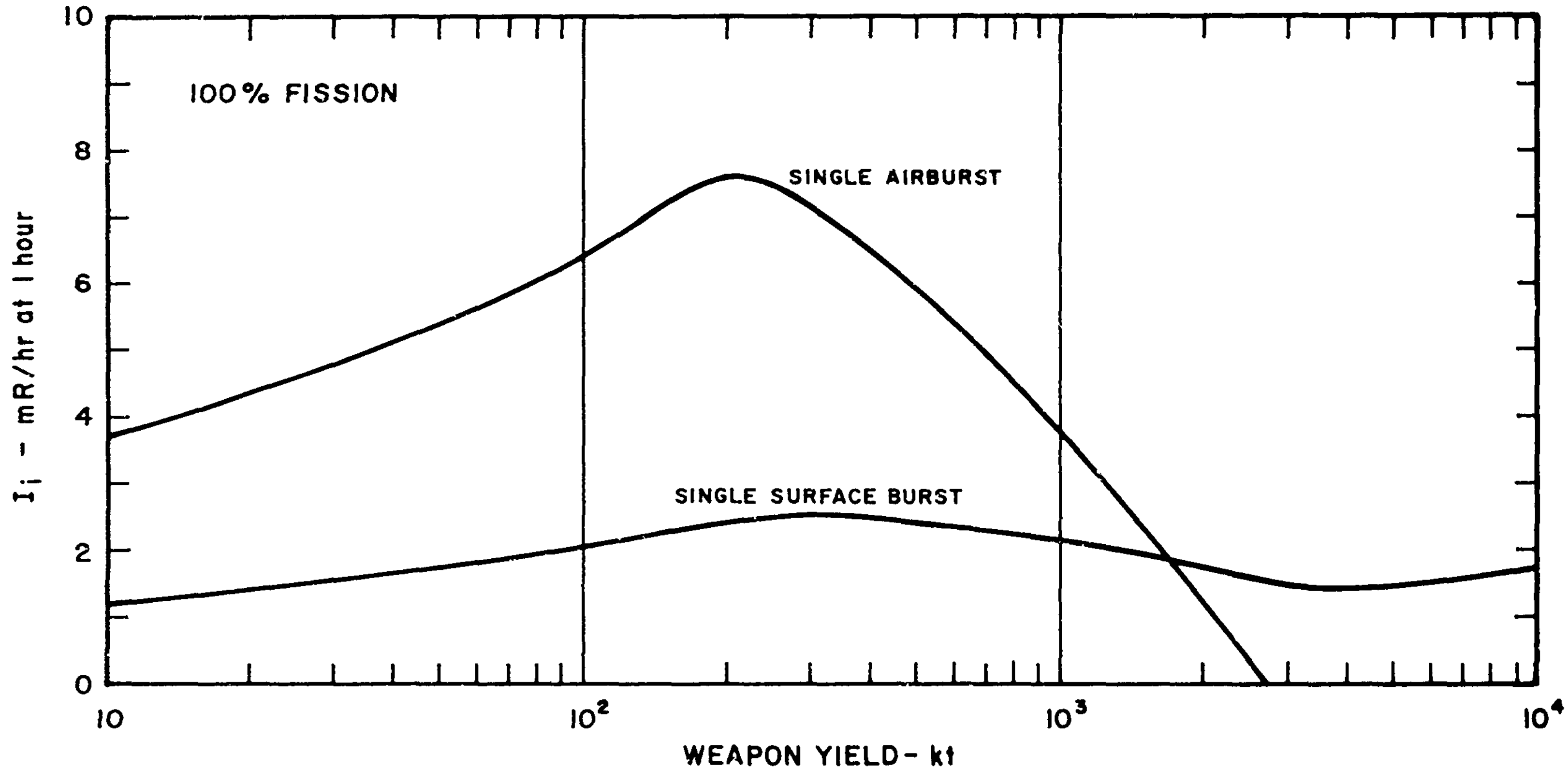

FIGURE 8 CALCULATED TRANSOCEANIC STANDARD INTENSITY

The deposition of transoceanic fallout on the United States from test detonations on the Asian mainland have by no means been uniformly distributed; thus, significant areas can be expected to be more contaminated than the levels indicated in Figures 6 and 7. Other areas may not receive any fallout deposition. The deposited activity for earlier arrival times, of course, would be increased. For later arrival times, it would be decreased. The transoceanic fallout estimation procedure appears to provide reasonable estimates of precipitation activity deposition.

The range of transoceanic fallout contamination that can result from single-weapon detonations has been estimated. The calculated data indicates that, on a per-unit-yield basis, the lower yield detonations have a higher transoceanic contamination potential. The indicated differences would be increased if the higher yield detonations were thermonuclear weapons. In estimating the transoceanic fallout from a nuclear war on the Asian mainland where the total nuclear yield is in the order of a few thousand megatons, one must consider the probable weapon mix, the target region, and the time over which the nuclear weapons are detonated. For a massive nuclear employment, it can be anticipated that a high percentage of the total yield will be from high-yield weapons. A mix of weapon yields would mean a wide range of stabilized cloud altitudes, and it can be anticipated that, for different altitudes, the effective fallout winds will be different. It can also be anticipated that the target region will be large and that the detonations will occur over a significant period of time. All these factors (high yields, mixed yields, large target region, and detonations spaced over a period of time) would have the tendency to minimize the transoceanic fallout concentration. Nevertheless, it is estimated that such a nuclear employment could produce transoceanic fallout equivalent to exposure rates in the order of several R/hr at 1 hour.

As examples, four hypothetical nuclear employment scenarios with the calculated transoceanic fallout standard intensities (for a five-day fallout arrival time) for each scenario are presented here. Scenario 2 is a strategic nuclear exchange between China and the Soviet Union. In this case, since some of the targets would be in Europe, the calculated standard intensities presented are on the high side. Scenario 3 is a Sino-Soviet war in which tactical nuclear weapons are employed. Scenario 4 is a Sino-Soviet war in which both strategic and tactical weapons are employed. See Tables 1 through 4.

As can be seen, the transoceanic fallout threat from a tactical nuclear war with a total weapon yield of 630 MT (Scenario 3) is about nine times greater than that from a strategic nuclear war with a total yield of 4,500 MT (Scenario 2). Also, for the tactical nuclear war, if all the weapons employed were air bursts, the calculated total standard intensity would be increased from 34 to 50 R/hr at 1 hour. The calculated results may be summarized as follows:

- A nuclear war in Asia with massive employment of strategic-sized weapons could produce transoceanic fallout on parts of the United States (where precipitation is coincidental with the nuclear cloud passage) equivalent to a standard intensity of about 4 R/hr at 1 hour.*
- A nuclear war in Asia with massive employment of tactical-sized weapons could produce transoceanic fallout on parts of the United States (where precipitation is coincidental with the nuclear cloud passage) equivalent to a standard intensity of about 50 R/hr at 1 hour.*

---

*The probability of precipitation being coincidental with transoceanic nuclear cloud passage over some part of the U.S., is shown in Section V-B-3 to be high.

Table 1

SCENARIO 1: SOVIET STRATEGIC ATTACK

Number of Weapons	Type	Weapon Yield (MT)	Fission Fraction	Total Yield (MT)	I_1 (R/hr at 1 hr)
150	Air	5	0.5*	750	0
150	Surface	5	0.5	750	0.109
200	Air	2	0.5	400	0.122
200	Surface	2	0.5	400	0.175
250	Air	1	0.5	250	0.471
250	Surface	1	0.5	250	0.266
300	Air	0.5	0.5	150	0.872
300	Surface	0.5	0.5	150	0.360
1,800				3,100	2.375

*An assumed value for the hypothetical attack.

Table 2

SCENARIO 2: SINO-SOVIET STRATEGIC NUCLEAR EXCHANGE

Number of Weapons	Type	Weapon Yield (MT)	Fission Fraction	Total Yield (MT)	I_1 (R/hr at 1 hr)
200	Air	5	0.5	1,000	0
200	Surface	5	0.5	1,000	0.145
300	Air	2	0.5	600	0.183
300	Surface	2	0.5	600	0.262
400	Air	1	0.5	400	0.754
400	Surface	1	0.5	400	0.426
500	Air	0.5	0.5	250	1.453
500	Surface	0.5	0.5	250	0.600
2,800				4,500	3.823

Table 3

SCENARIO 3: SINO-SOVIET TACTICAL NUCLEAR WAR

Number of Weapons	Type	Weapon Yield (MT)	Fission Fraction	Total Yield (MT)	I_1 (R/hr at 1 hr)
500	Air	0.2	1	100	3.8
500	Surface	0.2	1	100	1.2
1,000	Air	0.1	1	100	6.4
1,000	Surface	0.1	1	100	2.05
1,500	Air	0.05	1	75	8.055
1,500	Surface	0.05	1	75	2.588
2,000	Air	0.02	1	40	6.8
2,000	Surface	0.02	1	40	2.8
10,000				630	33.693

Table 4

SCENARIO 4: SINO-SOVIET STRATEGIC AND TACTICAL NUCLEAR WAR

Number of Weapons	Type	Weapon Yield (MT)	Fission Fraction	Total Yield (MT)	I_1 (R/hr at 1 hr)
2,800	----- (See Scenario 2) -------			4,500	3.82
800	Air	0.2	1	160	6.08
800	Surface	0.2	1	160	1.92
1,000	Air	0.1	1	100	6.40
1,000	Surface	0.1	1	100	2.05
2,000	Air	0.05	1	100	10.74
2,000	Surface	0.05	1	100	3.44
3,000	Air	0.02	1	60	10.20
3,000	Surface	0.02	1	60	4.20
16,400				5,340	48.85

III FOOD AND WATER CONTAMINATION

A. Estimation Procedures

The intake of radioactively contaminated food and water will lead to internal organ exposure doses. Because the uptake of activity by internal organs is selective, it is necessary to estimate the internal organ exposures with respect to specific radionuclides. Past studies of radioactivity intake and organ exposures have shown that the more important radionuclides are Sr-89, Sr-90, Ru-106, I-131, and Cs-137. The calculative procedures for estimating organ exposures include estimating the radionuclide fractions in the fallout and expressing these fractions in terms of "zero-time" atoms per unit yield or per unit infinite smooth-plane exposure rates. The number of zero-time atoms is an artifact that is a convenient reference for calculating radionuclide intake rates at various times.

Transoceanic fallout deposited in open waters can be considered totally soluble; it will settle and mix slowly. If water is drawn from near the bottom of a deep reservoir, it would take a considerable time to draw the fallout activity into the processing and distribution network. If the deposits are well mixed, then the concentration per cubic volume is inversely proportional to the depth of the body of water. Source reservoirs of many surface water systems are hundreds of feet deep; however, some are relatively shallow as are most distribution reservoirs.

The fraction of transoceanic fallout that will initially deposit and be retained on plant foliage and the rate of weathering loss with time could vary considerably. If fallout is deposited in heavy rains, only a small fraction will be retained. If it is dry when deposited, especially on plants wet with dew and in the absence of wind, a substantial fraction would be retained. The rate that activity is removed depends on the subsequent weather. The estimated values of plant contamination factors, a_L^w, for worldwide fallout derived by Miller are shown in Table 5.[8] He assumed that superficial activity was removed by normal washing and that the data reported for the estimates reflected true tissue absorption. The transoceanic foliar contamination is neither like worldwide contamination nor local fallout contamination. It is unlike worldwide contamination because its deposition rate is faster and its deposition period is shorter. It is unlike local fallout contamination because its deposition rate is slower and its particle sizes are smaller. The a_L^w values for transoceanic fallout, therefore, can be expected to be smaller than those for worldwide fallout. Also, those crops that are harvested soon after transoceanic arrival will have but a short time for tissue absorption. When compared to local fallout contamination, the foliar deposition factors and the decontamination factors (for washing or processing) can be expected to be higher.

Meat and dairy products from animals eating contaminated food or drinking contaminated water will also become contaminated. The contamination in meat and milk depends on the intake rate of the animals and the rate that various nuclides are accumulated in various organs. A representative retention factor for pasture grass is 0.15 (it can be expected to be much lower in heavy rain), and a representative weathering half-life is 15 days.[9] The zero-time nuclide concentrations in meat can be estimated by the equation*

$$C_i^o = \frac{f_i}{m} \frac{I_1 N_i^o \text{ (prf) (UAF)}}{(\lambda_i - k_w)} \left(e^{-k_w t} - e^{-\lambda_i t}\right) \qquad (27)$$

*Adapted from Reference 8.

Table 5

ESTIMATED VALUES OF a_L^w FOR SELECTED CROPS AND RADIONUCLIDES

Crop	a_L^w = $\frac{10^{-5}\text{ atoms/gm dry weight}}{\text{atoms/sq ft soil}}$: Sr-89, Sr-90	Zr-95, Ce-144	Ru-106	Cs-137
Corn	90	0.1	0.3	40
Sorghum	90	9.0	27	450
Wheat	90	9.0	27	425
Oat	90	9.0	27	450
Barley	30	3.0	9.0	180
Dry bean	20	2.0	6.0	800
Soy bean	20	2.0	6.0	240
Alfalfa	600	600	600	600
Clover	700	700	700	700
Potato	1	0.1	0.3	100
Green pea	6	0.6	1.8	18
Sugar beet	1	0.1	0.3	100
Tomato	500	500	500	1,750
Snap bean	20	2.0	6.0	60
Cabbage	300	300	300	1,050
Dry onion	1	0.1	0.3	100
Carrot	1	0.1	0.3	100
Lettuce	500	500	500	1,750
Apple	50	5.0	15	150
Peach	300	30	90	900
Orange	50	5.0	15	150

where m is the muscle mass in grams, f_i is the fraction of the nuclide that is assimulated (in meat), prf is the plant retention factor, UAF is the area utilization factor, t is the ingestion period in days, λ_i is the biological elimination rate constant for the nuclide, and k_w is the concentration reduction rate constant due to weathering and plant growth. The muscle weight of beef cattle is estimated at 1.8 x 10^5 grams; the UAF varies with pasture growth, and an average UAF is estimated at 500 ft^2 per day; and k_w is 0.0495 for an estimated half-life of 14 days.

The secretion of ingested iodine into cow milk has been relatively well studied, and the percent of daily intake appearing in each liter of milk has been found to vary by an order of magnitude.[10] The relationship between environment contamination and average zero-time I-131 contamination in milk at various times after ingestion can be estimated* by

$$C^{o}_{I-131} = 0.011\ I_1 N^{o}_{I-131} (prf)(UAF) \left(e^{-0.0495t} - e^{-0.28t}\right) \text{atoms}/\ell. \tag{28}$$

Implicit in Equation (28) is a pasture weathering half-life of 14 days and an average iodine secretion rate to milk at 1%/ℓ.

B. Calculations

The number of zero-time atoms of various radionuclides in worldwide fallout that provides the more significant internal exposure doses are estimated as follows:[8]

*Adapted from Reference 10.

Radionuclide	N_i^0/ft^2/R/hr at 1 hr
Sr-89	4.3×10^{10}
Sr-90	4.8×10^{10}
Ru-106	7.0×10^{10}
I-131	4.8×10^{10}
Cs-137	9.2×10^{10}
Ba-140	8.5×10^{10}
Gross fission products	1.54×10^{12}

Calculations of the fraction of the total activity provided by I-131 using $N_i^0 = 4.8 \times 10^{10}$ at seven days after burst were about 25% higher than those reported in the transoceanic fallout sample from the Chinese test detonation of 18 November 1971.[5]

The calculated number of zero-time atoms for 1 R/hr at 1 hour in water for a reservoir depth of 10 feet are as follows:

Radionuclide	N_i^0/ℓ/R/hr at 1 hr
Sr-89	1.5×10^8
Sr-90	1.7×10^8
Ru-106	2.5×10^8
I-131	1.7×10^8
Cs-137	3.2×10^8
Ba-140	3.0×10^8
Gross fission products	5.4×10^9

The calculated zero-time concentrations on vegetables and grain after decontamination are shown in Table 6.

Table 6

ZERO-TIME CONCENTRATIONS ON
VEGETABLES AND GRAIN AFTER DECONTAMINATION,
N_i^o/g/R/hr at 1 hr
(10^7)

Crop	I-131*	Sr-89	Sr-90	Ba-140†	Ru-106	Cs-137
Grain	0.04	3.87	4.32	7.62	1.89	41.4
Dry bean	0.15	0.86	0.92	1.70	0.42	73.6
Potato	--	0.043	0.048	0.085	0.021	9.2
Dry onion	--	0.043	0.048	0.085	0.021	9.2
Carrot	--	0.043	0.048	0.085	0.021	9.2
Tomato	0.14	21.5	24.0	42.5	35.0	161.
Cabbage	0.72	12.9	14.4	25.5	21.0	96.6
Lettuce	0.72	21.5	24.0	42.5	35.0	161.

*Based on local fallout retention.
†Tissue absorption assumed to be similar to Sr-89-90.

The calculated maximum zero time radionuclide concentrations in beef and the contaminated pasture intake period at which the maximum concentration is reached for each nuclide are as follows:

Radionuclide	f_i	λ_i	$t_{C_i^o \max}$	N_i^o/gram/R/hr at 1 hr
Sr-89	0.053	0.35	7 days	2.0×10^6
Sr-90	0.053	0.35	7 days	2.2×10^6
I-131	0.090	0.05	21 days	1.3×10^7
Cs-137	0.38	0.045	21 days	1.1×10^8

The calculated maximum zero time I-131 concentration in milk (five days of contaminated pasture intake where the prf is 0.15 and a secretion rate of 1%/ℓ) is 2.25×10^{10} atoms/ℓ/R/hr at 1 hour.

Early after transoceanic fallout arrival, the two most active radionuclides leading to significant internal doses are Sr-89 and I-131. The infinite smooth-plane exposure rates and the Sr-89 and I-131 activity in food and water at various times after burst for transoceanic fallout deposition equivalent to 1, 5, and 50 R/hr at 1 hour are presented in Table 7. A transoceanic fallout arrival time of five days was assumed for the calculation of the activity concentrations.

The gross fission product activity in water (10 feet deep) and on lettuce with no weathering loss and prior to decontamination at various times after burst for transoceanic fallout deposition equivalent to 1, 5, and 50 R/hr at 1 hour are presented in Table 8.

The most available measured data on transoceanic fallout from Chinese tests are I-131 concentrations in milk at various times after the burst date. Since the external exposure rates are generally not measurable, and the arrival times are generally not known, a five-day ingestion period can be assumed for the purpose of comparing calculated estimates with measured data. To facilitate comparisons, it is convenient to convert the measured I-131 content in milk in p Ci/l to equivalent environmental contamination in $\mu Ci/m^2$ at 139 hours so that it could be directly compared with the data in Figure 6. The conversion factors for 5 plant retention factors are as follows:

Plant Retention Factor	Conversion Factors for an Arrival Time of Nine Days
0.05	0.00294
0.10	0.00147
0.15	0.00098
0.20	0.00074
0.25	0.00059

The resulting product is the equivalent environmental contamination in $\mu Ci/m^2$.

Table 7

COMPARISON OF EXPOSURE RATES AND FOOD CONTAMINATION AT VARIOUS TIMES AFTER BURST

I_1 (R/hr)	Time After Burst (days)	I_t mR/hr	I-131 Milk (nCi/l)	I-131 Water (nCi/l)	Sr-89 Water (nCi/l)	SR-89 Leafy Vegetables* (nCi/g)	Sr-89 Meat (nCi/g)
1	10	1.4	240	2	0.81	1.2	0.0077
5	10	7	1,200	10	4.05	6	0.0385
50	10	70	12,000	100	40.5	60	0.385
1	15	0.86	160	1.3	0.76	1.1	0.0074
5	15	4.3	800	6.5	3.8	5.5	0.037
50	15	43	8,000	65	38	55.	0.37
1	20	0.6	87	0.78	0.71	1	0.006
5	20	3	435	3.9	3.55	5	0.03
50	20	30	4,350	39	35.5	50	0.3

*Activity per gram dry weight after decontamination.

Table 8

COMPARISON OF EXPOSURE RATES AND GROSS FISSION PRODUCT ACTIVITIES IN WATER AND ON LEAFY VEGETABLES

I_1 (R/hr)	Time After Burst (days)	$\dot{I}_t$ mR/hr	Water nCi/l	Leafy Vegetables* nCi/g
1	10	1.4	29	250
5	10	7	145	1,250
50	10	70	1,450	12,500
1	15	0.86	18	150
5	15	4.3	90	750
50	15	43	900	7,500
1	20	0.6	13	110
5	20	3	65	550
50	20	30	650	5,500

*Dry weight, no decontamination.

For example, a measured milk sample, 14 days after a Chinese 250 kt tower burst contained 930 p Ci I-131/l.[11] When multiplied by the conversion factor for an arrival time of nine days and for a plant retention factor of 0.15, this is equivalent to 0.91 $\mu Ci/m^2$. Figure 6, on the other hand, shows estimated worst-case average environmental concentrations of 0.43 $\mu Ci/m^2$ and 1.28 $\mu Ci/m^2$ for 250 kt surface and air bursts, respectively. In another case, a milk sample, 14 days after a Chinese 45 kt burst was measured at 220 p Ci I-131/l.[12] This is equivalent to 0.22 $\mu Ci/m^2$ at 139 hours for an arrival time of nine days and for a plant retention factor of 0.15. Figure 6 shows estimated worst case average environmental concentrations of 0.29 $\mu Ci/m^2$ and 0.9 $\mu Ci/m^2$ for 45 kt surface and air bursts, respectively.

The comparison of calculated estimates with the few measured data has indicated that

- The calculated air concentrations are similar to the measured peak activity concentrations.
- The calculated worst-case deposited concentrations are about a factor of 2 or 3 lower than the measured peak activity concentrations.
- The calculated I-131 concentration in milk compared favorably in one case and was a bit higher than the measured peak concentration in the second case.

If the comparative data were all from a single event (they were not), then, for the second comparison to be consistent with the first, it is necessary that the scavenged volume of the activity cloud was greater than the product of the deposition area and the thickness of the cloud below the tropopause. Since the activity cloud may take several days to pass over a deposition area, it is very possible for it to be scavenged several times during its passage. For the case where the calculated I-131 in milk appeared to be a bit high, a lower prf and a lower secretion rate could account for the discrepancy.

Since the tropospheric scavenging associated with the depositions for the measured data and the fallout arrival times are not known, and the iodine secretion rate and the prf could vary over relatively wide ranges, the apparent differences are not significant. The transoceanic fallout threats from nuclear wars in Asia, calculated and summarized in Section III, can therefore be considered to be reasonable estimates if one remembers that limited areas could be higher and that many areas would be several times lower. Also, plant retention factors in the range between 0.05 and 0.25 appear to be appropriate for estimating the activity on pasture grass.

IV EXPOSURE DOSES

A. External Exposure Doses

The external exposure dose received by an individual over an exposure period for deposited fallout can be calculated provided the radiation shielding received by the individual and the weathering reduction of the deposited activity were known or could be estimated. For local fallout, 0.7 is commonly used as the ground roughness multiplier. Within an urban area, however, it can be estimated that the out-of-doors shielding for urban inhabitants will be higher because they will seldom be standing in the center of an open expanse of ground. Also since the transoceanic fallout particle sizes are small, it can be anticipated that the deposited activity on paved surfaces (sidewalks and streets) and on certain roofs would be substantially reduced by the first heavy rain.

For the purpose of comparing transoceanic external exposure doses with internal exposure doses, the exposure dose for an exposure period from five days to 104 days will be estimated for a standard intensity of 1 R/hr at 1 hour. Assuming no weathering reduction over this period, the dose rate multiplier for this period is about 0.80. If 0.7 is used as the ground roughness multiplier, then the external exposure dose for outdoor exposures over this period is 0.56 rems for I_1 = 1 R/hr at 1 hour. Even under normal conditions, however, the population can be expected to be spending a considerable amount of time indoors; thus, population exposures can generally be expected to be significantly lower. For example, an individual that stays indoors 20 hours each day, with an indoor shielding factor of five, would only receive 0.23 rems over this period. It was estimated that significant areas of the United States may be contaminated by transoceanic fallout to about 5 R/hr at 1 hour for massive strategic nuclear weapons employment in Asia, and about 50 R/hr at 1 hour for massive tactical nuclear weapons employment in Asia. The corresponding estimated external exposure doses for these contamination levels are about 1 rem and 10 rems respectively.

B. Food and Water Ingestion Doses

Although contaminated water, green vegetables, milk, and meat can be expected to reach consumers a relatively short time after transoceanic fallout arrival, there generally is a considerable lag time between grain harvest and grain consumption. The absorbed doses for adult human organs per unit ingestion rate of zero-time radionuclides for various periods of ingestion are shown in Table 9.[8] The modified model values are for foods whose initial origin was pasturage (i.e., beef, mutton, and milk), and the unmodified model values are for all other foods and water. Except for Sr-90, Ru-106, and Cs-137, the absorbed doses are rapidly reduced for later ingestion start times, t. Thus, if the lag time between grain harvest and grain consumption were six months, only these three radionuclides will be the significant contaminated grain contributors to organ doses.

The radionuclide ingestion rate depends on the diet. The estimated average daily dietary intake rates[9] for adults are as follows:

Water	1 liter	Onion	2 grams (dry)
Milk	0.6 liter	Carrot	1 gram (dry)
Meat	200 grams	Tomato	2 grams (dry)
Grain	200 grams (dry)	Cabbage	1 gram (dry)
Bean	30 grams (dry)	Lettuce	1 gram (dry)

For the above intake rates, the calculated adult organ doses for an ingestion start time of 14 days ($t_o = 14$) and an ingestion period of 90 days ($t - t_o = 90$) are those presented in Table 10.

Table 9

ABSORBED DOSE PER UNIT INGESTION RATE FOR ADULT HUMANS
(10^{-14} Rems per Atom per Day)

$\frac{t-t_o}{t_o}$	Sr-89		Sr-90		Ru-106		I-131		Cs-137		Ba-140	
	1	14	1	14	1	14	1	14	1	14	1	14
a. Total Body (unmodified)												
29	15	13	0.2	0.2	0.35	0.35	72	23	0.29	0.29	3.4	1.6
90	92	78	2	2	1.4	1.3	99	32	2.3	2.3	6.5	3.0
b. Total Body (modified)												
29	9.7	4.2					49	8.2				
90	33	14					59	9.9				
c. Bone (unmodified)												
29	240	200	3.9	3.9	2.2	2.1	85	28	0.29	0.29	89	42
90	1400	1200	31	31	10	9.9	110	34	2.5	2.5	170	80
d. Bone (modified)												
29	150	64					57	0.64				
90	500	220					63	11				

Table 9 (concluded)

$\frac{t-t_o}{t_o}$	Sr-89		Sr-90		Ru-106		I-131		Cs-137		Ba-140	
	1	14	1	14	1	14	1	14	1	14	1	14
e. Large, Lower Intestine (unmodified)												
29	460	390	6.1	6.1	260	250			0.02	0.02	850	400
90	1000	880	19	19	780	760			0.06	0.06	1100	510
f. Large, Lower Intestine (modified)												
29	240	100										
90	280	120										
g. Thyroid (unmodified)												
29							110,000	36,000				
90							150,000	50,000				
h. Thyroid (modified)												
29							76,000	13,000				
90							91,000	15,000				

Table 10

CALCULATED INTERNAL ORGAN DOSES*

	Total Body	Bone	Large, Lower Intestine	Thyroid
Water	0.00019	0.0021	0.0047	0.085
Milk	0.0017	0.0074	0.0033	2.03
Meat	0.00032	0.001	0.00047	0.4
Grain	0.0075	0.11	0.18	0.048
Vegetables	0.0023	0.016	0.032	0.019
Total	0.013	0.14	0.22	2.6

*For transoceanic fallout at 1R/hr at 1 hour; $t_o = 14$; $t - t_o = 90$.

It should be noted that the ingestion of contaminated milk contributed 80% of the thyroid dose. It should also be noted that the thyroid of infants with the same daily intake of contaminated milk would receive about 10 times the adult thyroid dose. Thus, at $I_1 = 5$ R/hr at 1 hour, the infant thyroid exposure dose would be about 102 rems, and at $I_1 =$ 50 R/hr at 1 hour, the infant thyroid dose would be about 1,020 rems. Although the consumption of grain produced the highest dose contributions to bone, large, lower intestine, and the total body, a delay of contaminated grain consumption of six months would reduce the ingested grain doses to the bone and the total body by a factor of eight and reduce the ingested grain dose to the large, lower intestine by a factor of three. Also, the supply of contaminated mature vegetables would not last 90 days. Vegetables harvested early after transoceanic fallout arrival will have very little tissue absorbed contamination and, after decontamination, lower radionuclide retention rates than used in the calculation. Immature vegetables at the time of fallout arrival will also have less tissue absorption of radionuclides than used in the calculations because of small foliage size at contamination, subsequent increased mass from growth, and contamination losses because of weather over time. For all crops planted prior to transoceanic fallout arrival, root uptake contamination is insignificant. For crops planted after transoceanic fallout arrival, the Sr-90 content in vegetables from root uptake could lead to significant bone doses because the biological half-life of Sr-90 is extremely long. However, although the dose accumulation rate increases with time, the initial dose rate is relatively low and the rate of increase is relatively slow. For this reason the countermeasures for root uptake contamination can be applied at a later time; that is, uptake contamination is not an emergency problem and no preparations before the event are necessary.

C. Inhalation Doses

Transoceanic fallout particles in the air near the surface of the earth are available for inhalation. These could include resuspended particles. The amount available for inhalation depends on the concentration in the air and the duration of that concentration over a point location. Where little or no scavenging occurs, the inhalation of transoceanic fallout particles could be the primary hazard. If it is assumed that the deposited activity concentration is the result of scavenging a column of air from the tropopause to the ground surface, then the average radionuclide concentration in the air, in the absence of scavenging, can be related to the deposited activity (where scavenging occurs). For a deposition threat equivalent to 1 R/hr at 1 hour, the average activity in the air is calculated to be about 3 $\mu Ci/m^3$ at 1 hour. This concentration is equivalent to about 10 nCi/m^3 at five days. The 1-131 activity at five days is estimated at 0.15 nCi/m^3. Air samples taken over the United States after two of the Chinese test detonations (18 November 1971 and 7 January 1972) indicated a I-131-to-total activity ratio about twice that estimated above.[5,6] The inhalation exposure period depends on the speed that the transoceanic fallout particle volume is moved over a location by the winds aloft. Absorbed doses to the thyroid, the most critical organ, from inhalation can be estimated by the equation*

$$D = 4\ A_T T_h / m \tag{29}$$

where D is in rems, A_T is the total activity inhaled in μCi, T_h is the effective half-life in days, and m is the mass of the thyroid in grams. The estimated inhalation exposure doses to infant and adult thyroids for I-131 concentrations at 0.15 nCi/m^3 at five days for various inhalation periods starting at five days after burst are shown in Table 11. A comparison of the thyroid doses from inhalation with the thyroid doses from the ingestion of contaminated food and water shows the inhalation threat to be about two to three orders of magnitude lower than that from ingesting contaminated food and water.

Table 11

PROJECTED THYROID DOSES FROM INHALATION
(0.15 nCi I-131/m^3)

Inhalation Period (days)	Infant Thyroid Dose (mrems)	Adult Thyroid Dose (mrems)
1	10	4.9
2	19	9.3
3	28	13
4	35	17
5	42	21

*Adapted from Reference 13.

D. **Exposure Dose Effects**

The estimated three-month exposure doses for transoceanic fallout deposition equivalent to a standard intensity of 1 R/hr at 1 hour and for an arrival time of five days are summarized in Table 12.

Table 12

TRANSOCEANIC EXPOSURE DOSES FOR 1 R/hr AT 1 HOUR
(Rems)

Radiation Source	Infant Thyroid	Adult Thyroid	Bone	Intestine	Whole Body
Inhalation	0.042	0.021	--	--	--
External	0.23	0.23	0.23	0.23	0.23
Water	0.4	0.085	0.0021	0.0047	0.00019
Milk	20.3	2.03	0.0074	0.0034	0.0017
Meat	--	0.4	0.001	0.00047	0.00032
Vegetables	--	0.019	0.016	0.032	0.0028
Grain	--	0.048	0.11	0.18	0.0075
Total	21.0	2.83	0.37	0.45	0.24

The organ doses for transoceanic fallout standard intensities equal to 5 R/hr at 1 hour and 50 R/hr at 1 hour are listed in Table 13.

A whole body exposure dose of 12 rems accumulated over a three-month period will not produce any noticeable early biological effects. However, an exposure dose of 12 rems received by a large population could result in some premature deaths in later years. If the available dose-effects data are extrapolated for low-exposure doses, the estimated risk in terms of excess deaths because of radiation exposure is about 92 to 165 deaths per million persons per rem during the first 27 years after exposure.[14] The excess deaths in later years can therefore be estimated by the expression

$$N_D = P\,\bar{D} \times 130 \times 10^{-6}$$

where P is the exposed population and $\bar{D}$ is the average dose received by the population in rems. For example, if for the worst case (50 R/hr at 1 hour for parts of the United States) the average exposure dose received by each of approximately 200 million people were two rems, the number of excess deaths would be estimated at 52,000, or about 2000 per year.

Table 13

TRANSOCEANIC ORGAN DOSES FOR 5 R/hr AT 1 HOUR AND 50 R/hr AT 1 HOUR

	Exposure Dose in Rems	
Organ	5 R/hr at 1 hr	50 R/hr at 1 hr
Whole body	1.2	12
Intestine	2.3	23
Adult thyroid	14	140
Infant thyroid	110	1100

The exposure dose to the intestine from internal exposures is roughly equal to that from external source exposures. A total dose of 23 rems accumulated over a three-month period will not produce any noticeable early biological effects. However, it is estimated that mortalities from radiation induced cancer of the gastrointestinal (GI) tract (includes the stomach) is approximately one death per million people per year per rem.[14] Thus, if the intestine dose from internal sources also averaged two rems for the worst case, then for a population of 200 million, the calculated additional deaths from ingested radiation exposures of the GI tract are 400 per year.

The exposure dose to the bone is similar to that received by the intestine. A total exposure dose of 20 rems accumulated over a period of three months will not produce any noticeable early biological effects. It is estimated that mortalities from radiation-induced cancer of the skeleton is about two deaths per 10 million people per year per rem. Thus, if the ingested average dose for the worst case were two rems, the calculated deaths from bone cancer would be an additional 80 per year.

The calculated adult thyroid dose from ingested activity is 12 times greater than the external exposure dose, but the adult thyroid is relatively resistant to radiation damage, and an exposure of 140 rems accumulated over a three-month period will not produce any noticeable early biological effect. For adults, it has been estimated that radiation-induced cancer of the thyroid is less than two cases (not deaths) per million people per year per rem. Thus, for the worst case, if the average adult thyroid dose from ingested activity were 20 rems for an adult population of 100 million, the calculated number of thyroid cancer cases (not deaths) would be 4,000 per year.

The thyroid of the young are more susceptible to radiation damage and the development of late effects. Nevertheless, an exposoure dose of 1100 rems accumulated over a three-month period probably will not produce any noticeable early biological effects. However, it is estimated that a very high percentage of the children with thyroid exposure doses at this level will develop thyroid tumors, a small percentage of which will be malignant.[15] It has also been estimated that for children, radiation exposures will produce about six cases (not deaths) of thyroid cancer per million children per year per rem.[14] Thus, if for the worst case the average infant thyroid dose were 200 rems among an infant population of 10 million, the calculated number of infant thyroid cancer cases (not deaths) would be 12,000 per year. The remaining population, about 90 million young people will have an average thyroid dose greater than that for adults but less than that for infants. If the average thyroid exposure dose for the remaining 90 million were 75 rems, the calculated number of cancer cases per year for this group is 40,000 per year. In addition to the thyroid cancers it is estimated that several million will likely develop benign thyroid tumors.

Besides the somatic effects discussed above, other effects of radiation exposure include genetic mutations leading to increased diseases of various seriousness, abnormalities, and physical and mental development impairment. The effects of relatively low-exposure doses received by a large population (e.g., tens of thousands of delayed fatalities and an equal number of delayed serious diseases), therefore, are not insignificant. For the strategic attack case (5 R/hr at 1 hour for parts of the United States) the delayed effects are about a factor of ten less severe.

E. Exposure Dose Limits

Because transoceanic fallout is a possible event over which the United States has little control and the magnitude of the event could vary over a wide range, there is little point in setting dose-limiting recommendations at this time. This does not mean, however, that preparations should not be made to minimize the exposure doses from a transoceanic fallout event produced by an Asian nuclear war. As pointed out above, the consequences of the exposure doses from such an event could be a serious threat to life and health, albeit delayed and spaced over many years.

According to relativities in the 1971 Dose-Limiting Recommendations of NCRP for occupational exposures, the hazard associated with a whole-body exposure of five rems can be considered to be similar to that of an internal-organ exposure of 15 rems. Also, it may be considered to be similar to a fetal exposure of 0.5 rems. The ratios of the dose limits for internal organs to the dose limits for whole-body exposures are compared with the ratios of the transoceanic fallout doses for internal organs to the transoceanic fallout doses for whole-body exposures in Table 14.

Table 14

COMPARISON OF ORGAN EXPOSURES TO WHOLE-BODY EXPOSURES

	Dose Ratios		
	Transoceanic Fallout	Occupational Limits	Transoceanic Fallout to Occupational Limits
Adults			
Thyroid/Whole-body	12	3	4
Bone/Whole-body	1.52	3	0.51
Intestine/Whole-body	1.85	3	0.62
Infants and children*			
Thyroid/Whole-body	93	(3)	31
Pregnant Women			
Fetus/Whole-body*	1.0	(0.1)	10

*Nonoccupational.

The ratios above indicate that transoceanic fallout is most hazardous to infant and children thyroids. Fetal thyroids, because of extreme small size and high uptake could be even more vulnerable than infant thyroids if the less vulnerable pregnant hosts had high intake of I-131.

Since the ingestion of contaminated milk is the primary source of infant and fetal thyroid exposures, the provision of uncontaminated milk or fresh milk substitutes for infants and pregnant women is a high priority countermeasure. Of next concern are fetal exposure doses. With low intake of radionuclides by the pregnant host, fetal doses come primarily from external exposures. For this reason, pregnant women should make every effort to minimize their external exposure doses (more so than the remaining population). A third concern is for juvenile and adult thyroids. However, since the primary source of thyroid exposure is contaminated milk, the countermeasure of not drinking contaminated milk (or any milk) over a relatively short period of time should be no problem for juveniles and adults. Bone and intestine doses should be of less concern than external whole-body exposure.

V PREPAREDNESS FOR TRANSOCEANIC FALLOUT

A. Discussion

To maximize countermeasure effectiveness, it is necessary that (1) the nature of the possible hazards be known, (2) preparations are made to cope with the possible hazards, (3) the hazards are recognized and evaluated when they do occur, and (4) the appropriate actions are taken to reduce, evade, or overcome the hazards. The relative magnitudes of the transoceanic fallout hazards have been estimated and discussed. The greatest threat is the exposure dose to infant thyroids from the intake of I-131 in contaminated milk from dairy cows grazing in contaminated pastures. Fetal thyroids are also susceptible to high exposures if pregnant hosts have high intakes of I-131. It is very possible that, unless preventative measures are taken, transoceanic fallout could result in infant and fetal thyroids receiving very high exposure doses, that is, hundreds of rems in heavy deposition areas. The possible external gamma exposure doses also warrant consideration of countermeasures. Of less significance are the possible organ doses from inhalation, eating contaminated vegetables and meats, and drinking contaminated water.

The preparations to cope with the possible hazards include the establishment of a capability to recognize and evaluate the hazards and the establishment of a capability to carry out the suitable countermeasures. For example, if the countermeasure is to avoid drinking milk that is contaminated with I-131 above a specified concentration, then one must be prepared to be able to assess the I-131 content in milk; and, in the event that the milk is not acceptable, one must be prepared to provide a substitute to supplement fresh milk in the normal diet.

The capability to recognize and evaluate transoceanic fallout hazards generally requires assessment personnel, assessment equipment, and assessment facilities. Operating procedures are required to collect and analyze data, to disseminate information, and to issue instructions. To direct and coordinate operations a management organization is required.

Countermeasure capabilities generally include the capability for public and organization response, the capability to carry out various operational procedures, and an organization to coordinate and manage operations. The feasible countermeasures that are available, however, are limited in number. As will be discussed later, some are relatively limited in effectiveness.

The preparations will require an initial outlay of money, and a continuing outlay will be required to maintain a state of readiness until the emergency arises. There will also be operational costs during the emergency. If the preparations costs, together with the operational costs, are high with respect to the possible gains that can be derived by the preparations and the operations, then the preparations and the operations cannot be justified.

B. Monitoring of Transoceanic Fallout

1. Current Capabilities

There currently exist monitoring capabilities for sampling air activity concentrations, sampling milk and food contamination, sampling water contamination, and sampling deposition contamination. Detailed descriptions of current capabilities are presented in the Appendix. These capabilities are summarized in Table 15. The existing sampling networks are relatively sparse. Also, except for gross beta measurements of air filters (air contamination samples), which could be taken at the sampling location, all analytical measurements are made only at a very limited number of facilities.

Table 15

SUMMARY OF CURRENT SAMPLING AND MONITORING CAPABILITIES

Sponsoring Agency	Network	Sampling	Sampling Location	Monitoring Capability	Analysis	Analysis Center
Environmental Protection Agency (EPA)	Environmental Radiation Ambient Monitoring Systems (ERAMS)	Air sampling component (formerly RAN)	Continental U.S., Alaska, Hawaii, Guam, Puerto Rico, Canal Zone (Figure A-1*)	19 operating stations 54 standby	Gross beta	Eastern Environmental Radiation Facility (EERF)
		Water surveillance component (drinking, surface, rivers)	Continental U.S., Alaska, Hawaii, Guam, Puerto Rico, Canal Zone (Figure A-1*)	76 tritium monitoring stations ~ surface water stations (Reference A-5*)	Tritium Gamma scan Gross beta	
		Milk surveillance component (pasteurized milk)	Continental U.S., Canal Zone, Hawaii, Alaska, Virgin Islands, Puerto Rico	65 stations (Figure A-5*)	Sr-89, Sr-90, I-131, Ce-137 Ba-140, K-40	
Atomic Energy Commission (AEC)	Worldwide monitoring	Precipitation dry fallout	U.S. and other countries, Western Hemisphere (Figure A-7*)	33 stations in U.S. 90 other countries	Sr-90	Health and Safety Laboratory (HASL)
	80th meridian network	Milk and diet samples	New York, San Francisco		Sr-90	
	AEC installations	Air, water, milk		29 installations	External gamma dose, other radiation (Table A-1*)	
	Private power reactors (AEC regulated)	Liquids, air, some milk, soil, vegetation	~ 10 nuclear power reactors sites in U.S.		Principle radionuclides Some gamma dose	
EPA-AEC	Nevada Test Site (NTS)	Air Surveillance Network (ASN)	21 states west of Mississippi (Figure A-2*)	49 operational 72 standby		National Environmental Research Center--Las Vegas (NERC-LV)
		Water Surveillance Network (WSN)	Nevada, Utah, California			
		Milk Surveillance Network (MSN)	300 miles surrounding NTS	21 stations		
		Standby Milk Surveillance Network (SMSN)	Beyond 300 miles around NTS (Figure A-6*)			
Individual states		Air sampling	31 states, Washington, D.C.	521 stations	Gross beta	
		Milk sampling	35 states		Sr-89, Sr-90, I-131, Ce-137 Ba-140, K-40	
Defense Civil Preparedness Agency (DCPA)	Radiological Defense (RADEF) System		State and local governments	50,000 stations (planned)	Gamma radiation dose and dose rates	
Military service			Military bases in U.S.		Similar to DCPA monitoring	
Commander-in-Chief North American Air Defense Command (CINCNORAD)	NORAD Nuclear Biological and Chemical Warning and Reporting System (NBSCWRS)		Continental U.S., Canada, Alaska	350 reporting activities	Gamma dose-rate	North American Air Defense (NORAD)
National Weather Service of the National Oceanic and Atmospheric Administration (Department of Commerce)			Major airports in U.S., Alaska, Puerto Rico, Pacific Ocean (Figure A-8*)	140 stations	Gamma dose-rates	

*Appendix.

2. The V-700 Radiac

The Defense Civil Preparedness Agency has distributed over 500,000 CDV-700 radiological survey meters and has trained over 200,000 monitors that could be used in a transoceanic fallout emergency. If these resources are properly utilized, such an event should not be an unmanageable problem.

These instruments, however, were only intended for the areal monitoring of deposited fallout or the contamination on objects or people in locations where such measurements are possible, i.e., in locations of relatively low background radiation. Thus, in the event of transoceanic fallout, the V-700 radiac has the sensitivity to measure the environmental exposure rates. For locations of unusually heavy transoceanic fallout, providing exposure rates higher than 50 mR/hr, the V-715 could be used.

Because its wide distribution provides a relatively dense network, if the V-700 could be used to monitor food and water contamination, the food and water monitoring requirements could be adequately met. For example, it would be advantageous to be able to determine the I-131 content in milk on the farm before it is collected (so that unacceptable milk would not be mixed with acceptable milk) or to be able to determine the activity on vegetables before harvest. To obtain this capability at low cost, Kearny has suggested the possible use of the V-700 to measure the I-131 content in milk at the farm level in the event of transoceanic fallout.[12] If this proves to be feasible, then it may also be possible to measure the gross activity on vegetables at the farm level.

These instruments, however, were never intended for measuring I-131, and monitors have not been trained for this application. Nevertheless, because of the potential, this application is worthy of exploration. Kearny suggests that the V-700 might be applicable for measuring I-131 activity in milk if the milk is placed in an uncontaminated pit and the V-700 probe is inserted into the milk. His reported experimental data indicated that a V-700 probe inserted into 16 liters of milk contaminated with I-131 to 0.08 μCi/l registered about 10 net counts per minute. The background count rate in the test geometry was not reported; however, it has been confirmed that the experiment was conducted under normal background conditions, which for the location of the experiment meant about 0.005 mR/hr. The V-700 manual states that normal background (in the open) produces about 20 counts per minute, but it also states that normal background would register about 0.01 to 0.02 mR/hr. Therefore, 0.005 mR/hr should produce about six counts per minute. The background in the test geometry (in the empty pit) can be estimated to be about one count per minute. If the probe were inserted into uncontaminated milk (in the pit), the background count rate might be reduced to about five counts per 10 minutes. That is, the background count for the experiment was negligible.

From previous calculations, it was estimated that at 10 days after burst for an infinite smooth-plane exposure dose rate of 1.4 mR/hr, the I-131 in milk would be about 273 nCi/l for a plant retention factor of 0.15 (see Table 7). The estimated environmental gamma exposure rate to milk contamination ratios for various plant retention factors and for various days after burst are shown in Table 16. The equivalent contamination ratio for the Kearny-Auxier test is estimated to be about 0.06 for the case where the "milk" had an I-131 concentration of 0.08 μCi/l. Thus, at 10 days after burst, the relative environmental gamma background interference for the plant retention factors listed is about 50 to 260 times higher than the experimental conditions. At later times, the relative environmental background interference is increased. Also, if the dairy cows are taken off contaminated pastures, after a grazing period, the relative environmental background interference would be even more severe.

Table 16

RATIO OF PASTURE CONTAMINATION* TO
MILK CONTAMINATION--mR per hr/μCi per ℓ

Plant Retention Factor	Days After Burst 10	15	20	35
0.05	12.2	11.2	14.6	56
0.10	6.1	5.6	7.3	28
0.15	4.1	3.7	4.9	19
0.20	3.1	2.8	3.7	14
0.25	2.4	2.2	2.9	11

*Gamma activity only.

For milk contaminated with I-131 to 0.08 μCi/1 and for a fallout arrival time of five days, the environmental exposure rate at 10 days is estimated to be about 0.13 to 0.68 mR/hr (over open terrain). The instrument responses for various probe locations for two cases where milk might be contaminated by I-131 to 0.08 μCi/1 are shown in Table 17. As can be seen, in some cases, the I-131 activity in milk would be difficult to detect, much less measure, with the V-700 (for the suggested measurement geometry), in the presence of the environmental background interference. In the actual situation, the detection and measurement of I-131 in milk would be even more difficult because some probe contamination, monitor contamination, and pit contamination would most likely occur. If the dairy cows are taken off contaminated pasture after a period of exposure, the environment-to-milk contamination ratio could be increased to the point that the detection of I-131 in milk by this procedure would be virtually impossible. In a transoceanic fallout situation, higher concentrations of I-131 in milk are equally difficult to measure because

Table 17

ESTIMATED V-700 RESPONSES FOR VARIOUS PROBE LOCATIONS

Location	Count Rate or Reading	
	At 10 Days	At 35 Days
In the open*	100 c/m to 0.7 mR/hr†	0.6 mR/hr to 3.1 mR/hr†
In empty pit*	25 c/m to 130 c/m	90 c/m to 1.1 mR/hr†
In uncontaminated milk in pit	12 c/m to 60 c/m	45 c/m to 0.56 mR/hr†
In contaminated milk in pit	22 c/m to 70 c/m	55 c/m to 0.56 mR/hr†

*Gamma activity only. For "open window," the count rate could be considerably higher.
†Off scale on x1 range.

the environmental background interference will also be proportionately higher.

Since it is the relatively high transoceanic fallout radiation background that will make the detection and measurement of I-131 in milk difficult, if not impossible, greater shielding of the interfering radiation is required. Alternatively, the I-131 could be removed from the milk, concentrated, and then measured. Because of the large amount of shielding required, the difficulty of removing I-131 from milk, and the difficulty of maintaining a contamination-free measuring area, neither prospect appears to be generally feasible on the farm. Some farms, on the other hand, may have well-shielded locations, and those lacking well-shielded locations could transport milk samples to the nearest structure, perhaps in the nearest city, that would provide the shielding needed. It is estimated that a shielded location with a protection factor greater than 100 is required to measure reliably the I-131 in milk from a transoceanic fallout environment. The V-700 is obviously capable of measuring low levels of transoceanic fallout in the environment, however. Thus, it is capable of indicating the magnitude of possible milk and crop contamination. That is, it is capable of indicating the advisability of taking animals off pasture or returning animals to pasture, the advisability of harvesting crops, or the advisability of submitting milk and crop samples for quantitative analysis. Such a procedure would reduce the work load at facilities with a quantitative analysis capability. For example, to be on the safe side, a plant retention factor of 0.3 can be assumed until quantitative analysis proves otherwise. The ratios of gamma dose rates in mR/hr to I-131 in milk in μCi/l, for a prf of 0.3 and for various fallout arrival times, at various times after burst are shown in Figure 9. Thus, if an I-131 concentration in milk of 0.5 μCi/l is deemed to be acceptable in a transoceanic fallout situation, then if the appropriate ratio in Figure 9 is multiplied by 0.5, the maximum pasture dose rate for acceptable milk is obtained. For example, if the fallout arrival time were 10 days and the pasture dose rate measurement were made on the 20th day after burst, the maximum measured pasture dose rate for acceptable milk would be 0.5 x 2.05, or about 1.0 mR/hr.

Because the prf could be less than 0.3 and the iodine secretion rate could be lower than that used in Equation (28), milk from pastures with dose rates from the maximum to 10 times the maximum could be placed in the questionable-quality category, and milk from pastures with dose rates exceeding 10 times the maximum could be considered to be definitely unacceptable.

The V-700 survey meters, therefore, can be used as a low-cost initial screening instrument. Open-field exposure rates can also be prescribed for three screening levels (acceptable, suspect, and unacceptable) for other agricultural products. Thus, if the V-700 instruments

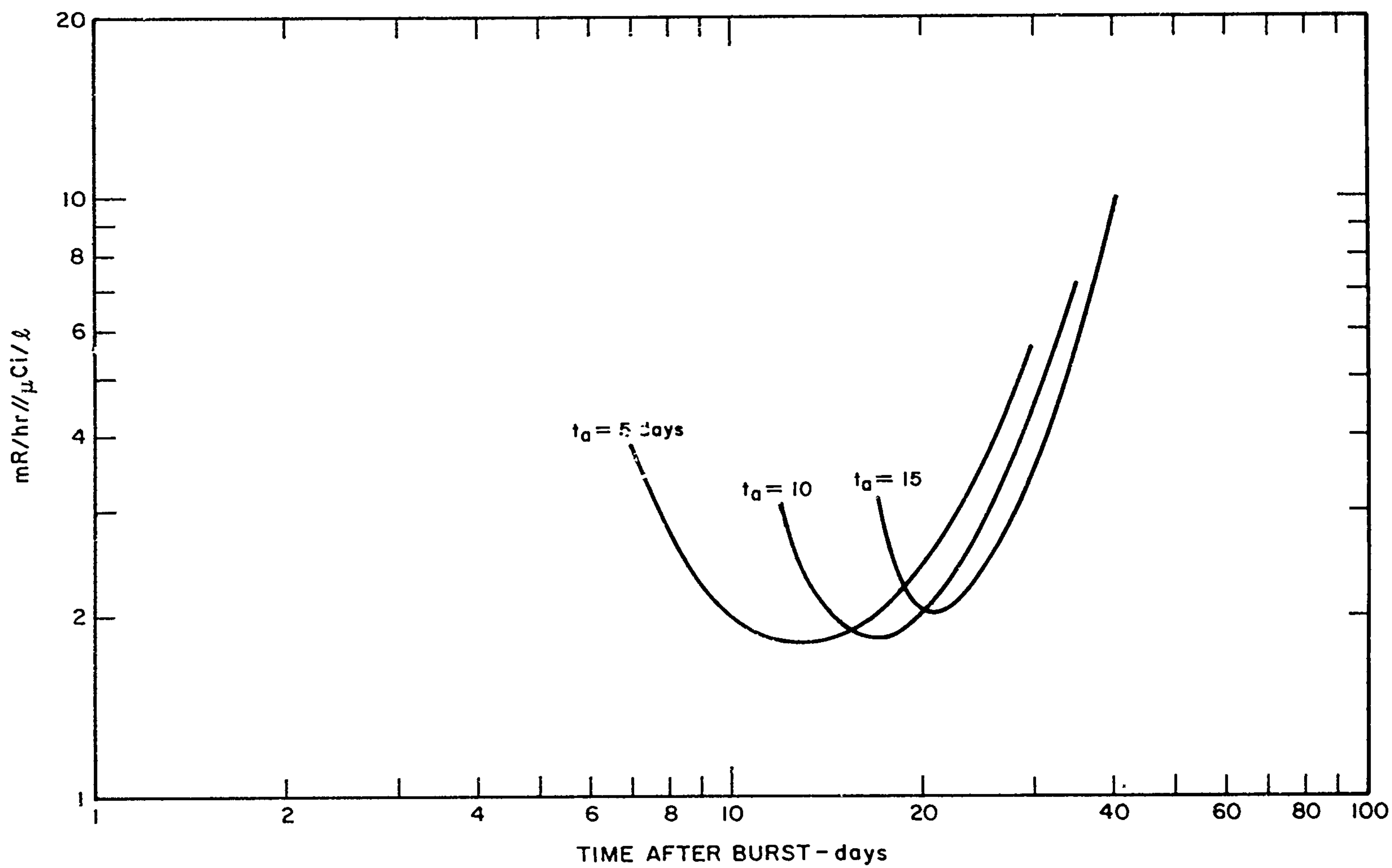

FIGURE 9 ENVIRONMENTAL DOSE RATE TO IODINE-131 MILK CONTAMINATION RATIOS FOR prf = 0.3

and the emergency monitors are deployed for this type of operation, a relatively dense network of surveillance screening would exist.

3. Cost Limits

To complete the measurement system, more elaborate equipment and facilities are required. The costs associated with increasing the density of existing, more elaborate systems must be commensurate with the advantage that can be gained. If current capabilities have the capacity for making all the measurements, then only a decrease in delay time is gained by increasing measurement capability density. If the delay time is relatively long, and the area where agricultural products in the suspect level is large, then the loss of the safe agricultural products in the suspect level could mean more than an avoidable production loss; that is, it could lead to other consequences. If the delay time is relatively short, then the only loss that is incurred is an economic or production loss. Therefore, provided a system with a measurement delay time that would cause only economic losses, any increment of improvement should be based on the economic gain.

The probability of a Sino-Soviet nuclear conflict of massive proportions over any future period is difficult to estimate; however, a general opinion (at this time) is that the probability is low. Should such a conflict occur, there is about an 80% probability that the initial transoceanic fallout direction will be to the east or northeast, and there is a very high probability that, with these winds, the fallout debris will be carried over some parts of the United States. The probabilities of precipitation on the 48 contiguous states on any single day are as follows:

Percent of U.S. Area	Daily Chance of Precipitation
> 5%	> 99 percent
> 10%	> 95 percent
> 15%	> 88 Percent
> 20%	> 78 percent
> 30%	> 52 percent
> 40%	> 28 percent
> 50%	> 12 percent
> 60%	> 5 percent
> 70%	> 1 percent
> 80%	< 1 percent

It should be noted, however, that the precipitation statistics are for the entire 48 contiguous states and that it is less likely that the fallout debris would pass over all the states. The probability of precipitation scavenging causing significant areas of radiation hazards exceeding current guidance levels, nevertheless, is high. If the combined probability within the next five years is 10% that one-tenth of the daily milk production would be in the suspect range and that one-half of this milk is acceptable, then a measurement delay of one week would only mean a probable loss of $700,000 worth of acceptable milk (i.e., $0.1 \times 0.1 \times 0.5 \times \$7.3 \times 10^9/52 = \$700,000$). If only milk is considered, then the five-year costs of improving and maintaining a milk monitoring system that would decrease the measurement delay time by one week should not exceed $700,000. The limiting five-year costs for other probabilities are shown in Table 18. A week's delay in harvesting other agricultural products generally would incur relatively minor production losses. Also, certain crops could be harvested between the time of nuclear war initiation and transoceanic fallout arrival. Assuming the arguments presented are valid, only a relatively low level of funding for improving existing monitoring capabilities can be justified.

Table 18

LIMITING MEASUREMENT SYSTEM COSTS FOR DECREASING MILK MEASUREMENT DELAY BY ONE WEEK

Probability of Massive Sino-Soviet War in Five Years (percent)	Probability of Transoceanic Fallout Winds (percent)	Daily Milk Production in Suspect Range (percent)	Limiting System Costs, Five-Year Total (10^6 dollars)
1%	80%*	10%	0.056
		20	0.112
5	80	10	0.281
		20	0.562
10	80	10	0.562
		20	1.123
20	80	10	1.123
		20	2.246

*This is a high estimate (not all nuclear debris clouds initially headed towards the United States will pass over all of the U.S.).

C. System Requirements

1. Early Warning

An early warning capability will provide the United States population time for preparations. An increase in discord between two nuclear nations is, in effect, an early warning; however, only a very few would react to this type of warning. An outbreak of war between two nuclear nations is a more urgent warning and would be cause for an alert status. The onset of nuclear war is a positive warning and would be cause for an emergency status. In effect, an adequate early warning system exists; that is, an increase in discord or an outbreak of war will be made known to the public through the news media in short order, and current capabilities can detect the onset of nuclear employment.

2. Environmental Monitoring

a. Air Monitoring

Air monitoring over the Pacific will provide confirmation that airborne nuclear debris is being transported towards the United States. It would also serve to provide estimates of the magnitude of the threat and times of arrival. In the United States, air monitoring serves to confirm arrival at various regions, and it provides measures of the activity concentrations in the air in these regions at any time. Even if some preparations for transoceanic fallout are made immediately after the detection of nuclear employment, there are other preparations that could be advantageously delayed. Thus, air monitoring over the Pacific would provide a margin of time for total or final commitment to preparatory actions. For the stated purpose, an adequate capability for air monitoring over the Pacific exists. Since the inhalation hazard will be relatively minimal and the feasible countermeasures are very limited, existing air monitoring capabilities in the United States (RAN, ASN, and individual state networks) are considered to be adequate, even though the coverage in the region of Indiana, Ohio, Tennessee, Kentucky, Virginia, and West Virginia is relatively sparse. Only a gross beta-activity measurement capability is required, and this capability exists at all air sampling locations

b. Deposition Activity Monitoring

Monitoring of deposition activity will provide the data to ascertain the appropriate countermeasures to take against external radiation exposure. It will also provide a good measure of the national problem. It could also be used to identify safe acceptable food and water areas. The sensitivity of the V-700 radiac is sufficient for this purpose. The V-715 is adequate for all exposure rates exceeding the maximum range of the V-700. The number of V-700 and V-715 radiacs issued is sufficient to provide the areal coverage required.

c. Food and Water Monitoring

Food and water monitoring is needed to verify the contamination level of food and water. A capability for food and water monitoring exists; however, its current operational capacity is grossly inadequate for a transoceanic fallout emergency. It is recommended that preparations be made to enlist and coordinate the use of all government (national and local), university, and commercial facilities with the capability to screen food and water based on gross activity levels. Facilities with the capability for performing quantitative analytical procedures could be used to determine the acceptable gross activity limits. Because of the large number of V-700 instruments that has been widely distributed, the adaptability of this instrument for monitoring the acceptability of food and water should be further explored. For example, there currently exists a much larger number of very well-shielded locations within which the V-700 could possibly measure the gross beta activity in milk than there are facilities that currently have the capability to measure the gross beta activity in milk.

3. Countermeasures

a. Inhalation

The transoceanic fallout inhalation exposure dose hazard is relatively minor. Because the inhalation doses will be low, because air contamination can be expected to be widespread, and because the duration of the event can be expected to be relatively short, evacuation is not feasible. The recommended countermeasure during the early warning period is to make the necessary preparations for several days of indoor stay. During the passage of the airborne transoceanic fallout particles, close off building openings to permit only the slow movement of air. Where feasible, close off the external air supply to ventilation systems. Minimize outdoor excursions and physical activity. Breathing through several layers of handkerchief will provide a moderate amount of protection, but this countermeasure is not practical for infants.[17] This countermeasure is also not very satisfactory for adults because the time span of air contamination could be several days.

b. External Exposure

In areas where heavy deposition of the transoceanic fallout occurs, the accumulated external exposure dose could be considerable. Although exposure doses leading to acute effects are unlikely, the exposure doses could be sufficiently high to produce long-term effects among a population, e.g., increases in the occurrence of neoplasms and genetic anomalies. Prolonged shelter stays are generally impractical, and short shelter stays will only provide marginal protection. For example, a normal daily routine for an individual is one where most of his time is spent indoors and a dose reduction of three with respect to infinite smooth-plane exposures is readily obtained. If the fallout arrival time is one week and the normal routine is preceded with a stay of two weeks in a shelter with a protection factor of 40, the calculated dose reduction over a three-month period is a dose reduction of 4.5. The net dose reduction gained by a two-week shelter stay over no shelter stay is, therefore, only 50%. The purposeful daily avoidance of higher exposure locations would also help to reduce the dose accumulation rate. For example, if one's daily routine were regulated so that his daily exposure was four hours outdoors with a protection factor of two and 20 hours indoors with a protection factor of five, his daily exposure dose would be reduced by a factor of four.

Since the decay rate is slow and high exposure doses are accumulated only with long exposures, evacuation or partial evacuation from regions with relatively heavy fallout deposition is feasible. The evacuation process could be scheduled over a sufficiently long period of time to be accomplished in an orderly manner. Decontamination is also feasible, and, it can be staged over a considerable period of time. What is more, it can be accomplished on an individual basis. For example, the home owner could apply a soap solution to the hard surfaces on his property (roofs and paved areas), scrub the surfaces with a brush or broom and then rinse these surfaces with water applied by a garden hose. Shrubbery could be hosed and lawns could be sprinkled and then tilled with a garden spade. The effectiveness that can be obtained depends on the type of structure and the type of surfaces surrounding the structure. In general, a reduction of interior dose rates by a factor of five to 10 can be obtained.[18]

c. Contaminated Water

The hazard of internal organ exposures from drinking water contaminated by transoceanic fallout is relatively minor. The thyroid exposure dose could be further reduced if an uncontaminated drinking supply is drawn during the warning period for use in the event the normal supply becomes contaminated. A dose reduction factor of two can be obtained for each eight days of delay. Water processing will reduce the strontium and cesium content significantly. Well water will be relatively uncontaminated. People whose water supply is collected off roofs could decontaminate their roofs. Contaminated water in shallow distribution reservoirs could be drained and refilled with cleaner waters from deep source reservoirs.

d. Contaminated Milk

High infant thyroid doses could result from drinking milk contaminated with transoceanic fallout. The production of contaminated milk could be avoided by removing dairy cows from pasture prior to fallout arrival and providing them with clean feed and water. (Milk contamination through inhalation will be insignificant.) Where this countermeasure is not taken or where it is necessary to return animals to contaminated pasture and the I-131 in milk is unacceptably high, fresh milk substitutes could be used until acceptable fresh milk is available. The unavailability of fresh milk over a short period of time will cause no health problems. The loss of revenue because of milk contamination, however, could be an economic problem for milk producers. If emergency plans are made, much of the contaminated milk produced could be processed for later distribution and consumption instead of being destroyed. Where acceptable fresh milk or fresh milk substitutes are in short supply, it may be necessary to limit or divert distribution so that the needs of the very young in the affected communities are satisfied.

e. Contaminated Meat

The exposure doses derived from eating contaminated meat are relatively minor. Meat contamination can be avoided by removing the animals from pasture prior to fallout arrival and supplying them with clean feed and water. It can be reduced by removing animals from contaminated pasture and providing them with clean feed and water over a period of time prior to slaughter. Contaminated meat could also be processed for later distribution and consumption. During the warning period, the rate of animal slaughter could be increased to provide an uncontaminated supply for the emergency period. The slaughter of animals left in contaminated pasture could also be delayed until the radioactivity concentrations in the edible parts of the animals are reduced to acceptable levels. It is anticipated that the meat supply problem can be satisfactorily resolved by the selective slaughter of acceptable animals and distribution management.

f. Contaminated Grain

The hazards from eating contaminated grain products are relatively insignificant. The long delay times between harvest and consumption and the decontamination during processing will generally produce acceptable grain products. In the event that some grains are contaminated to unacceptable levels, their storage period could be increased, or they could be processed for animal feed. Where feasible, mature grain crops could be harvested prior to fallout arrival. The distribution of acceptable grain products should not be a problem. The exporting of grain could be restricted to assure an adequate uncontaminated supply for domestic consumption.

g. Contaminated Vegetables

The exposure doses derived from eating contaminated vegetables are relatively minor. Legumes and tubers will only be lightly contaminated. Leafy vegetables, which will be more contaminated, are normally washed before consumption. Previously processed substitutes or vegetables shipped from acceptable areas could be consumed until safe local crops are available. Contaminated vegetables could also be processed for later distribution and consumption. Vegetables nearing maturity could also be harvested prior to fallout arrival.

h. Prophylactic Agents

The efficacy of potassium iodide as a blocking agent against thyroid uptake of I-131 has been proved.[15] It has been cited that the English are prepared to distribute potassium iodide tablets to affected populations in the event of a release of I-131 from a nuclear reactor accident.[15,16] Since the uptake of I-131 by the thyroid, especially the thyroid of infants and juveniles, is the primary hazard from transoceanic fallout, this countermeasure warrants consideration. Unlike radioactive contamination from a nuclear reactor accident or from early fallout, which could produce a severe inhalation threat, however, the major source of transoceanic fallout exposure to the thyroid is the intake of contaminated food and water, particularly contaminated milk. Also, although the expected thyroid doses from transoceanic fallout are significant, they are not severe. Since the cited countermeasures for reducing the intake of transoceanic I-131 can be reasonably accomplished, it is difficult to justify the use of prophylactic agents.

VI CONCLUSIONS AND RECOMMENDATIONS

Precipitation scavenging of the airborne nuclear debris from a massive nuclear war in Asia, while it is passing over the United States, will probably produce transoceanic fallout on significant parts of the United States on an order of magnitude equivalent to standard exposure rates ranging from a few R/hr at 1 hour to several tens of R/hr at 1 hour. At the time of arrival, the dose rates will be reduced by a factor of about 300 to 500; nevertheless, without countermeasures the possible accumulated external exposure doses and the internal organ doses from ingested radioactivity are significant. The exposure doses will be insufficient to cause early fatalities or sickness, but for large populations so exposed, the probable deleterious late effects, such as increased occurrences of cancers leading to later fatalities, are very significant.

External radiation sources are the principal contributors to whole body doses. Infant and fetal thyroids are the most vulnerable organ to dietary intake of transoceanic fallout, and I-131 in milk from cows grazing in pastures contaminated by transoceanic fallout is the principal source of thyroid exposure. The exposure doses received by adults and the probable late effects are relatively minor, although significant, when compared to the threat to infants and fetuses. Countermeasures can be taken to reduce the potential transoceanic fallout exposure doses and thus reduce the probable incidents of late effects. Certain preparations are necessary, however, to assure that the feasible countermeasures could be effectively executed in a transoceanic fallout emergency.

The preparations to cope with the possible hazards include the establishment of a capability to recognize and evaluate the hazards and the establishment of a capability to carry out the suitable countermeasures.

There currently exists a monitoring capability for sampling air activity concentrations, sampling milk and food contamination, sampling water contamination, and sampling deposition contamination. The capacity for sample analysis, however, is very limited. The establishment of a capability to carry out suitable countermeasures also requires a population informed of the available countermeasures, the necessary preparations, and when to act.

To bolster the monitoring capabilities, it is recommended that

- Public and private facilities with the capability to analyze or measure radioactivity in food and water samples be enlisted and organized to participate in these activities in the event of a transoceanic fallout emergency.
- The V-700 instrument of DCPA be used by trained monitors to initially screen food-producing farms to lighten the load of the limited facilities with greater measurement accuracy.
- The V-700 instrument be evaluated under simulated transoceanic fallout conditions so that the maximum utility of this instrument could be exploited for monitoring purposes in a transoceanic fallout emergency.

It is also recommended that

- A program be initiated to inform the public and various political and economic entities of the hazards of transoceanic fallout and of the available countermeasures to reduce these hazards.
- DCPA formulate and organize an emergency management and operations system to cope with transoceanic fallout.

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Appendix

FALLOUT MONITORING CAPABILITIES IN THE UNITED STATES

Appendix

FALLOUT MONITORING CAPABILITIES IN THE UNITED STATES

1. Introduction

There are two kinds of radiation detection that would be useful in measuring and controlling radiation exposure of the U.S. population in the event of a transoceanic fallout threat from a nuclear strike or exchange of strikes in the northern hemisphere not directly involving the Americas: (1) detection developed to deal with peacetime radiation exposures (including fallout from nuclear weapons tests) and (2) detection developed to deal with nuclear war. Not all detection capabilities are directly useful in dealing with transoceanic fallout, but most of them are useful while others could be adapted readily. These capabilities, existing at all levels of government and private industry, are broadly dispersed throughout the 50 states. Since these capabilities were brought into being for specific purposes, they are best discussed by reference to the federal agency that has supported their development.

Those capabilities that were developed to deal with peacetime radiation exposure "belong" primarily to the Environmental Protection Agency (EPA) and the Atomic Energy Commission (AEC). When initially developed during the 1950s, the primary purpose of many programs was to detect and measure fallout radiation resulting from nuclear weapons tests. Following the 1963 treaty banning atmospheric testing of nuclear devices, these fallout monitoring capabilities began to deteriorate. They might have been phased out completely if it were not for the needs of the emerging nuclear power industry and the need to maintain a standby capability to resume atmospheric testing should the treaty be violated. Both of these requirements have influenced the character of the current capability.

Wartime radiation monitoring capabilities that could be used in the event of a transoceanic fallout threat have been developed and supported primarily for civil defense purposes by the Defense Civil Preparedness Agency (DCPA) and predecessor agencies. Additional capabilities are found in the armed forces and in a number of other federal agencies having special civil defense responsibilities. Because of reduced priorities and budgets for civil defense in recent years, significant retrenchments have occurred or are occurring.

Current capabilities will be described in the order mentioned above. Since significant changes are occurring in both peacetime and wartime capabilities, the data herein represent the status as of 1 April 1974.

2. <u>Environmental Protection Agency</u>

The objectives of the EPA's radiation monitoring programs are to provide the data necessary to evaluate the exposure of the public to environmental radiation, to establish ambient radiation standards, and to define the degree of compliance by controllable sources. Although the EPA operates directly some monitoring networks, a major element of the program consists of technical and financial assistance to states and local jurisdictions who actually perform the monitoring activities.

The EPA operates a national system for the collection and analysis of samples of air, water, milk, human bone, and other biological matter to identify the levels of radioactivity throughout the environment. This national system is called the Environmental Radiation Ambient Monitoring System (ERAMS). EPA also operates a monitoring program for the Atomic Energy Commission around the Nevada Test Site and in the western part of the United States. Elements of the program would be useful in event of a transoceanic fallout threat. As noted above, many states operate their own programs for monitoring environmental radiation.

The monitoring networks for each media (air, water, milk, and the like) appear to operate more or less independently of each other. It is, therefore, convenient to summarize the capabilities for each of the media in turn. In passing, it should be noted that there is little emphasis or capability in the EPA program on direct dosimetry of external radiation by means of film badges, thermoluminescent devices, or the like. Sample measurements are usually interpreted as concentrations, which are then used to estimate exposures.

3. Air Sampling

The primary air sampling component of ERAMS was formerly called the Radiation Alert Network (RAN). RAN was established in 1956 to monitor worldwide fallout by air and deposition sampling. This network has served for years to document fallout trends, but, recently, with only an occasional nuclear atmospheric test, the capability of RAN has largely gone unused. A realignment has therefore been undertaken to monitor more closely peacetime sources of environmental radioactivity and to obtain maximum population coverage. Of the 68 previous sampling stations in the RAN, three were phased out, eight were moved to a new location, and nine were added for a new total of 74. Of these, 19 are operational, collecting continuous air samples, deposition samples, and precipitation samples. The remaining 55 are on standby status. Standby stations are activated yearly to check readiness, and they could be operational in a matter of minutes to hours in event of need. The location of the air sampling stations is shown in Figure A-1. Operating stations are indicated by a solid circle; standby stations by an open circle. Not shown are four standby stations in Guam, Hawaii, Puerto Rico, and the Canal Zone. The stations on Guam and Hawaii, together

FIGURE A-1 RAN STATIONS IN THE CONTINENTAL UNITED STATES with the standby station on Attu Island in Alaska, are the westernmost stations; they would be the first to obtain air and deposition samples in the event of transoceanic fallout.

Most of the stations are operated by state health department personnel using standardized sampling equipment and procedures provided by the EPA. A detailed description of the sampling and analytical procedures will be found in Reference A-1.* Briefly, the station operators perform a gross beta "field estimate" on the airborne particulate samples at five hours after collection, when most of the radon daughter products have decayed, and at 29 hours after collection, when most of the thoron daughter products have decayed. The airborne particulate samples and precipitation samples are then sent to the EPA's Eastern Environmental Radiation Facility (EERF) at Montgomery, Alabama, for more detailed analyses. The EERF manages the air sampling network and has the capacity to analyze the samples from both operational and standby stations.

A second air sampling network of potential utility in event of a transoceanic fallout threat is the Air Surveillance Network (ASN), operated by the EPA's National Environmental Research Center--Las Vegas (NERC-LV) under a memorandum of understanding with the Nevada Operations Office of the AEC. The AEC funds this activity, which is operated in support of nuclear testing at the Nevada Test Site (NTS). Although the continuation of the ASN has come under fire periodically because of the low level of underground testing at the NTS, it has been defended as essential for readiness to resume atmospheric testing should conditions warrant.

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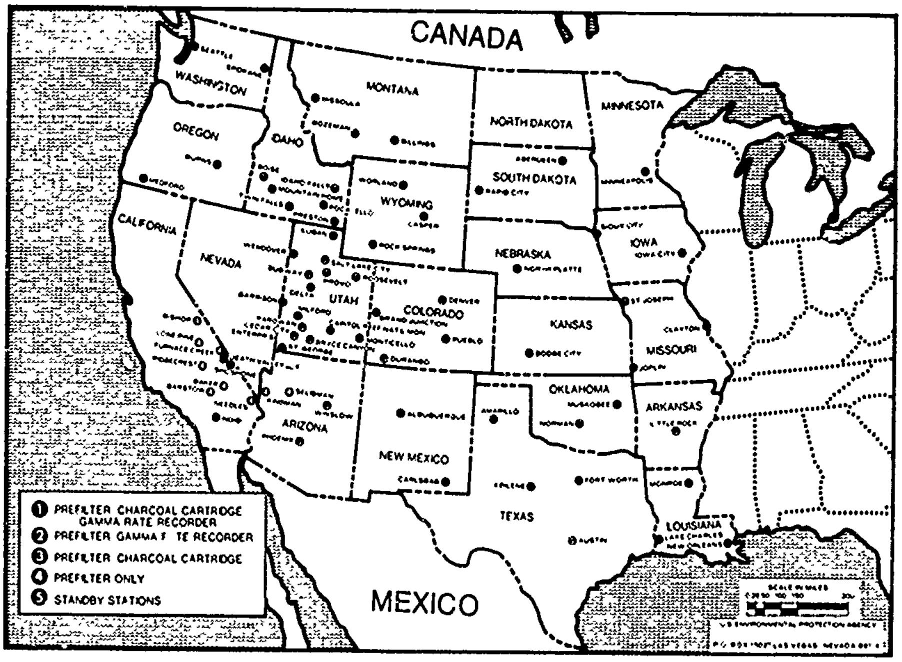
*Appendix references are on page A-33.

The Air Surveillance Network consists of 49 active and 72 standby sampling stations located in 21 states west of the Mississippi. Those outside of Nevada (where 33 active sampling stations and 18 standby stations are located) are shown in Figure A-2. All but 16 of the stations shown are on standby. Nonetheless, some of the best data on fallout from recent Chinese atmospheric nuclear test detonations have been collected by the ASN. The stations are operated by state health department personnel and by private individuals on a contract basis. All active stations are operated continuously with filters being changed every 24 to 72 hours. All samples are mailed to NERC-LV for analysis unless special retrieval is arranged in advance. A complete description of sampling and analytical procedures is presented in Reference A-2.

According to Reference A-3, 31 states and the District of Columbia have air sampling programs operating under state environmental laws. The 19 that do not perform air sampling are Alaska, Arizona, Connecticut, Delaware, Indiana, Kentucky, Mississippi, Missouri, Montana, Nebraska, Nevada, New Mexico, Ohio, South Dakota, Tennessee, Virginia, Washington, West Virginia, and Wyoming. Stations are classified in Reference A-3 as either general or source-oriented. Within the states that have air sampling programs, there are a total of 524 stations, of which 300 are classified as general. The general stations are those originally established to monitor fallout from nuclear tests. The categorization was adopted by the EPA to measure the progress in orientation toward specific sources, such as nuclear power reactors. This differentiation is not significant for the problem at hand, since all stations would sample transoceanic fallout if it were present. The data do indicate the variable nature of the various state systems, however. For example, all 52 Massachusetts stations are general stations, whereas only one of New York's 28 and none of New Hampshire's six are general. To a considerable extent, these variations reflect state emphases as well as



SOURCE: Radiation Data and Reports (December 1973).

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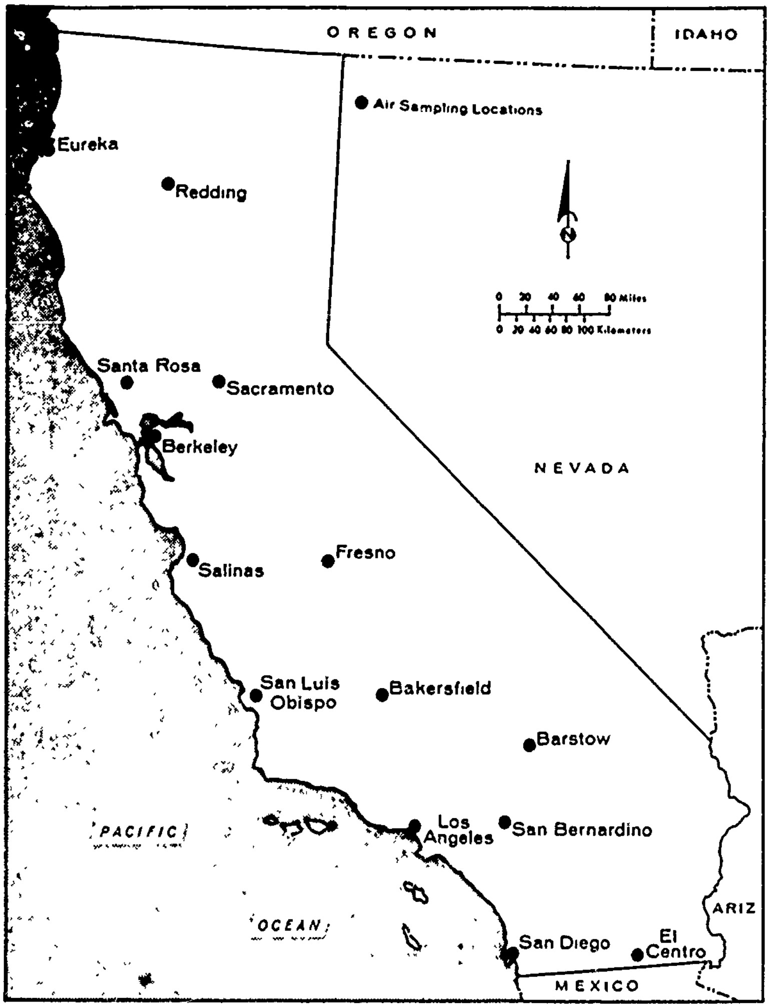
FIGURE A-2 AIR SURVEILLANCE NETWORK STATIONS OUTSIDE NEVADA the presence or absence of peacetime sources of radioactivity. Sampling schedules and the kinds of analyses also vary. Gross beta measurements are made by all states, but other measurements vary. Thus, no typical state program can be cited. California's program is described in some detail in Reference A-4. The 14 general stations are located as shown in Figure A-3. In addition, there are six source-oriented sampling stations in California. At each station, air is continuously sampled and filtered through a 47-millimeter membrane filter with 0.8 micron pane size using a Gast air pump of about two cubic feet per minute capacity. Air volumes are measured by a direct-reading gas meter. Filters are replaced every 24 hours except on holidays and weekends. The filters are analyzed for gross alpha and beta radioactivity 72 hours after collection. The daily samples then are composited into a monthly sample for gamma spectroscopy and an analysis for strontium-89 and strontium-90. The source-oriented stations collect a sample once a year rather than daily.

4. Water Sampling

The Water Surveillance Component of the ERAMS is a restructuring of the former Tritium Surveillance System instituted in 1964 to measure tritium concentration in major river systems downstream from selected nuclear facilities. Major revisions were made in 1970 to include drinking water and an expanded network of surface water stations. A total of 76 stations monitor the tritium in drinking water in population centers, around nuclear facilities, and other potential sources. Tritium analyses are made quarterly. A gamma scan and measurement of gross alpha and gross beta radioactivity are made annually. Presumably, sampling could be instituted upon the threat of transoceanic fallout. All but 16 of these stations are in the same locations as RAN stations (Figure A-1). Additionally, there are 55 surface water sampling stations on rivers and large bodies of water that might be useful should transoceanic fallout occur. Locations of these stations are listed in Reference A-5.



SOURCE: Radiation Data and Reports (December 1973).

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FIGURE A-3 CALIFORNIA AIR SAMPLING STATIONS (GENERAL)

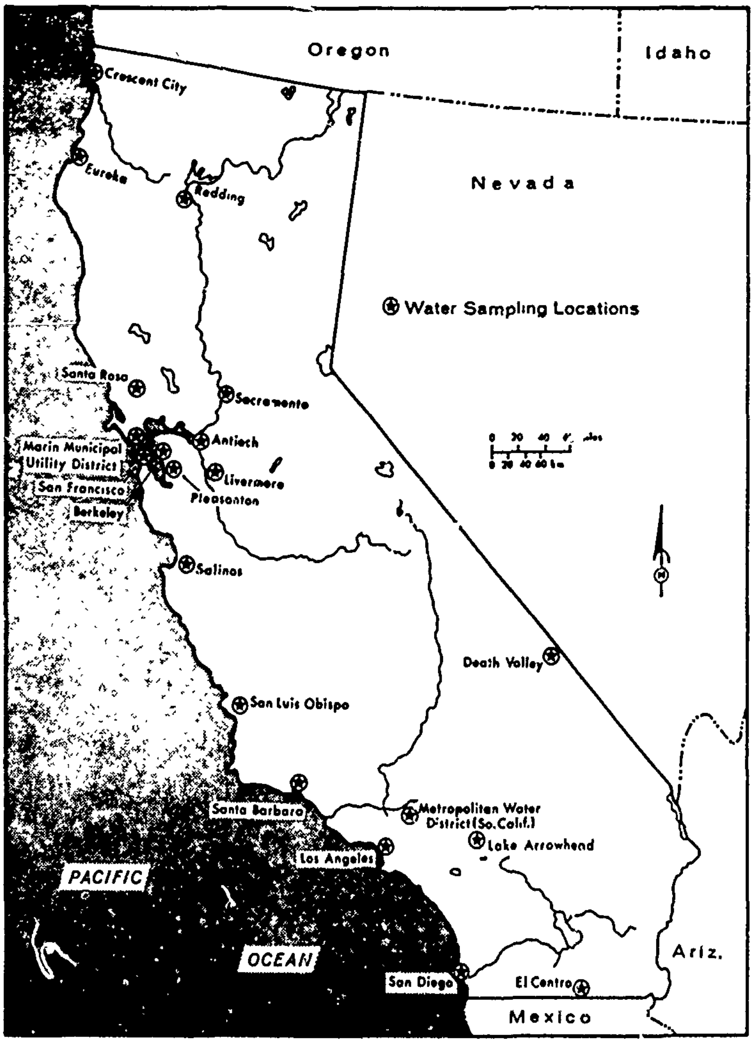
The EPA also operates a Water Surveillance Network (WSN) in support of the AEC in the off-site area surrounding the Nevada Test Site. The geographical area covered is limited to southern Nevada and adjacent portions of California and Utah. Hence, the WSN is of little use in the context of worldwide fallout.

The States operate extensive water sampling and analysis programs. Of the states cited earlier as having no air sampling program, all but Alaska, Arizona, Mississippi, Montana, Nevada, and South Dakota have a water sampling program. (Nevada is covered by the WSN cited above.) Most of the State programs include determinations of gross alpha and beta radioactivity and specific radionuclides. Analysis generally is done monthly, and sampling is done on a daily, weekly, or monthly basis. A current summary of state programs is contained in Reference A-3, and data is reported periodically in Radiation Data and Reports.

California again might be used as an example. The Radiologic Health Section of the California State Department of Health has maintained a program of domestic water sampling for radioanalyses since 1960. The California Domestic Water Network stations, 20 in number, are shown in Figure A-4. The monitoring program consists primarily of monthly sampling at the point of consumption (at the tap) and analyzing the samples for gross beta radioactivity. Yearly composites are analyzed for eight radionuclides by a gamma scan, and radiochemical analyses are performed to obtain radium and strontium-90 values. Analytical procedures are those recommended by the EPA.

5. Milk Sampling

The milk surveillance component of ERAMS was formerly known as the Pasteurized Milk Network (PMN), begun in 1960 to monitor fallout in the food chain of man. Milk was chosen as the food item that is most useful as a indicator of the general population's intake of radionuclide



SOURCE: Radiation Data and Reports (November 1973).

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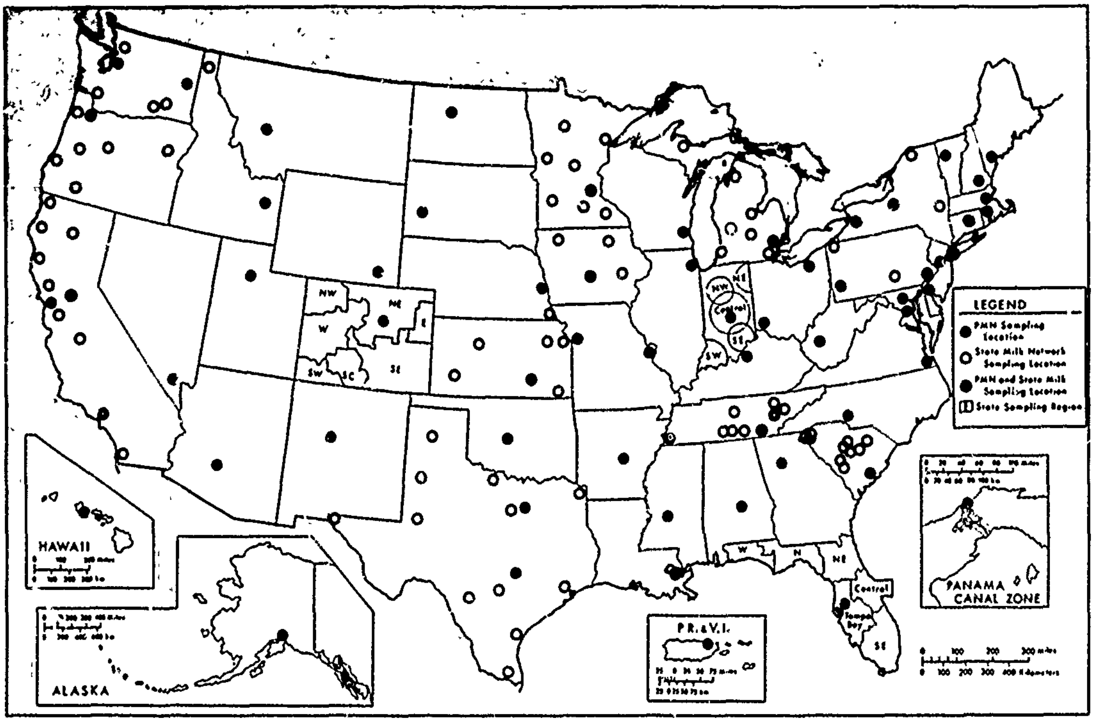
FIGURE A-4 CALIFORNIA DOMESTIC WATER-SAMPLING LOCATIONS contaminants. The location of the 65 milk-sampling stations is shown on Figure A-5. Additionally, 35 states operate State milk-sampling programs. Of these, data from 16 states are reported routinely in Radiation Data and Reports. The location of these sampling points is also shown on Figure A-5.

The various networks collect and analyze samples differently. Thus, it is not easy to characterize this capability. The samples may be raw milk from the farm or pasteurized milk from the distributor. The PMN stations collect pasteurized milk, and most of the 16 reporting states also collect pasteurized milk. Six states (Colorado, Florida, South Carolina, Tennessee, Texas, and Washington), collect raw milk almost entirely. South Carolina is perhaps typical of this group. The South Carolina Raw Milk Sampling Network presently consists of 12 locations distributed around 10 nuclear facility sites in the state. Samples of raw milk are collected quarterly at each point from the bulk storage tank in the dairy barn. The sample is transported immediately to the radiological laboratory for analysis.

Five fission products (strontium-89, strontium-90, iodine-131, cesium-137, and barium-140) and naturally-occurring potassium-40 are commonly assayed by these networks. Particular attention is paid to strontium-90 and cesium-137, and for this reason, the analysis of raw and pasteurized milk samples is considered comparable by the EPA. Whether the nonreporting states sample raw or pasteurized milk is not made clear in the published literature. It seems, however, that source-oriented sampling points (these are in the minority) tend to collect raw milk, whereas the general sampling points collect pasteurized milk.

In the event of transoceanic fallout, removing the dairy herd from pasture can have a marked effect on the contamination of the milk. It follows that being able to identify and separate the milk from farms



SOURCE: Radiation Data and Reports (December 1973).

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FIGURE A-5 PASTEURIZED MILK NETWORK (PMN) AND SELECTED STATE MILK-SAMPLING LOCATIONS that took effective countermeasures is an important capability. An ability to measure, at least grossly, the amount of radioactivity in the milk sample at the individual farm would be required. This capability is generally lacking at present.

An additional milk sampling capability is the Milk Surveillance Network (MSN) and the Standby Milk Surveillance Network (SMSN) operated by NERC-LV in support of AEC operations at the NTS. The Milk Surveillance Network consists of 24 locations in the area around the NTS (out to 300 miles) where one-gallon milk samples are collected on a monthly basis from family milk cows, Grade A raw milk for local consumption, Grade A raw milk for pasteurization, and commercial pasteurized milk. If need be, milk supplies and producers beyond 300 miles are sampled by the SMSN at the locations shown on Figure A-6.

6. Atomic Energy Commission

In addition to the AEC-funded sampling programs operated by the EPA's NERC-LA, there are major environmental radioactivity measurement capabilities within the AEC "family." Three potentially useful programs are summarized here. They are: (1) the sampling programs of the Health and Safety Laboratory (HASL), (2) the environmental monitoring programs at major AEC installations, and (3) the environmental monitoring programs at private nuclear facilities associated with electric power generation.

7. Health and Safety Laboratory

For about two decades, the AEC's HASL has been monitoring the worldwide inventory of strontium-90. At the present time, monthly fallout deposition rates for strontium-90 are determined for 33 sites in the United States and 90 locations in other countries. Those in the western hemisphere are shown in Figure A-7. The series of stations from Greenland down the eastern part of Canada and the United States and along the western seaboard of South America are part of HASL's 80th

SOURCE: Radiation Data and Reports (December 1972).

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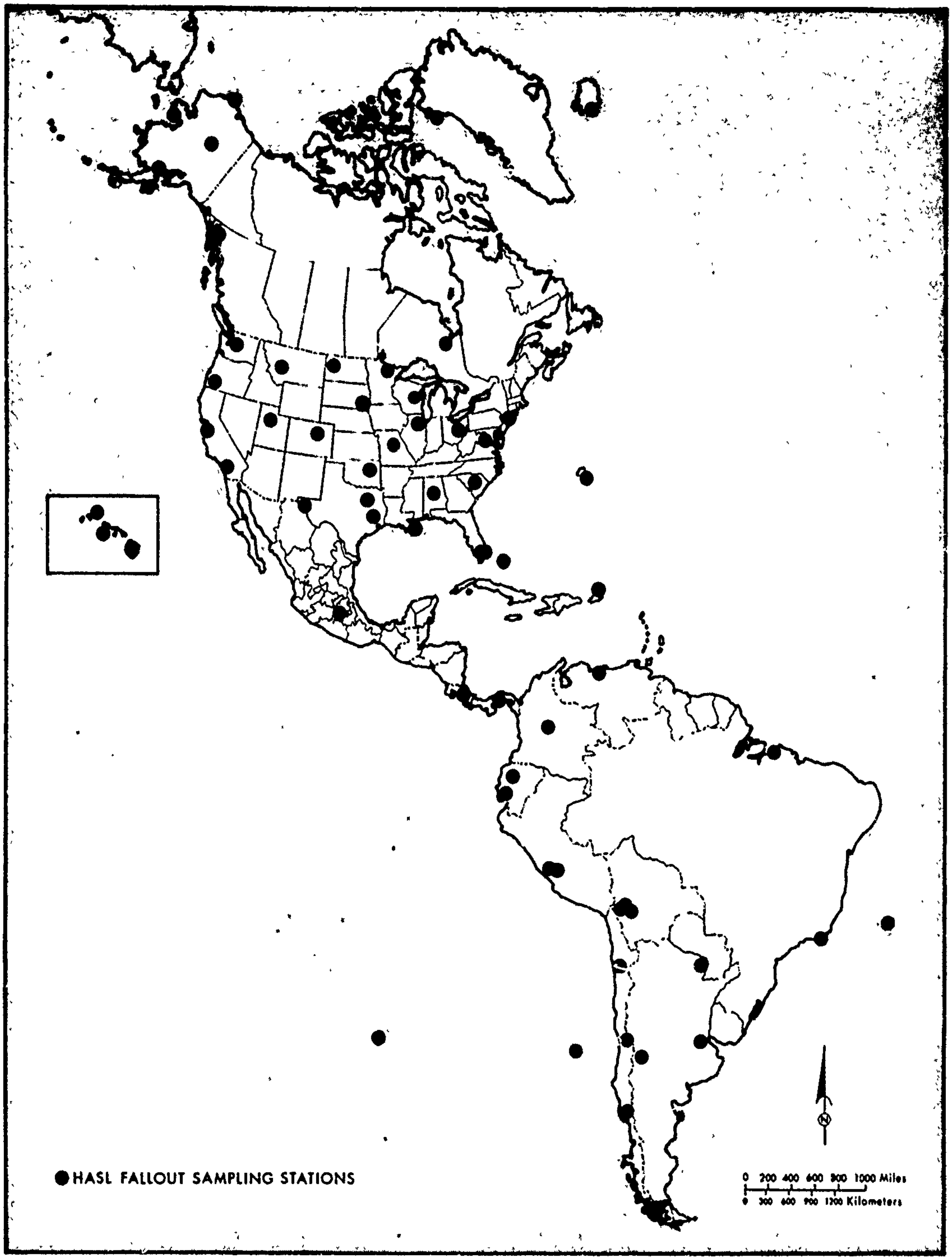
FIGURE A-6 STANDBY MILK SURVEILLANCE NETWORK



SOURCE: Radiation Data and Reports.

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FIGURE A-7 HASL FALLOUT SAMPLING STATIONS IN THE WESTERN HEMISPHERE

Meridian Network. Precipitation and dry fallout collections are made continuously, and samples are shipped monthly to HASL for analysis. The results are reported annually by HASL and in Radiation Data and Reports, published monthly by the EPA.

HASL also monitors the quantities of strontium-90 in milk and diet samples purchased in retail stores. Originally, three cities (New York City, Chicago, and San Francisco) were the sites monitored, but Chicago was dropped in 1968 since the data indicated that levels of strontium-90 in the Chicago diet were consistently between those of New York City and San Francisco.

HASL also has the capability for gathering upper-air samples at certain of its sites. Although the HASL fallout program has concentrated on strontium-90 levels, collection schedules and analytic procedures could doubtless be modified should a transoceanic fallout threat materialize.

8. Major Contractor Sites

Historically, AEC installations that have a potential for environmental impact have been required to conduct an appropriate, routine environmental monitoring program. Typically, AEC sites are AEC-owned facilities that are operated by contractors. The basic purposes of the monitoring programs are to assess the adequacy and effectiveness of controls on operations, effluent treatment, and waste disposal and to determine compliance with applicable standards. In 1961, the AEC established uniform requirements for the preparation and distribution of periodic environmental monitoring reports by the major AEC installations. In August 1973, all of the annual reports through 1972 were published together for the first time in Reference A-6. This compendium provides a detailed accounting of the monitoring capabilities at AEC installations. The essential characteristics of current capabilities are summarized in Table A-1.

Table A-1

MONITORING CAPABILITIES AT MAJOR AEC CONTRACTOR SITES

Installation	Types of Monitoring				
	Gamma Radiation	Air	Water	Milk	Other Radiation
1. Bendix, Kansas City		No radioactive materials			
2. Los Alamos Scientific Laboratory	TLD*	Yes	Yes	No	Yes
3. Mound Lab, Miamisburg, OH	No	Yes	Yes	Yes	Yes
4. Pantex Plant, Amarillo, TX	No	Yes	Yes	No	Yes
5. Pinellas Plant, St. Petersburg, FL	No	Yes	Yes	No	Yes
6. Rocky Flats Plant, Golden, CO	No	Yes	Yes	No	Yes
7. Sandia Labs, Albuquerque, NM	No	No	Yes	No	Yes
8. Ames Lab, Ames, IA	No	Yes	Yes	No	Yes
9. Argonne National Laboratory, Argonne, IL	TLD*	Yes	Yes	Yes	Yes
10. Battelle Laboratory, Columbus, OH	No	Yes	Yes	No	Yes
11. Brookhaven National Laboratory, Upton, NY	TLD*	Yes	Yes	Yes	Yes
12. Elk River Reactor, Elk River, MN	No	Yes	Yes	Yes	Yes
13. Dairyland Power, Genoa, WI	TLD*	Yes	Yes	Yes	Yes

*Thermoluminescent dosimeter.

Table A-1 (concluded)

Installation	Types of Monitoring				
	Gamma Radiation	Air	Water	Milk	Other Radiation
14. National Accelerator Laboratory, Batavia, IL	Yes	Yes	Yes	No	No
15. National Reactor Test Station, Arco, ID	TLD*	Yes	Yes	Yes	Yes
16. Bettis Laboratory, Pittsburgh, PA	TLD*	No	Yes	No	Yes
17. Knolls Laboratory, Schenectady, NY	TLD*	Yes	Yes	No	Yes
18. Shippingport Reactor, PA	Yes	No	Yes	No	Yes
19. Nevada Test Site (NERC-LV)	TLD*	Yes	Yes	Yes	Yes
20. Feed Materials, Fernald, OH	No	Yes	Yes	No	Yes
21. Oak Ridge Facilities, TN	TLD*	Yes	Yes	Yes	Yes
22. Paducah Plant, KT	No	Yes	Yes	No	Yes
23. Portsmouth Plant, Piketon, OH	Yes	Yes	Yes	No	No
24. Hanford Facilities, Richland, WA	TLD*	Yes	Yes	Yes	Yes
25. Atomics International, Canoga Pk, CA	TLD*	Yes	Yes	No	Yes
26. Lawrence Livermore Laboratory, CA	TLD*	Yes	Yes	Yes	Yes
27. Savannah River Plant, Aiken, SC	TLD*	Yes	Yes	Yes	Yes
28. Lawrence Berkeley Laboratory, CA	Yes	Yes	Yes	No	Yes
29. Stanford Linear Accelerator, CA	Yes	No	Yes	No	Yes

*Thermoluminescent dosimeter.

Of 29 installations reported in Reference A-6, all but the first listed in Table A-1 have some degree of radiological monitoring capability. Several, however, are engaged in operations, such as preparation of fissile materials, that lead to emphasis on monitoring for transuranic elements rather than fission products. It is likely that most of these have qualified personnel and the necessary equipment to monitor fission product activities.

A characteristic of the majority of AEC installations is the capability to measure external gamma dose. Of 18 facilities having this capability, 13 employ arrays of thermoluminescent dosimeters (TLD) on the site boundary and, in many cases, for considerable distances from the site. Of the remaining five (indicated by "Yes" in the first column of Table A-1), one employs film badges, one uses GM tubes, and three use ion chambers.

Nearly all AEC installations conduct air sampling programs. All have some form of water sampling program. Eleven monitor milk supplies in the vicinity. All but two have other radiation sampling programs as well, ones mainly concerned with other foodstuffs, vegetation, and/or soils or sediments. Typically, the national laboratories and large production sites have the most extensive capabilities for fallout monitoring.

9. Private Power Reactors

There are currently about 40 operational nuclear power reactors; most are owned and operated by a public utility. The generation of electric power by means of nuclear reactors is expected to increase dramatically in the next several decades. The design, construction, and operation of nuclear power plants is regulated by the AEC, regulations with the force and effect of law being contained in Title 10 of the Code of Federal Regulations. General Design Criterion 64, "Monitoring

Radioactivity Release," of Appendix A to 10 CFR 50 requires that licensees provide for monitoring the plant environs for radioactivity that may be released from normal operations including anticipated operational occurrences and postulated accidents. Each plant operator is required to submit a report to the AEC twice a year that, in addition to specifying the quantity of each of the principal radionuclides released in liquid and airborne effluents, provides sufficient information to estimate annual radiation doses to the public from these effluents.

In January 1973, the AEC issued a Regulatory Guide (Reference A-7) describing an acceptable basis for designing a program to measure and report levels of radiation and radioactivity in the plant environs. (Regulatory Guides do not have the force and effect of law, but alternative procedures must provide an equivalent means of satisfying the regulations.) The Guide is quite flexible in its suggested principles. Potential for human exposure to the types and quantities of radionuclides released are to be determined before the plant is operational. During the first three years of commercial power operation, the environmental measurement program should be relatively comprehensive to verify possible correlations between radioactive effluents and levels in environmental media. Thereafter, the number of media sampled and the frequency of sampling may be reduced if it can be demonstrated that the doses from a particular pathway are sufficiently small.

The character of current AEC regulations and guides is such that most operating nuclear power plants have monitoring capabilities equivalent to those AEC installations that have reactors (see Table A-1). In addition to effluent monitoring, one can expect that air and water sampling would be undertaken near the site boundary and in the low population zone surrounding the plant. Milk sampling as well as vegetation, soil, and other sampling would seem appropriate. Gamma dose measurement by means of thermoluminescent dosimeters or other means is probable in the vicinity of boiling water reactors (BWR).

Finally, one must add that the quantities of radioactivity being measured, in the cases of nuclear power plants, are very small. Although the capability to monitor levels associated with potential accidents is required, most of the experience and equipment in use is concerned with measurements at the near-background level.

10. Defense Civil Preparedness Agency

The DCPA and the civil defense agencies that preceded it (FCDA, OCDM, and OCD) have had a long history of development of a nationwide radiological monitoring, reporting, and evaluating system to provide information on the extent, intensity, and duration of fallout hazards that could result from nuclear attack. There are three key elements in the system:

1. A monitoring capability at strategically located monitoring and reporting locations and at public fallout shelters and vital facilities plus trained emergency services personnel and aerial monitoring teams.
2. A capability for evaluating and processing data at emergency operating centers (EOCs) located at all levels of government.
3. A capability located in each state to maintain and calibrate the radiation detection and monitoring equipment used in the monitoring system.

Because of the nature of the nuclear war fallout threat, emphasis has been placed on the measurement of gamma radiation dose-rates and doses. Through the fiscal year 1972, nearly one and one-half million gamma survey meters and nearly four million self-reading dosimeters had been procured. The great majority of these instruments have been issued to state and local governments or have been placed in public shelters.

For many years, the goal was a nationwide total of 150,000 monitoring stations independent of the instruments stocked in shelters. Each station was to have four trained monitors. By mid-1972, approximately 200,000 monitors had been trained in the federally-supported training effort (an unknown additional number are trained in local programs), and about 60,000 operational monitoring sets have been distributed to state and local monitoring stations. About 15,000 monitors are trained yearly, probably an insufficient number to compensate for losses to the system. At the present time, DCPA is contemplating a significant redirection of this system. Under funding and feasibility pressures as well as in response to study recommendations, the monitoring stations aimed for are being cut back in number to about 50,000. Other operating criteria are being eased. Retrofit programs have increased the reliability of the instrumentation, allowing for reduced maintenance and calibration loads at the state maintenance shops and thereby freeing some of the state technician time to be directed toward bolstering the personnel aspects of the system. Despite the shortfalls that have occurred with respect to previous goals, the currently deployed civil defense monitoring capability must be considered impressive.

DCPA encourages involvement of the radiological monitoring network in peacetime nuclear incidents because such use would improve the likelihood of readiness for wartime use. A significant constraint in this respect, in addition to the already-mentioned emphasis on gamma measurement, is that the instrumentation is designed mainly to measure high dose-rates and doses relative to those of concern in routine environmental monitoring. Much of the instrumentation is too insensitive for application to the transoceanic fallout threat. The exceptions to this statement are capable, however, of playing a major role.

The DCPA operational dosimeters are of the self-reading quartz-fiber pocket type, in which the dissipation of an impressed electrical charge by ionizing radiation causes a vertical fiber to move across a graduated scale in the eyepiece. Almost 85% of the nearly three million dosimeters deployed in the field are the "workhorse" V-742s, with a full-scale reading of 200 roentgens. Since this dosimeter is too insensitive to be used in training, there exist over 200,000 training dosimeters (V-138s) that are 1000 times more sensitive (the full-scale reading is 200 mR). These training dosimeters, which are widely distributed, could be of use in event of transoceanic fallout. The next most useful dosimeter is the V-730, with a full-scale reading of 20 R. There are over 150,000 of these intermediate-range dosimeters distributed in the States.

The most useful survey meter in the DCPA inventory is the V-700, a low-range instrument with a probe-mounted Geiger-Muller tube. The lowest range on this instrument has a full-scale reading of 0.5 mR/hr. A range-changing switch permits full-scale readings of 0.5, 5, and 50 mR/hr. The standard V-700 has a side window on the probe that provides a beta detection capability. The meter face has a scale ranging from 0 to 0.5 for measurement of gamma dose-rate. There is only one control, a selector switch, that includes an off position and three ranges labeled X100, X10, and X1. On the X1, the X10, and X100 ranges, the meter readings must be multiplied by a factor of 1, 10, and 100, respectively, to obtain the measured dose rate. The meter scale is also graduated in counts per minute from 0 to 300 for detection of beta radiation with the probe window open. Headphones are provided with the instrument to permit counting of pulses by means of the distinctly audible clicks. This procedure is to be preferred at counting rates less than about 50 counts per minute.

Should gamma dose rates in excess of 50 mR/hr occur as the result of transoceanic fallout, the V-715, a high-range gamma survey meter may be used. The V-715 is an ionization chamber instrument with a low range of 0 to 500 mR/hr. Three additional ranges permit measurements up to 500 R/hr. These higher ranges are unlikely to be of interest in the event of transoceanic fallout. There exist in the field about 500,000 of these instruments and approximately an equal number of the low-range V-700s.

A third survey meter of possible interest is the high-range V-720, of which about 100,000 have been deployed. The V-720 is an ionization chamber instrument with characteristics similar to the V-715 except that the ionization chamber has a movable shield so that beta and gamma radiation can be monitored together, with the shield open. This instrument permits monitoring of beta radiation at levels above those that would saturate the V-700. The V-720 does not, however, have the sensitive element mounted in a probe. Important technical specifications for DCPA instruments will be found in Reference A-8.

DCPA has contracted with Brookhaven National Laboratory to assist in applying the standard DCPA instruments to various peacetime radiological incidents. DCPA, with assistance from ORNL has developed an end-window Geiger-Muller probe for the V-700, and Brookhaven has demonstrated the use of the modified V-700 to measure I-131 levels produced by an air sample drawn through a charcoal-impregnated filter by a shop or home vacuum cleaner. The V-700 has also been adapted to be used as a background monitor and alarm in event hazardous levels of radioactivity occur.

11. Military Services

All of the military services have radiation detection equipment at military bases located throughout the country. Historically, each service has developed and procured instruments to meet its own requirements.

Standardization and inter-service procurements has occurred gradually over the years. During the past decade, the military services have depended increasingly on DCPA instruments, particularly at U.S. bases, as they are reliable and cost markedly less because of the large volume of DCPA procurements. (DCPA inventories of instruments are an order of magnitude larger than those held by the services.)

Technical descriptions of military radiation detection instruments are contained in Reference A-9. The DCPA instruments described above are listed in Reference A-9, as are military instruments, with a usage classification of "Standard" in all cases. The military equivalent of the low-range survey meter, V-700, is the AN/PDR-27, which has one probe-mounted Geiger-Muller tube with an end-window for beta counting and a second higher range GM tube in the meter itself. The probe has ranges of 0-0.5 mR/hr and 0-5 mR/hr. Higher ranges up to 500 mR/hr use the internal counter, with no beta detection capability. High-range radiacs with beta-gamma measurement capability are the AN/PDR-43, AN/PDR-45, AN/PDR-63/PD, and AN/PDR-68. These are military equivalents of the CD V-720. The IM-9 is the most useful self-reading dosimeter in both the Army and Navy versions. The IM-9 has a full-scale reading of 200 mR, the same as the DCPA's V-138. Also of possible interest is the Navy's IM-135 (full-scale reading of 5 R). In general, then, measurement capability equivalent to a DCPA monitoring station will be found at nearly every major military installation in the United States.

In addition to the above, Reference A-9 lists two Navy portable air samplers, HD-251/UD and HD-732, that may be available at certain military installations. These samplers have a filter paper holder designed to accommodate the end-window probe of the AN/PDR-27.

The Commander-in-Chief, North American Air Defense Command (CINCNORAD), is responsible for the detection and reporting of nuclear attack upon the North American continent. As part of this function, CINCNORAD has established the NORAD Nuclear, Biological, and Chemical Warning and Reporting System (NBCWRS). The NBCWRS consists of some 350 reporting activities located throughout the continental U.S., Canada, and Alaska. Each reporting activity has the capability to perform gamma dose-rate monitoring and to report the findings to NORAD. This system is exercised frequently, and it may be of use in event of the threat of transoceanic fallout.

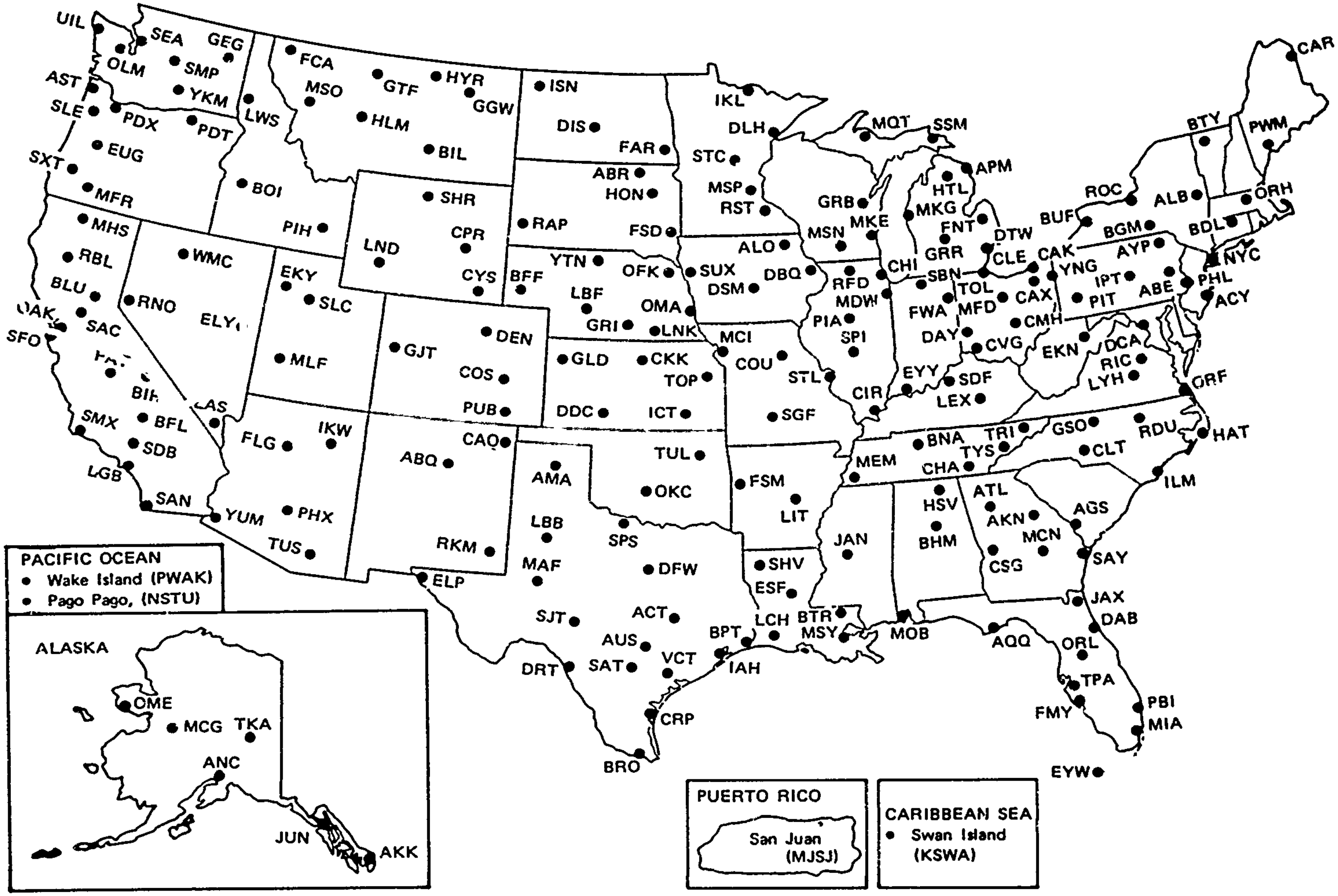
12. Other Federal Agencies

Several other federal agencies have radiological monitoring capabilities worthy of mention. In all cases, the monitoring is done with DCPA instruments that have already been described.

The National Weather Service of the National Oceanic and Atmospheric Administration, Department of Commerce, maintains a network of stations at major airports capable of measuring and reporting gamma dose rates to DCPA during national emergencies. The approximately 140 NWS stations are shown in Figure A-8. Twice-monthly observations are taken as an instrument check and to provide basic data for background levels.

The Federal Aviation Agency, Department of Transportation, has a similar capability at 27 centers throughout the country and at Dulles International Airport outside of Washington, D.C.

The Department of Agriculture had, until recently, a substantial monitoring capability in support of their agricultural and food responsibilities. At the present time, except for a few DCPA instruments in remote stations of the U.S. Forest Service, however, the department depends on DCPA for fallout data.



SOURCE: National Oceanic and Atmospheric Agency, Department of Commerce.

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FIGURE A-8 NATIONAL WEATHER SERVICE MONITORING STATIONS

Appendix

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