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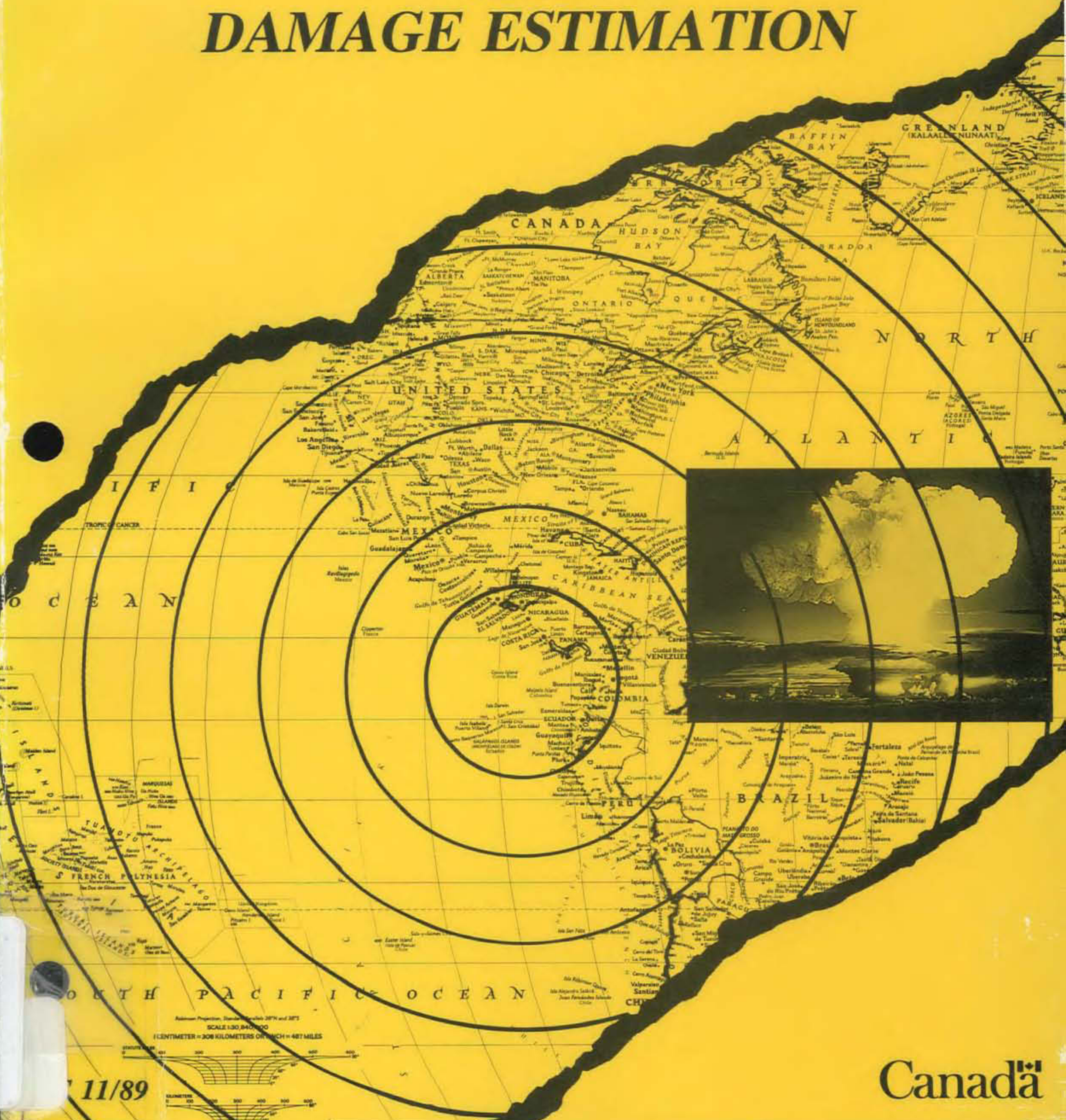
NUCLEAR WEAPONS EFFECTS AND DAMAGE ESTIMATION



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Canada

EMERGENCY PREPAREDNESS CANADA

NUMBER	TITLE
*EPC 1/82	Rustic Plan (Confidential)
*EPC 2/81	Planning Guidance in Relation to a Nuclear Attack on North America in the 1980s
EPC 3/88	Bomb Threat Manual
*EPC 4/82	Emergency Preparedness Canada Readiness Plan
EPC 5/89	Government of Canada Alert Dissemination Manual
*EPC 6/82	Manual of Responsibilities and Procedures in Peacetime Emergencies or Disasters
*EPC 7/78	Emergency Government Headquarters Operational Procedures Planning Guide
*EPC 8/78	Emergency Government Headquarters Staff Procedures Planning Guide
*EPC 9/78	Civil Emergency Communications Operation Guide
EPC 10/85	A Guide to Civil Emergency Planning for Municipalities
EPC 11/89	Nuclear Weapons Effects and Damage Estimation Manual (restricted distribution)
EPC 12/87	Guide to the Preservation of Essential Records
*EPC 13/80	Concepts of Emergency Operations in the Life-Saving Period
*EPC 14/81	Standing Operating Procedures for Staffing those Positions Assigned to Canada in the Nato Civil Wartime Agencies (confidential)
*EPC 15/82	Situation Room Standing Operating Procedures(discontinued)
*EPC 16/81	Joint Standing Orders and Operational Procedures for the Central Emergency Government Facility
*EPC 17/81	Central Relocation Unit Operational Procedures and Administrative Instructions
EPC 18/87	Space Objects Contingency Plan
EPC 19/87	Omnibus, An Emergency Warning System for Public Service Employees of the National Capital Region
EPC 20/88	Message Writing Manual for Emergency Government Headquarters
*EPC 21/81	Procedures for the Coordination of Crisis Management Operations
EPC 22/88	Disaster Financial Assistance Arrangements
*EPC 23/82	National Emergency Agency Planning Guidelines
EPC 24/88	Joint Emergency Preparedness Program
*EPC 25/83	Procedures for Operating Kitchens in Emergency Government Facilities
EPC 26/88	Vital Points Manual

*This manual is not available. The information contained is not current and is being updated.

NUCLEAR WEAPONS EFFECTS

Fallout, Casualty and Damage Assessment Manual

This manual was prepared by Ron P. Kreitzer for Emergency Preparedness Canada, under contract No. 6A-519, dated June 8, 1987.

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CONTENTS

CHAPTER I

OVERVIEW

Purpose

The purpose of this manual is twofold:

- to satisfy the need for an authoritative description of nuclear weapons effects that can be read and understood by non-technical planning officials; and

- to provide federal and provincial emergency operations personnel, and others, with procedures and specific quantitative data to make intelligent estimates of casualties and damage resulting from nuclear attack on Canada or adjacent U.S. territory.

Method of Presentation

A thorough overview of the damaging effects of nuclear weapon explosions is presented in Chapter II. All subsequent chapters deal entirely with the problem of damage estimation and include the estimation of casualty figures. Readers who only desire an understanding of the phenomena and characteristics of nuclear explosions need not read past the weapon effects chapter. On the other hand, damage estimation procedures and supporting information presented in succeeding chapters can also be used without thoroughly understanding the complexities of nuclear explosion phenomena. Readers primarily interested in damage estimation procedures may therefore find it sufficient to give only cursory reading to the nuclear weapon effects introduced below and described in Chapter II.

Introduction

A nuclear explosion, like other explosions, results in a very rapid release of a large amount of energy within a limited space. The amount of energy release (or "yield") is much larger than that released by other weapons and can range from a fraction of a kiloton (1 kt = 1 000 tons) to many megatons (1 Mt = 1 000 000 tons) equivalent of TNT. One kiloton is the energy released from the complete fission of two ounces of fissionable material, approximately equivalent to the energy of 1 kt of TNT, or 320 tonnes of coal (or 4.2×10^{12} joules).

Few people have seen a nuclear explosion. Only two weapons have actually been used in war and there have been a few hundred test explosions carried out, for obvious reasons, in sparsely populated areas of the globe. It is therefore difficult to give an impression of what a nuclear explosion in a familiar city environment would be like. The Nagasaki bomb was rated at 20 kt; 10 times as much energy as was released by the explosion of the ammunition ship Mont Blanc which was carrying 2 000 tons of TNT and which all but destroyed Halifax in 1917. A comparable bomb could no doubt complete the job today. Moreover, nuclear explosions 1 000 times as powerful as the Nagasaki bomb are now possible, but it is incorrect to assume that they would necessarily produce 1 000 times as much damage. Before becoming too alarmed at the prospect of large nuclear bursts, natural catastrophes and phenomena may involve a much larger energy release. For example, it has been calculated that 1 Mt would be sufficient to keep a hurricane in business for about 20 seconds. A volcanic eruption can produce far more debris than the largest nuclear bomb. Many cities face a finite risk of such cataclysms without undue apprehension.

A nuclear weapon which can produce heavy damage and casualties out to a radius of several kilometres is much larger than is needed for normal military purposes. To destroy a military installation, it is unnecessary and probably undesirable to produce damage for several kilometres around it. There was some value in large damage radii when delivery systems were so inaccurate that miss distances of two or three kilometres and more were to be expected, but this is no longer the case. It has been estimated that increased accuracy will prove to be nearly 10 times as effective as increased payload, particularly when being used against "hard" targets such as missile silos. Nuclear warheads are getting smaller, more accurate and very numerous as the strategic advantage of multiple warheads has been recognized. It may be that multi-megaton warheads are obsolescent, but some are still retained in the inventories of the superpowers and form an impressive threat for deterrent purposes. Even though the possibility of their use against economic targets is diminishing, their use must still be considered.

There are three major sub-ranges of warhead size within the overall range of nuclear weapons.

Low Yield Weapons

. this group covers warheads from a fraction of a kiloton up to a few kilotons. Because of the existence of a critical mass for fission explosions, low yield weapons require sophistication in weapons design and are produced mainly for tactical military purposes. They are, therefore, often referred to as "tactical" warheads and are only likely to be of concern to countries which may become involved in land battle.

Fission Warhead Range

. this group ranges from slightly below the size of the original 20-kt bomb up to more "strategic" yields of several hundred kilotons. The group covers some of the individual warheads in multi-warhead missiles and will probably include most of the weapons produced as a result of nuclear proliferation.

Fusion Warhead Range

. fusion releases more energy than fission, but takes place at very high temperatures that can only be conveniently obtained by means of a fission explosion as the triggering device. These warheads are therefore fission/fusion weapons with strategic yields in the megaton to multi-megaton range. Some multi-warhead strategic missile weapons systems contain separate warheads with yields around several hundred kt to 1 Mt.

For most conventional weapons, the assessment of weapon effects is relatively simple because they are designed to attack specific types of target. Nuclear weapon effects, on the other hand, are rather indiscriminate; even if a weapon is aimed at a specific target there will always be structures, people, or perhaps natural resources in the neighbourhood that are likely to be damaged or destroyed. A nuclear weapon explosion anywhere in Canada would produce measurable damage of one kind or another, if only to the environment. A detailed description of the unique immediate and residual destructive effects of nuclear explosions is given in Chapter II.

The Need for Casualty and Damage Estimations

Experience with large-scale natural disaster indicates that an affected locality or area cannot furnish, particularly immediately after the disaster, accurate information on the extent of damage and number of casualties. It is understandable that, during the early post-nuclear attack period, responsible officials will find it difficult to obtain a clear picture of the damage parameters. General confusion and severe disruption of communications likely will make it impossible to receive initial reports. Response managers will be forced to act on approximations of damage estimates until more exact assessment of actual damage can be assembled through air and ground reconnaissance, detailed surveys and census of people and resources. Casualty and damage estimations provide initial appreciation of the magnitude of the problem by defining devastated areas and indicating locations of surviving population and resources so intelligent decisions can be made for rescue, relief, and recovery operations.

A capability to make quantitative estimates of the direct effects of the attack should be developed at each Emergency Government Headquarters (EGHQ) level in the continuity-of-government organization which has been established in Canada in the event of a nuclear calamity. Each echelon of the emergency government organization, identified as central (CEGHQ), regional (REGHQ), zone (ZEGHQ) and local/municipal (MEGHQ), will need early estimations of likely damage to the extent necessary to perform activities within its scope of responsibility. MEGHQs may find that early estimations of the dimensions of the damaged areas will be superseded rapidly by factual damage reports collected as they co-ordinate on-scene rescue and relief operations. At higher EGHQ levels, estimates necessary to co-ordinate regional relief and national recovery will be superseded over a longer period of time as factual assessments are gradually reported up the chain of command. Early casualty and damage estimation requirements at EGHQs will therefore include some, or all of the following points to the degree necessary to commence relief activities and recovery planning:

- a visual depiction of the probable distribution of damage and casualties in the target area;

- estimates on the status of key structures (designated shelters, bridges, vital points, etc.);
- estimates of the numbers of casualties;
- estimates on surviving utilities and resources; and
- routes of entry into target areas for relief operations personnel and equipment.

Overall casualty and damage assessment will be a primary responsibility of operations staffs in the EGHQs. In the case of specific resources, however, the estimation process will be accomplished more effectively by assigning, insofar as is possible, responsibility to develop damage estimates for those government departments or agencies within each EGHQ that are accountable for each resource, utility, or activity. Thus, the need to understand nuclear weapons effects and the ability to make appraisals of probable damage extends throughout EGHQ management and control organizations.

Overview of Casualty/Damage Estimation Procedures

Procedures for manual casualty/damage estimation are conveniently described as being "preliminary" or "detailed." The term "manual" is used also to differentiate from computer-produced estimates. Comprehensive casualty and damage assessment is well suited to data processing systems and development of appropriate software is ongoing. Nevertheless, in the context of nuclear warfare, there will always be a number of situations that must rely upon manual methods. Computer techniques are not discussed in this manual. However, the information presented can be the basis for simple programs suited to micro-computers.

Preliminary Estimates - The first necessity following nuclear attack is to make gross estimates of damage to the target area. Based on known information and astute assumptions regarding the target and weapon employed, a series of four damage rings around ground zero is depicted on maps to delineate the estimated areas of complete destruction, heavy, moderate and light damage. The estimated percentage of casualties (fatal and injured) is determined readily from the damage rings also, as is the extent of fires (multiple and scattered) within the damage areas. This technique for gross preliminary assessment of damage assumes the target area is composed entirely of "average" urban structures. It is used by the Canadian military and is more properly referred to as the "zone A-B-C-D technique" of damage estimation. It is an expedient method and, by the use of a simple pre-printed worksheet, can be accomplished with minimal training. A complete description of the procedure is given in Chapter III.

Detailed Estimates - In contrast to the broad assumption made in zone A-B-C-D estimates that the target area is composed of a composite of average buildings, "detailed" damage estimation is much more explicit in nature. This procedure is done only where there is a need for more tailored estimates on the likely condition of specific buildings, bridges, transport equipment, resources, etc., around the target area. It is accomplished by referring to special damage-distance tables and other devices that have been compiled for the purpose. Detailed estimations require more intimate knowledge of the location, type and characteristics regarding the physical construction of the structures of interest. Chapter IV describes damage-distance tables given in the annexes for numerous types of buildings and bridges, assorted transport equipments, and other resources for which detailed damage estimates may be required.

Detailed casualty estimation is accomplished when the estimated **numbers** of casualties are tallied. This is done by applying the preliminary estimated percentages of fatalities and injured persons to special charts which show population distribution throughout the target area. A more detailed appreciation of the fate of specific groups can also be made if their distance from ground zero and the nature of their protection is known. On the other hand, estimates of fallout radiation casualties must be somewhat vague. No valid method exists to estimate the numbers of casualties that could result from the downwind deposition of radioactive fallout. There is, however, a fallout prediction procedure which delineates the area of greatest hazard and, in general terms, defines the degree of risk to people located within it. This procedure is described in Chapter VI entitled "Fallout Prediction."

Figures on the distribution of the Canadian population are required to prepare the special maps and tallies for detailed casualty estimations. The prime source of this information is from decennial census data collected and published by Statistics Canada. Chapter V describes the use of census publications for this purpose and offers an expedient method to transfer the data onto casualty estimation maps.

Sources of Nuclear Attack Data

In estimating damage it will be necessary to have information on the geographic location of ground zero, time of burst, type of burst (air, ground, etc.) and the yield of the nuclear weapon. Fragments of information could come from local observations and, for some intelligence items, prudent assumptions or worst-case scenarios may have to be used. Most likely, however, information on the occurrence of nuclear detonations will be received via the Canadian Forces Warning and Reporting System (CFWRS). The CFWRS is the agency responsible for reporting particulars on nuclear detonations affecting Canada to the civil emergency government organization and, for fallout warning purposes, to the Canadian populace through the Emergency Broadcast System. Included in Chapter VI are examples of CFWRS fallout warning broadcast messages and an explanation of the sort of data contained in nuclear detonation (nudet) reports and radiation monitoring (radmon) reports.

Use of Maps

In addition to a general understanding of nuclear weapon effects, persons involved in damage assessment operations will require the ability to present and interpret damage information on situation maps. The fundamental skill required is to be able to find and identify geographic locations. The two most common position reference systems that will be encountered are the latitude and longitude graticule system and the Universal Transverse Mercator (UTM) co-ordinates system. The final chapter of this manual (Chapter VII) provides basic instruction on how to use these systems along with information on appropriate map scales suitable for damage estimation and operations centre display purposes.

CHAPTER II

NUCLEAR WEAPONS EFFECTS

General Information

Sources - The prime source of data presented in this chapter is the unclassified publication The Effects of Nuclear Weapons published by the U.S. Department of Defense and the U.S. Department of Energy. The Lovelace Nuclear Bomb Effects Computer, a circular slide rule which accompanies the publication, was also used extensively to determine comparative values for detonations of differing yields. Those readers desiring more detail than presented here, or information on the technical and mathematical aspects of nuclear weapons effects, are directed to this source.

Units of Measures - Although the foregoing U.S. source publication uses imperial measures throughout, this volume, with few exceptions, is presented in the International (metric) System of units (SI). The following conversion factors which were used to calculate SI measures of blast pressure, radiant heat exposure and nuclear radiations may be of interest:

- pressure - 1 psi = 6.895 kilopascals (kPa);
- radiant exposure - 1 cal/cm^2 = 4.187 joules/cm^2 (J/cm^2);
- nuclear radiation - 1 rad = 1 centigray (cGy) For simplicity in nuclear radiation units, 1 rem and 1 r (roentgen) were also equated to 1 cGy.

Subsequent chapters of this manual present numerous damage-distance tables for making estimates of the expected number of casualties and structural damage in the area of nuclear explosions. In this chapter, only sufficient comparative information is given to show the unique nature of nuclear explosion effects and to show how they change in magnitude as the size of the burst is increased or decreased.

Development of a Nuclear Explosion

Immediate Effects - Provided a nuclear explosion takes place at an altitude where there is an appreciable atmosphere, the weapon residues almost immediately incorporate material from the surrounding medium and form an intensely hot and luminous gaseous mass, roughly spherical in shape, called the fireball. The expansion of these gases, which are at a very high temperature and pressure, initiates a shock wave in the surrounding medium. In air this is referred to as the blast wave. In earth or rock it is called ground shock and, in water, water shock. Because of the high temperatures in the fireball, a fairly large proportion of the energy of the explosion is emitted in the form of light and heat. Together they are referred to as thermal radiation. In addition, there is "initial nuclear radiation" consisting primarily of prompt gamma rays and neutrons which are highly penetrating and harmful to living organisms. For an air burst, these three mechanisms -- blast, thermal radiation, and initial nuclear radiation -- are the principal effects for producing casualties and damage, each in its own way.

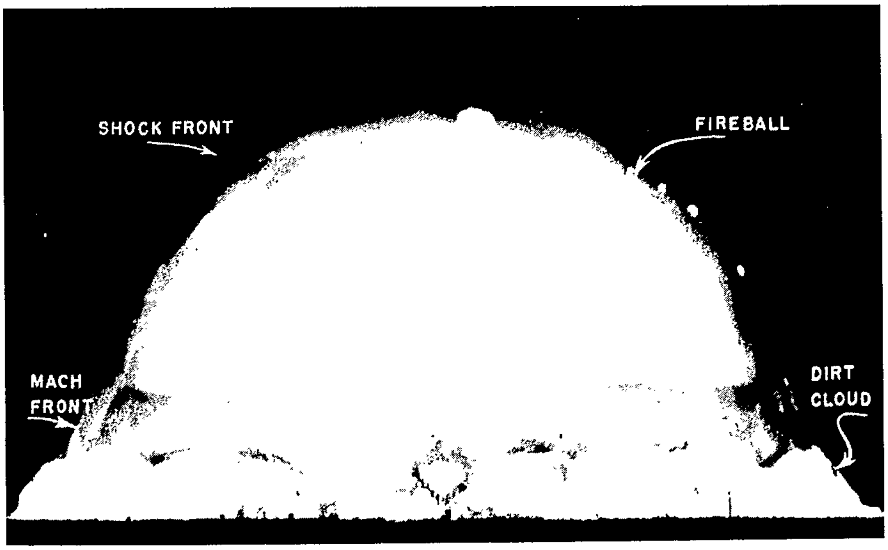


Figure 1 A fraction of a second after detonation, a faintly luminous shock front is seen just ahead of the fireball soon after breakaway. (ENW)

Delayed Effects - The substances remaining in the neighbourhood of the burst after a nuclear explosion are highly radioactive due to neutron activation (neutron capture). They form part of the "residual radiation" effect around the burst site -- referred to as neutron induced radioactivity. As well, when the burst occurs near surface level, part of the explosion is constrained by ground (or water) with a consequent reduction in the intensity of blast and radiation. This decrease is traded for cratering and an increase in ground shock, which may be important where underground installations are part of the intended target, but a much more important addition to the residual radiation effect from the ground burst is "fallout." Fallout occurs when the burst scoops out a crater in the ground (or water) and the debris is carried upward in a stem into the nuclear cloud formed by the rising fireball. The nuclear cloud formation can be extremely large and much higher than that of normal clouds -- in the range of 15 000 to 30 000 metres high for large yield strategic weapons. Radioactive fission products and other weapon residues from the burst then condense onto the surface material drawn into the cloud and, under the influence of gravity and winds, slowly fall as visible particles which create a large downwind hazard area of residual contamination.

Figure 2 Low burst showing nuclear cloud and stem forming. (ENW)

In the case of an airburst, the residual nuclear radiation is insignificant because the radioactive residues from the warhead alone are involved. They condense into very fine particles which are swept up by a rising wind into the upper reaches of the atmosphere where they are widely dissipated. They may ultimately add a little to the global level of background radiation, but this delayed fallout does not create the local contamination problem that results from weightier fallout particles from a surface burst.

Finally, there are some electromagnetic phenomena accompanying nuclear explosions which, under certain conditions, can create a specialized form of temporary interference or permanent damage. They include:

- the ionization produced in the atmosphere which disrupts the normal pattern and therefore causes temporary interference with radio communications and radar; and
- electromagnetic pulse (EMP), consisting of electromagnetic waves (or energy) which radiate outward from a nuclear detonation and can cause considerable damage to electrical and electronic equipment.

Summary of Effects

The major effects of a nuclear explosion can be summarized as:

1) Blast

The air blast wave causes damage to structures, utilities and the natural environment. It may also cause direct casualties, but most casualty production comes from secondary effects such as collapse of buildings, and flying glass. Blast is also associated with ground and water shock waves and cratering depending on the height of burst.

2) Thermal Radiation

The thermal pulse emits light strong enough to damage vision, and heat sufficient to initiate fires and cause burns to exposed skin. It is non-penetrating and therefore people and buildings can often be screened from its direct effects. In favourable conditions for fire development, it can produce damage over a larger area than any of the other immediate mechanisms.

3) **Initial Nuclear Radiation**

The fission/fusion reaction essentially delivers an instantaneous dose of damaging radiation to persons within its range. Since initial radiation is highly penetrating, it is difficult to shield personnel from it. Its lethal radius, however, is usually much less than that of the other damage mechanisms for all but low yield weapons.

4) **Residual Nuclear Radiation**

Fallout, created in the case of surface bursts, causes a contaminated environment downwind that gives off penetrating radiations which can build up over time to lethal dosages. It does not damage structures or equipment, but can prevent their use until decontaminated or until radiation decays to tolerable levels.

5) **Electromagnetic Phenomena**

These phenomena are complex and their effects are difficult to relate to a convenient physical measurement. They affect only electric and electronic equipment and can be considered apart from other damage- and casualty-producing mechanisms.

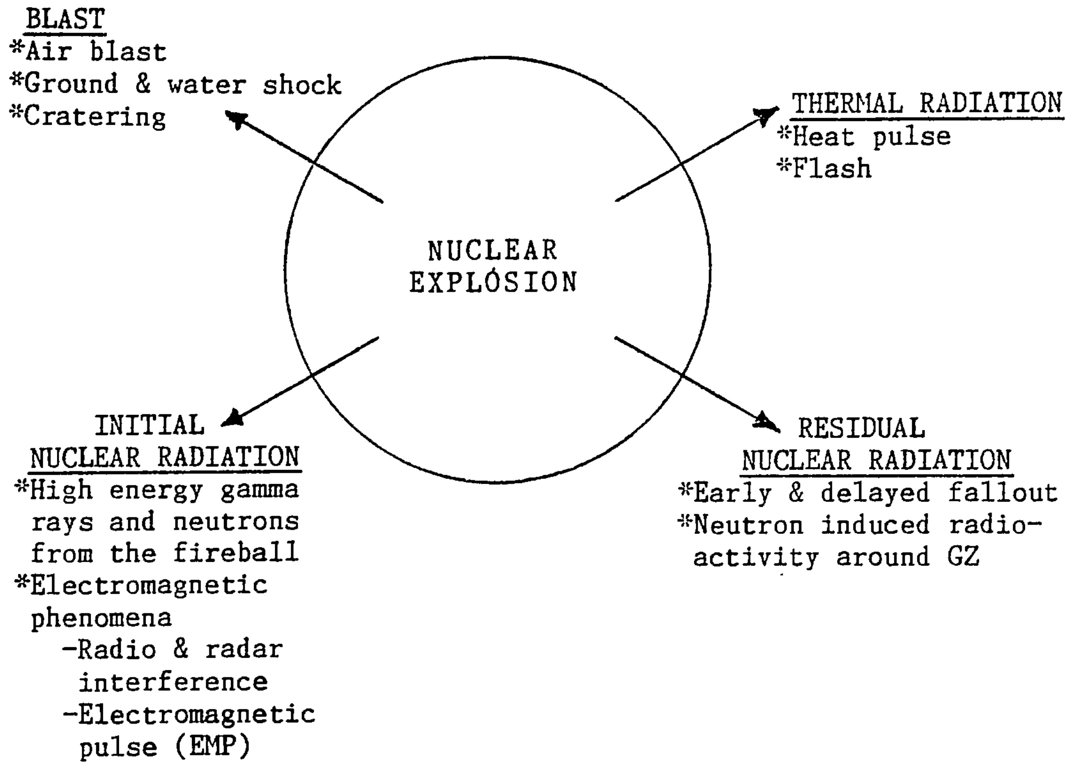


Figure 3 Summary of Nuclear Explosion Effects

Height of Burst

Mention has been made of conditions of burst, of which the height above (or below) ground is most important. All the weapon effects previously discussed vary with height of burst in very significant ways. An indication of how different burst heights alter the relative preponderance of a particular effect is shown by Table 1. Note particularly that an air burst maximizes the three main immediate casualty- and damage-producing mechanisms -- blast, heat, and initial nuclear radiation. Note also that early fallout is produced only by surface bursts. A surface burst is defined as a detonation where the fireball touches the surface of either land or water. For EMP, a surface burst will produce a strong pulse but only out to a limited distance from ground zero, whereas a high altitude burst will produce a weaker pulse (which will nevertheless damage equipment) over a very extensive area.

Burst Conditions	Air Blast	Ground or Water Shock	Thermal		Initial Nuclear radiation	Early Fall - Out	EMP
			Light	Heat			
High Altitude	*		****	**	*		****
Air	****	*	***	****	****		**
Ground Surface	***	**	**	***	***	****	**
Water Surface	***	**	**	***	***	****	**
Confined Subsurface		****					*

Table 1 Relative Importance of Effects for Various Types of Burst. Relative preponderance is indicated by the number of asterisks. Burst conditions are:

High Altitude - an explosion at an altitude above 30 000 m

Airburst - a burst below 30 000 m but at such a height that the fireball does not touch the surface of the earth

Surface burst - a burst at or near the surface

Subsurface burst - a burst with centre below ground or water.

It is clear from Table 1 that the types of burst of most interest to the defence planner, from the point of view of damage done, are the normal air burst and the surface burst. High altitude bursts and contained sub-surface bursts would only be used for special purposes and their casualty-producing potential is limited. Defence planners should keep in mind also that, to a target analyst, if a city were the target the air burst likely would be the type of burst chosen because it inflicts the greatest amount of damage. The fallout-producing surface burst actually causes less widespread damage in the target area and, unless it is particularly desired, fallout is to be avoided because the consequences resulting from the residual effect are very far-reaching and could ultimately be global.

Damage Mechanisms

In the remainder of this chapter, separate and more detailed descriptions are given for the damage- and casualty-producing mechanisms inherent in nuclear explosions. Readers should be aware, however, that there are certain dangers in considering each mechanism in isolation because they act concurrently or consecutively and can reinforce or interfere with each other. Also bear in mind that, although the area of virtually complete destruction caused by nuclear weapons is much larger than that caused by most conventional bombing attacks of the past, the area of repairable damage and survivable casualties is enlarged in even greater proportion as well.

Blast Wave Dynamics

Air Blast Damage - The high temperature in the centre of the explosion heats the adjacent air to such a degree that its high rate of expansion produces a shock front. It breaks away when fireball expansion slows and it rapidly travels outward in all directions from the point of burst, behaving like a moving wall of highly compressed air. (See Figure 1.)

The damage resulting from the air blast of the shock wave may be brought about in two ways. First, there is the sudden increase in pressure when the blast wave arrives. The pressure rises almost instantaneously to a maximum value called the "peak overpressure" and then gradually falls off. The time taken for the pressure to return to atmospheric gets longer as the peak overpressures decrease at greater distances from the explosion. Peak overpressure is frequently used as the basic measure for the blast damage effect of a nuclear explosion.

As stated earlier, the range of blast wave damage is greater from an air burst than from a surface burst of the same yield. This effect is not simply a matter of a towering burst height and hence greater target coverage, but rather that when the downward-directed blast wave strikes the surface, it bounces back up to form a reflected pressure wave. The reflected wave then catches up to and merges with the incident wave as it spreads outward from ground zero. This phenomenon, called the "Mach effect," reinforces the incident blast wave. It has the effect of increasing the peak overpressure of the expanding blast wave and carrying higher overpressures out to a greater distance than would be the case if burst at or near the surface. Figure 4 shows the development of the Mach effect with a series of diagrams depicting the blast wave at successive times after the detonation.

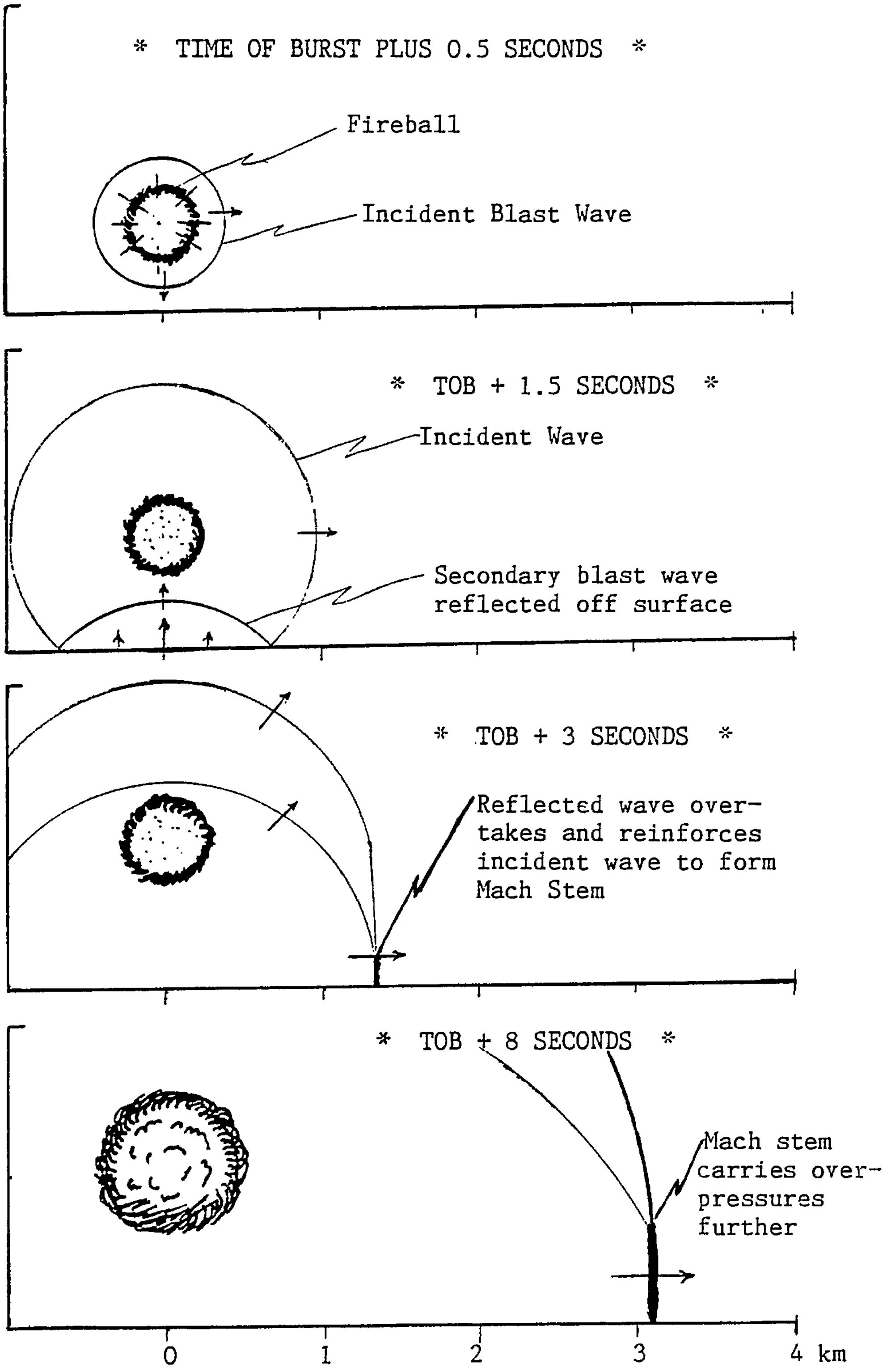


Figure 4 Development of the Mach Effect from a 20 kt Airburst.

In smaller scale, a pressure reflection effect also happens whenever a blast wave strikes any surface, such as directly on the side of a building. There is an instantaneous rise in overpressure at the surface of the building to two or more times the incident value. These pressures are referred to as "reflected overpressures" on the facing surfaces upon which they occur. Their force is very much dependent upon the angle of incidence, type of surface involved and the overpressure of the blast wave.

Diffraction Loading - The process that causes blast damage is much more complex than a direct dependence on peak overpressure. It is also necessary to consider a number of other physical measurements of blast effects. As the blast wave engulfs a structure, pressure differences act upon it to crush and deform the structure. This is called a diffraction effect or "diffraction loading" and the degree of damage in this phase depends upon the magnitude of the peak overpressure.

Drag Loading - Immediately following the shock front of the blast wave, there is a strong outward-blowing wind which lasts as long as the pressure is above atmospheric. (A much weaker returning flow then occurs.) The blast wind exerts a dynamic (pushing) pressure and the long duration of this wind is one of the important differences between nuclear blast and conventional high explosive blast. The shoving, tearing and tumbling effect of the wind on structures is called "drag loading" and the amount of damage it causes depends not only on the dynamic pressure exerted by the wind, but upon the length of time the pressure is applied.

Target Response to Blast - Whether the diffraction loading or the drag loading dominates in causing damage to a particular structure depends on the size and shape of the structure and whether it is fastened down. Anything not solidly anchored, or which has relatively slender structural members, will predominately respond to drag loading; such targets are poles, towers, truss bridges, steel frame buildings with frangible walls, vehicles, and people. Houses, as well as many larger structures, respond mainly to the diffraction effect. Generally, cities are considered as diffraction type targets.

The amount of blast required to damage a specific target type is often expressed using the common term of peak overpressure, irrespective of the dominant damaging effect, diffraction loading or drag loading. As an example of how the different blast effects correlate with peak overpressure, Table 2 gives figures on the overpressures experienced at increasing distances from ground zero along with other blast wave measurements for 100 kt, 500 kt and 1.0 Mt yields. The table also compares the difference in values between air burst (at optimum height) and surface bursts. For a perspective on the destructive capability of the values presented, consider the following:

- 100 kilopascals (kPa) - normal atmospheric pressure;
- 7 kPa peak overpressure - shatters most windows;
- 20 kPa peak overpressure - severely damages most homes;
- 35 kPa peak overpressure - collapses wall-bearing apartment buildings; and
- 50 kPa peak overpressure - severely damages reinforced concrete buildings.

Bomb Yield	Distance From Ground Zero (km)	Peak Overpressure (kPa)*	Max Dynamic Overpressure (kPa)	Max wind Speed (km/h)	Time to Arrival of Peak (Seconds)	Duration Positive Phase (Seconds)
		AB/SB	AB/SB	AB/SB	AB/SB	AB/SB
100 kt	2	70/36	12/4	425/275	4.5/4.4	1.2/1.5
	4	25/11	2/0.4	190/93	12/10	1.6/1.9
	6	13/5.6	0.6/0.1	106/48	16/14	1.7/2.3
	8	9/4	0.3/0.05	72/32	25/22	1.8/2.3
	10	6/2.7	0.2/0.02	56/23	30/26	1.9/2.4
	2	155/97	56/27	805/588	4.2/2.2	1.6/1.8
	4	55/28	9/2	378/212	9/7.5	2.2/2.7
	6	29/14	3/0.8	225/116	15/14	2.6/3.4
	8	20/8	1.2/0.2	148/71	20/18	2.8/3.5
	10	14/6	0.6/0.1	110/50	26/28	3/3.7
	15	12/3	0.2/0.04	66/27	31/40	3.2/3.9
	2	200/154	221/66	1500/850	4/5.8	1.7/2.1
	4	85/43	16/6	483/314	9/7	2.4/2.9
	6	43/21	6/2	314/170	14/12	3/3.7
	8	27/13	2/0.6	209/106	20/17	3.2/4.3
	10	21/9	1.2/0.3	151/72	26/23	3.4/4.6
	20	7.4/3	0.2/0.03	61/26	60/56	4.1/4.9

(*1 psi = 7 kPa approx.)

Table 2 Physical Blast Measurements vs Distance for Air Bursts and Surface Bursts (AB/SB).

Air Blast Casualties - In general, because the human body is composed mostly of uncompressible water, people are much more resistant to direct blast overpressure effects than buildings. In the case of a pure blast weapon, it would be sensible to encourage people to stay in the open away from buildings. With nuclear weapons, however, people in the open are extremely vulnerable to the drag effect, thermal radiation and, from small yield weapons, initial nuclear radiations which would lead to more casualties. As a result, peak overpressures as such are not an important direct cause of casualties. Blast casualties result indirectly by collapsing buildings, and by translational injuries from flying glass and debris, or by bodily displacement. Table 3 gives a comparison of the expected biological effect of various peak overpressures with the structural damage from similar pressure levels.

Peak Over-pressure (kPa)*	Biological Effect	Peak Over-pressure (kPa)	Structural Effect
	Eardrum Rupture		
35	Threshold	35	Houses collapse
100-240	50% casualties	75	Multistory wall bearings buildings; some walls collapse.
	Lung Damage		
85	Threshold	100	Reinforced concrete buiding: incipient collapse.
175	Severe		
	Lethal Overpressure		
275	Threshold	240	Earthquake-proof structures: severe damage.
415	50% deaths		
620	100% deaths		

(*Ambient atmospheric pressure is about 100 kPa).

Table 3 Estimated Overpressures for Direct Blast Casualties Compared with Overpressures for Structural Effects.

From a consideration of the mechanisms by which casualties are caused, it follows that, even where structural damage is extensive, blast casualties can be greatly reduced by taking cover from flying glass and debris, and by seeking areas in a building that provides protection from falling objects. In the open, injuries may be caused by translational mechanisms, that is, by high blast winds propelling people so they impact with hard objects. There is some delay between the explosion and the arrival of the blast wave for the same reason that there is a delay between a lightning flash and its thunderclap (see Table 2, Time to Arrival of Peak). The shock wave travels somewhat faster than the speed of sound. In the short interval before the blast wave arrives -- usually a few seconds -- it may be possible for people in the open to take action to increase their chance of survival, such as by dropping behind the best available nearby cover. It is re-emphasized that, with nuclear explosions in comparison to conventional high explosive bombs, there is a huge area outside the centre of complete destruction where taking protective evasive action can be successful.

Ground Shock - When a nuclear weapon is burst near a ground surface, the burst is partially contained and some of the energy that would have otherwise contributed to air blast is imparted directly to the ground. The effect is to dig out a crater and to rupture and compress the soil for some distance around it. A significant consequence of the crater is that the material scooped out is a primary component in the formation of subsequent radioactive fallout. As well, ground deformation can produce damage to underground structures in the neighbourhood. Air blast can also contribute to ground shock sufficiently to damage near-surface underground works. This effect occurs out to the range of 800 kPa peak overpressure (about 1 km from a 1 Mt burst).

The size of the crater varies according to the position of the centre of burst relative to the ground surface and also to the type of soil around the burst. Some typical examples of the size of the holes scoured out of dry soil by surface bursts follow. Ejected material forms a lip around the edges making the craters appear even larger than indicated by these dimensions:

- 100 kt - radius 74 m, depth 34 m;
- 500 kt - radius 120 m, depth 55 m;
- 1 Mt - radius 148 m, depth 68 m.

As the height of the centre of burst above ground increases the crater dimensions decrease. Conversely, if the point of burst is below ground, the dimensions increase but, since it is difficult to construct a bomb to penetrate the earth and still detonate correctly, underground bursts are mainly of interest for pre-placed devices and are not considered further. Crater dimensions will be about 30 percent larger in wet soil; 20 percent smaller in dry hard rock.

The range to which damage occurs to underground structures also depends on the type of ground and is usually expressed in terms of crater radii. Underground structural damage distances for severe to light damage range from 1.5 to 3 times the crater radius.

Water Shock - In the case of a burst just off shore or in a harbour, the effect against people and structures on land would be much the same as a burst on land at comparable ranges. In particular, the early fallout from a surface burst with on-shore effective winds could be just as extensive and troublesome over the land as that from a ground burst. There is, however, an additional option with the water burst and that is to use the water rather than the air as a destructive agent. Bursts in water generate a water shock wave which travels outward through the water and is particularly damaging to the hulls of vessels and their contents. This effect makes the use of water bursts in naval and shipping ports more plausible.

In addition to water shock, water waves are started which can travel considerable distances to damage and flood shore installations. Heights of the waves are difficult to predict. They depend not only on the yield of the weapon but also on the depth of water and depth of burst. Waves will be smaller for bursts in shallower water. The depth of flooding they cause depends upon the composition and contours of the bottom near the shore and the angle of incidence of the approaching wave. Under the worst conditions, flooding depth can be twice the height of the approaching wave.

To illustrate the waves that can be created, a 1 Mt detonation in water 30 m deep can generate wave heights as follows:

- 6 m high at 2 km distance;
- 3 m high at 5 km; and
- 1 m high at 16 km.

Thermal Radiation Dynamics

Thermal Delivery - Starting at the moment of the explosion, considerable heat is given off. This thermal radiation travels at the speed of light; indeed it behaves essentially like light in all respects. The duration of the effective thermal pulse increases with energy yield. For example, a 1-kt thermal pulse lasts 0.4 seconds; for 10 Mt it is about 24 seconds. Because the thermal radiation is so similar to light in behaviour, it can be stopped by any opaque material. Moreover, variations in atmospheric conditions -- clouds, haze, fog -- will modify the heat radiation in exactly the same way they modify sunlight. These factors make it impossible to predict exactly what will happen in any particular city if attacked.

As might be expected, the larger the weapon the greater the thermal energy emitted. At any specified distance from the point of burst, the total quantity of heat delivered is roughly proportional to the yield of the weapon for the same atmospheric conditions. Hence, if a 1-kt bomb delivers 4 joules (about 1 calorie) per square centimeter (J/cm^2) at 2 km from the point of burst, a 100-kt bomb would deliver 400 J/cm^2 at the same distance under the same conditions. What happens to a surface which receives thermal radiation depends upon how much thermal radiation it receives and how fast it receives it. The sun delivers thermal energy to the earth at the rate of about 8 J/cm^2 per minute. The 16 J/cm^2 delivered in two minutes by the sun has a decidedly warm feeling on the skin, but that is all. Delivered in 24 seconds by a 10-Mt explosion, however the same 16 J/cm^2 causes a first-degree burn (skin reddens), and delivered in 0.4 seconds by a 1-kt explosion it causes a second-degree burn (skin blisters).

The distances to which skin burns can be expected from various yield weapons are readily calculable. However, the major fire damage (and perhaps most casualties) will occur from burning buildings, and the extent of the area within which this occurs is much more difficult to estimate since thermal radiation does not ignite wooden and other structures directly. The extent of fires will depend on many things -- the existence of ignition points, the distribution of combustible material and weather conditions. It is therefore appropriate to consider burns affecting persons in the open separately from fire damage to structures. However, before doing so it is useful to compare the range of the thermal effect with that of blast (see Table 4). Ranges of the initial nuclear radiation effect are also included for later discussion.

Distance from Ground Zero	Effect	Yield				
		100 kt	500 kt	1 Mt	5 Mt	10 Mt
3 km	Overpressure (kPa)	38	92	127	(Within area of the fireball)	
	Thermal radiation (J/cm2)	126	800	1700		
	Initial nuclear radiation (cGy)	5	35	110		
6 km	Overpressure	13	29	43	105	138
	Thermal radiation	25	163	300	1800	3700
	Initial nuclear radiation	-	-	-	-	1
10 km	Overpressure	6	14	21	44	62
	Thermal radiation	6	42	84	460	1200
	Initial nuclear radiation	-	-	-	-	-
20 km	Overpressure	-	5	7	14	22
	Thermal radiation	-	4	8	59	188
	Initial nuclear radiation	-	-	-	-	-
30 km	Overpressure	-	-	3	8	12
	Thermal radiation	-	-	2	21	50
	Initial nuclear radiation	-	-	-	-	-
40 km	Overpressure	-	-	-	3	8
	Thermal radiation	-	-	-	8	15
	Initial nuclear radiation	-	-	-	-	-

Table 4 Comparison of Maximized Ranges of Weapon Effects. A dash (-) indicates that the effect has fallen off to nil or negligible at that range.

The table shows that the thermal pulse can be the most far-reaching of the immediate effects from a nuclear burst. It is especially true for large yields detonated at optimum heights to maximize the range of thermal emissions. In this respect, Table 4 is somewhat misleading as the optimum height of burst for greatest range of the thermal effect is generally higher than that for blast. Also, the blast effect is not diminished by atmospheric conditions such as cloud, haze, etc. Nevertheless, even allowing for some overestimation, the range at which significant thermal radiation could be delivered is much greater than that at which other immediate effects are experienced.

Thermal Radiation Casualties in the Open - It is important to remember that thermal radiation is stopped by any opaque material. The application of this fact can reduce fires and physical injuries markedly. Even though thermal radiation travels at the speed of light, large strategic yield weapons have a thermal pulse of long duration and it may be possible to avoid a significant portion of the thermal effect by taking prompt cover behind almost anything that will cast a shadow.

People in buildings away from windows and openings are protected, at least from the immediate thermal effect. People in the open are protected to some extent by clothing. At least two layers of clothing are desirable to decrease the range at which burns will affect the body. Clothing should be loose and, preferably, the outer layer of light colour. Flame-retardant treatment is advantageous. Clothing which is easily removed if it catches fire is also desirable.

Thermal Radiation Fire Damage - Thermal radiation can potentially lead to very extensive fire damage, even more extensive than the area of blast damage. However, for maximum fire damage to be produced, conditions must be extremely favourable and, to some extent, protective action can be taken to limit it. It is necessary to examine the process of fire spread to see what protective measures can be taken.

The heat of the sun starts few fires but the thermal pulse from a 100-kt nuclear explosion (20 J/cm^2 in 3 seconds) could ignite shredded newspaper and very dry rotted wood out to 6 km from ground zero. The ignition energy for various fabrics range from 40 to

400 J/cm^2 depending upon weight and colour. Construction materials such as wood siding will tend only to char on the side facing the burst rather than ignite, and will not lead to sustained fire. Consequently, the initiation of fires depends primarily on the existence of concentrations of material that can be readily ignited. These ignition points are of two types; external, consisting of piles of rubbish, including paper articles or dry vegetable material; and internal, consisting of paper, draperies, etc., within buildings, ignited through windows. Thus, the incidence of fires can be reduced considerably by such measures as cleaning up external rubbish and providing suitable protective screens such as venetian blinds for windows.

There can be an interval of several seconds between thermal radiation and the arrival of the blast wave. This interval is too short for any fire ignited by thermal radiation to have established itself and the effect of the blast wave on such ignition is uncertain; it may extinguish some and help others along. However, new fires may be started by secondary causes associated with the blast effect; upsetting of stoves, electrical short circuits, broken gas lines, etc. Perhaps even more important in the area of blast damage, fire-fighting equipment may be damaged or not able to get to fires because of blocked roads, or not able to operate because of shut-down of water supplies. In the two nuclear bursts over Japanese cities, there was an area somewhat larger than the area of severe blast damage in which "virtually everything combustible was destroyed." This may well be the case with any nuclear weapon but the kind of city and its inherent combustibility must also be considered.

Once started, the spread of fires within a city depends on a variety of factors. An important one is the distance between buildings. In a densely packed city, there will be a large rising column of hot air from the mass fire producing an inflow of air from surrounding areas which feeds the central fires, but which also tends to restrict the spread outward. In such a case there is little hope of saving anything in the central region, but outlying fires would be small and could be controlled by firefighters. In modern Canadian cities, where buildings are fairly widely spaced or contain a considerable amount of open space, "fire storm" conditions are unlikely to arise and a normal firespread down wind would be expected.

Non-urban Thermal Radiation Damage - Canadians are well aware how easy it is to start forest fires when conditions are right. Primary ignition of dried leaves and grass could occur at about 30 J/cm^2 and brown pine needles at $60/cm^2$ which, from a 100-kt yield, could be delivered as far as 4 km. Larger yields require more radiant energy to ignite such tinder but on a clear day, a 1-Mt airburst could deliver it out to 10 km and from a 20-Mt airburst, to 40 km. Some factors influencing the start and growth of forest fires, besides visibility and tinder, are forest density, moisture content of trees, topography, weather conditions and, of course, the season of the year. A deciduous forest in leaf is less prone to catch fire than are northern coniferous forests. Also, green leaves, green needles and tree trunks tend to shield a tinder-laden forest floor from the thermal pulse so the number of ignition points may be less numerous than it first appears.

The possibility of an intentional nuclear attack with large yield weapons on Canadian forests and ripened grain crops has been postulated. Present strategic concepts, however, do not attach a high probabiity to this kind of attack.

Flash Effects - Damage to the eyes from visual radiation is relatively minor and is only likely to be important under very special circumstances. It takes two forms:

- **Flashblindness** - A temporary dazzling of vision lasting from several seconds to several minutes. This condition could be important in the case of people engaged in some activity that requires continuous vision.

- **Retinal Burn** - Occurs when people receive the visual radiation from burst directly in their field of vision. It produces permanent (but usually slight) damage to the retina resulting in blind spots which the individual affected can usually compensate for by scanning. It would not normally be considered a serious impairment.

Distances to which these effects will be produced vary with the yield, height of burst, time of day, the degree of eye shielding and the blink reflex. A 100-kt airburst could produce temporary flashblindness in varying degrees to persons as far away as 30 km in daytime and to 100 km at night when eye pupils are more dilated. It is also interesting to note that at night people would not even have to be facing the burst to experience the dazzling effect of the tremendous flash. The same 100-kt burst could produce retinal burns out to 40 km in daytime and to 65 km at night, but only to those who have their eyes turned directly toward the centre of the explosion.

Ionizing Nuclear Radiations

Nuclear radiations are described as "ionizing" because these emissions have the ability to change the electrical characteristics of the atoms which make up all living cells. They result in inhibiting, limiting and changing the special chemical processes into which individual cells must enter to survive. Further, they are said to be "nuclear" radiations because they emanate from the nuclei of bomb material atoms involved in, and resulting from, the fission/fusion processes into which create the tremendous energy of nuclear explosions.

Initial Nuclear Radiation - Originating from the fireball, initial radiation consists mainly of high energy gamma rays and neutrons emitted at the time of burst. Highly penetrating, like powerful X-rays, initial nuclear radiations travel essentially at the speed of light and along straight lines, although a portion will be absorbed and scattered by the atmosphere. The distance initial (or prompt) gamma rays travel in air is several thousand metres. The range of neutrons is much less -- hundreds of metres. Very high doses of radiation can be received close-in to ground zero but the cutoff is sharp and, as indicated by Table 4, the range of initial nuclear radiation is very much less than that of lethal blast and thermal effects for the strategic size yields shown on the table.

People within range of the initial gamma and neutrons would only survive the other effects of large yield bursts if they were located in extremely well-protected structures. It is probably true, therefore, that initial nuclear radiation will contribute little to the total number of casualties in a nuclear attack on North America. However, it can be the most important casualty producer for low yield battlefield weapons of 2 kt and below. Enhanced radiation weapons -- "neutron bombs" -- are fission/fusion weapons of this type and, if used, are unlikely to be employed against civil resources.

Another aspect of initial radiation is that it can create a radioactive area around ground zero if the warhead is detonated at a low enough level. Gamma rays, although harmful to people, do not produce radioactivity. On the other hand, neutrons released at the instant of the explosion induce radioactivity in certain elements normally found in soil and water. Thus, the neutrons hitting the surface at ground zero penetrate the soil to a depth of about 45 cm and make it radioactive. This type of radiation is called "neutron induced activity" and, although it decays very rapidly, it does contribute to subsequent fallout and to residual radiation around the ground zero area.

Residual Nuclear Radiation: Early Fallout - Simultaneously with the emission of the initial radiation at the time of burst, a quantity of many different radioactive elements is created by the fissioning of uranium and/or plutonium in the warhead. This complex mixture of created substances is collectively called "mixed fission products." At the high temperature of the fireball, all fission products are vapourized. In the case of an airburst the vapourized materials condense selectively into very fine, invisible particles which float in the atmosphere for weeks, months or years before falling back to earth. This is called delayed (or long-range) fallout and more will be said later about its global distribution and long-term effect.

Early (or local) fallout is defined as that which reaches the surface within the first 24 hours after a nuclear explosion. This fallout is formed only with a surface type of burst. The soil and other surface material sucked up with the fast-rising fireball causes a distinct stem on the mushroom-shaped nuclear cloud. The surface material thus drawn into the cloud mixes with the vapourized fission products and, as they cool, they condense onto the heavier surface materials and form visible, ash-like radioactive particles. Under the influence of gravity and winds, the particles slowly fall to earth, the largest close to ground zero and the remainder fall progressively further downwind of the detonation. This is early fallout and where it lands on anything, that thing or area is said to be "contaminated" with fallout particles.

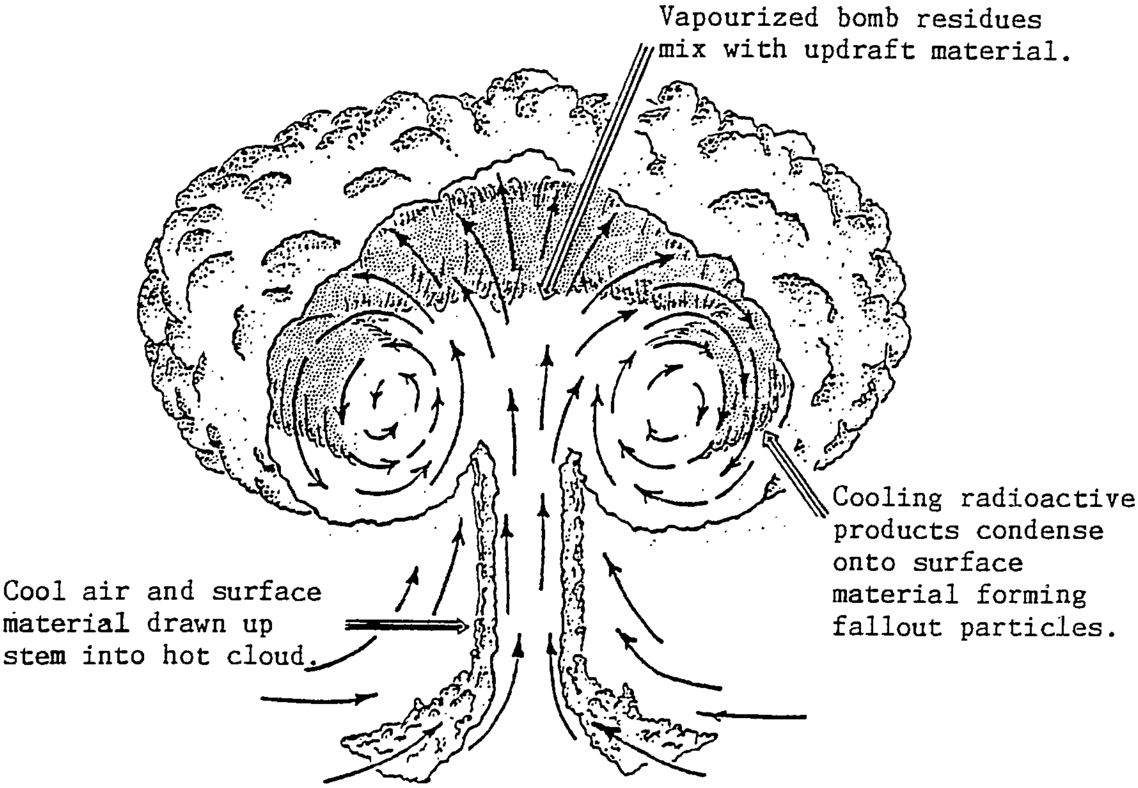


Figure 5 The formation of early fallout particles in a surface burst nuclear cloud.

Radiation Sickness - The amount (dose) of radiation that would cause sickness and death in humans varies considerably between persons. It depends not only on individual tolerance but also on how rapidly the dose is received. For example, an "acute" dose of initial radiation, received all at once, would be much more devastating than a similar "chronic" dose accumulated over a lengthy period of time from a fallout-contaminated area. The median lethal dose to humans is generally accepted to be 450 centigrays (cGy) which is accumulated in less than 24 hours. This means that 50 percent of the persons so exposed would likely die within 30 days (unless medical support is given). Following is a summation of the effects of short-term, whole body exposures to ionizing radiation:

- 0-100 cGy* dose - no obvious effects;
- 100-200 cGy dose - minor incapacitation;
- 200-600 cGy dose - sickness and some deaths;

- Over 600 cGy dose - few survivors; and
- Over 1 000 cGy dose - virtually certain death.

(*Reminder: For those more familiar with these exposures in units of rem or rad -- 100 cGy = 100 rem = 100 rad.)

Fallout Characteristics

Composition of Fallout - Fallout radiations, in order of severity, consist of gamma rays, beta particles and alpha particles. Residual gamma rays have considerably less energy and penetrating ability than does the prompt gamma emitted as initial radiation. The range of fallout gamma is only a few hundred metres in air, but some of the protection pluses are counterbalanced by the fact that, with fallout, you must deal with a large contaminated plain rather than the point-source of initial gamma. It is estimated that of the gamma dose a person would receive if out in a fallout contaminated area, 50 percent comes from more than 15 metres away and 25 percent from distances in excess of 60 metres. Fallout gamma radiation is said to be an external hazard because direct contact with fallout is not needed to be subjected to its harmful ionizing effect.

Most of the fission products in fallout decay by emitting beta particles (radiation) as well as gamma radiation. Beta particles are similar to high-speed electrons. They are ionizing but their range in air is generally less than a metre and they are not very penetrating. There is a risk of burn-like beta damage to the skin if fallout dust is allowed to remain on bare skin for any length of time. Protection from beta is achieved by wearing simple protective clothing (overalls, headgear, gloves and footwear) to keep dust off the skin and by washing exposed skin when it is contaminated with fallout dust. Protective clothing does not protect from the gamma hazard.

Alpha particles are emitted from unfissioned bomb material (plutonium and uranium) which is also found in the fallout. The particles pose only an internal hazard since they are completely absorbed in only a few centimetres of air and they cannot penetrate the skin, or even a thin film of water. Nevertheless, alpha articles are highly ionizing and can cause long-term internal damage if fallout particles are ingested or inhaled.

Fallout Decay - One prominent feature of radioactivity, which comes from its very activity, is that it gradually decreases or decays. Every radioactive substance has its own rate of decay, which is invariable, and is expressed as the time required to lose half of its activity. This process is called the "half-life" and it can range from micro-seconds to many years depending upon the radioisotope. For instance, krypton-90 has a half-life of 33 seconds, iodine-131 -- 8 days, strontium-90 -- 28 years, and so on, a definite half-life for each substance.

Fission products, a mixture of many radioisotopes created in the explosion, have no definite half-life. The apparent effect is a half-life that increases with age. The decay is therefore exponential and can, in general, be expressed by the statement:

> **For every sevenfold increase in time after the explosion, the dose rate from residual radiation is decreased tenfold.**

This statement is a simplification of what is expressed mathematically by the equation for the standard decay rate of mixed fission products --

$$I_t = I_1 t^{-1.2}$$

> **Where I_t is intensity in cGy/h at anytime in hours after TOB, I_1 is intensity in cGy/h 1 hour after TOB, and $t^{-1.2}$ is the decay exponent for standard rate of decay.**

Putting the rule of sevens into specific values, means, for example, that if the radiation intensity at a certain place at time of burst (TOB) plus 1 hour is known, it will decrease in intensity with time as follows:

> **If at TOB + 1 h the dose rate is 100 centigrays per hour;**
>
> **then at TOB + 7 h it will be 10 cGy/h;**
>
> **at TOB + 49 h it will be 1 cGy/h;**
>
> **at TOB + 2 weeks it will be 0.1 cGy/h; and**
>
> **at TOB + 3 months it will be 0.01 cGy/h.**

This relationship is valid within 25 percent for times after the explosion between 30 minutes and 200 days, provided there is no change in the quantity of fallout during the time interval under consideration. The formula cannot be used while fallout is still descending, or for fallout from multiple bursts or if much weathering has occurred. Nuclear warheads can also be "salted" to produce non-standard decay rates. In an actual situation, the dose rate still must be verified by measurement with radiation meters as frequently as possible.

It is apparent that the fallout dose rate falls off rapidly during the early hours after an explosion and relatively slowly later on. Hence, there is considerable risk to personnel remaining unprotected in a fallout area during the early hours following a burst. Many lives can be saved by using protective shelters which can be occupied during that period -- particularly if they are entered before the fallout arrives. There is also some automatic relief in that by the time fallout arrives downwind, there will already have been a considerable reduction in the dose rate.

Early Fallout Distribution - The shape and size of the downwind fallout pattern depends on many things. The radiation intensities occurring in it will be determined chiefly by the fission yield of the weapon as only that portion of the yield produces fission products. The size of the downwind pattern mainly depends upon the total yield (the greater the yield, the bigger and higher the nuclear cloud), and the direction and speed of the winds that influence the fallout particles as they fall from the nuclear cloud to earth. Precipitation will also alter downwind distribution patterns.

As an example, Figure 6 depicts an **idealized** fallout pattern for a 1-Mt surface burst (50% fission) with an effective wind of 25 km/h. The eliptical-shaped pattern produced shows that significant fallout intensities could extend as far as 320 km downwind. The highest intensities occur nearest to ground zero and decrease downwind as the quantity of heavier particles is gradually diminished. If the fission portion of the warhead were reduced -- say to 25 percent - from 50 percent - in our example -- the value of the contours would be, proportionally, half the values shown. On the other hand, if the **total** yield were increased, or the effective wind speed is increased, the size of the fallout area will be greatly enlarged, though not necessarily in proportion to the increases. It is conceivable that Canada, though not under direct attack itself, could be subjected to heavy fallout in its most populated areas from detonations on bordering U.S. territory.

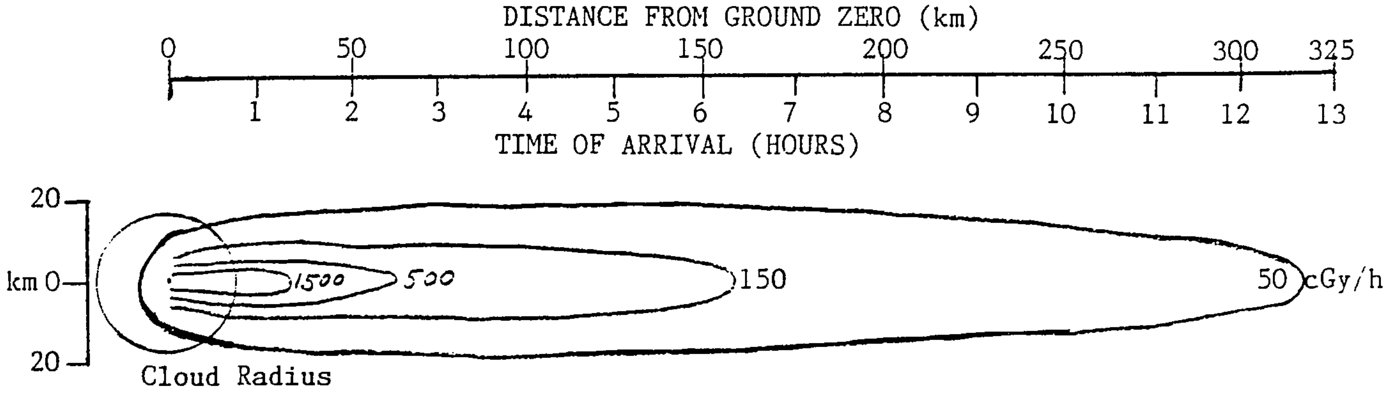


Figure 6 Idealized unit-time reference dose-rate contours (TOB + 1 hour) for a 1-Mt, 50% fission/50% fusion, surface burst, 25 km/h effective wind speed.

(The radiation intensity contour lines also represent accumulated one-week (exposed) dose contours as follows: contour 50 = 60 cGy dose; contour 150 = 260 cGy dose; contour 500 = 1,300 cGy dose; and contour 1,500 = 4,800 cGy dose. The lifetime accumulated dose on contour 50 would be 150 cGy; on contour 150, about 530 cGy; and on contour 500, a fatal 2,200 cGy).

Time of Arrival - The arrival time of fallout at downwind locations is also dependent upon the effective wind speed. For example, with the 25-km/h effective wind speed used for the pattern in Figure 6, fallout could be expected to arrive at a location 50 km downwind in approximately 2 hours; 100 km downwind in about 4 hours; and so on. During its travel time aloft the fallout decays rapidly. As shown by the time of arrival scale on the diagram, by the time it reaches the extremity of the 50-cGy/h contour (TOB + 1-hour reference dose rate), almost 13 hours will have elapsed and by then the actual dose rate will have decayed to about 2 cGy/h.

At any location in the downwind area, fallout arrival would be indicated on radiation detection meters by fast-rising radiation intensities until the nuclear cloud remnants, which may not be visible, have passed over. As the volume of descending fallout particles decreases and stops, a peak radiation intensity is reached and then it begins to decrease, very rapidly at first and gradually more slowly, as the radioactive material decays in the exponential manner described earlier.

Limitations of Idealized Contours - Idealized fallout patterns are only intended for overall planning and should not be used for fallout warning and survival operations. The data are applicable only to a very large, entirely smooth surface and with almost none of the many variables that would affect the actual distribution of fallout. To demonstrate, Figure 7 shows a diagram of the corresponding actual dose-rate contours that would more likely result from "real world" conditions.

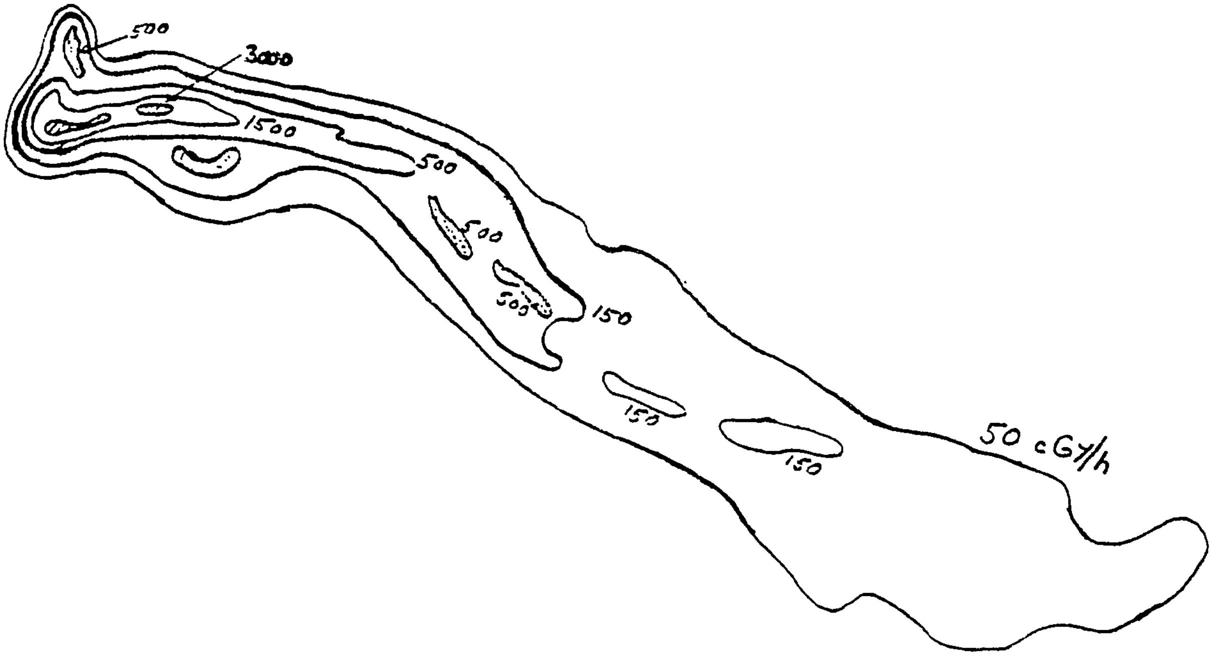


Figure 7 Corresponding (Figure 6) actual dose-rate contours more likely to occur.

Fallout Protection - In considering protection from fallout, the most dangerous component to deal with is gamma radiation. Incidentally, any method used to gain protection from gamma will result in attenuation of accompanying alpha and beta particles, as well. Stopping gamma radiation is not as simple as stopping thermal radiation as more massive amounts of shielding are necessary. Massive is the operative term since, over a considerable range of different materials, the amount of attenuation afforded by a shield of given weight per square metre is approximately constant. The more dense and heavier the material, the more effective it is in stopping gamma rays. The attenuation value of a particular material may be expressed in terms of either a "half thickness layer" or its "tenth value thickness"; the first being the thickness which will reduce the intensity of radiation passing through by half; and the second, that which will reduce intensity to a tenth of its incident value. For example, a half thickness of packed earth is about 10 cm and a tenth value 30 cm; a half thickness of steel is about 2 cm and a tenth value about 6 cm.

Shelter Protection Factors (PFs) - Half-and tenth-thickness measures of attenuation are more applicable to a narrow radiation beam from a point source, such as in initial radiation. With real buildings and structures that will be used as fallout shelters for people, there will be a variety of building materials involved and different angles of incidence so that protection is better measured by considering the structure as a whole. The amount of fallout gamma radiation attenuation afforded by various buildings can be determined and is usually expressed in terms of the structure's "Protection Factor" or "PF." The PF of a shelter is the number by which the external dose rate is divided to obtain the protected inside dose rate. For example, if at a particular time the outside dose rate is 100 cGy/h, then inside a shelter with PF 50 the dose rate would be 2 cGy/h (100 - 50). The same PF computation works in reverse (measured inside dose rate x PF = outside dose rate) and also for equivalent outside/inside accumulated doses.

Table 5 shows a sampling of typical PFs for various types of structures. In some cases the range of PFs given for the same structure is quite wide. Differences may be accounted for by dissimilar dimensions of the structures, shielding from varied arrangements of internal partitions and, a most important consideration when taking shelter from fallout, variations in the actual distance from the fallout outside and the amount of shielding obtained at different locations within each structure. Generally, the most protected locations above ground are in the centre areas of buildings and in basements, in the corners.

For additional information on fallout shelter concepts and design, readers are directed to the Public Works Canada/EPC publication entitled Home Fallout Protection.

Automobiles, Buses, Vans, etc.	PF 2
Frame House	PF 2 to 3
Basement	PF 10 to 20
Multistory Apartment Buildings	
Upper stories	PF 100
Lower stories	PF 20
Concrete Blockhouse Shelter	PF 11 to 143
20 cm walls	PF 33 to 1000
30 cm walls	PF 500 to 10 000
60 cm walls	PF 500 to 10 000
Shelter partly above grade:	
with 60 cm earth cover	PF 50 to 200
with 90 cm earth cover	PF 200 to 1000
One metre underground	PF 5000

Table 5 Protection Factors (PFs) for Various Types of Structures.

Delayed Fallout - Essentially all residues from air bursts become delayed fallout as does about 30 to 40 percent of the residues from a surface burst. Delayed fallout reaches the earth's surface after a period of weeks or months, by which time it may have travelled half way around the earth and more. During this time it will have lost most of the radioactivity that would pose an urgent and immediate threat. Whereas the principal hazard from early fallout is exposure to gamma rays from sources outside the body, the hazard from delayed fallout is exclusively a potential internal hazard due to ingestion of long-lived isotopes taken from the soil by plants. Thus, radioisotopes can enter into the food chain (especially in milk) over large areas of the earth quite remote from the nuclear explosions.

The most important and abundant of these long-lived radiosotopes is strontium-90 which tends to concentrate in the bones. Another, cesium-137, distributes throughout the body in muscle tissues. Iodine-131, a significant but shorter-term hazard, is attracted to the thyroid glands. These materials are removed slowly from the body by radioactive decay and natural processes.

Radiation from both early and delayed fallout causes an increased incidence of cancers and long-term genetic effects. However, in the massive destruction context of intercontinental nuclear warfare, these long-term effects are insignificant. Nevertheless, the cumulative result of several thousand large-yield bursts could produce severe genetic effects over a long period and could have serious repercussions in a nation that was not itself at war, even though most other countries would be experiencing the same problem.

Electromagnetic Damage

Interference to Radio and Radar - Transmission of electromagnetic waves with wavelengths of 1 mm or more, which are used for radio communications and radar, is often dependent on electrical properties, i.e. the ionization of the atmosphere. Radiation from the fireball and from radioactive debris can produce marked changes in the balance of atmospheric ionization and can, therefore, disturb the propagation of electromagnetic waves. Apart from the energy yield of the explosion, the effects are dependent on the altitude of the burst and its debris, and on the frequency of the electromagnetic waves. In certain circumstances, radio and radar signals may be blacked out for several hours.

For nuclear explosions occurring at altitudes below 15 km -- which include both surface bursts and air bursts designed to produce major surface damage -- most of the energy is deposited in the atmosphere in the immediate vicinity of the detonation and results in formation of a fireball and an air blast wave. The fireball region will be significantly ionized to absorb electromagnetic signals for at least 10 seconds and possibly for as long as three or four minutes. However, the spatial extent of the ionization will be small. There will also be a region further out from the fireball which will absorb electromagnetic waves appreciably for tens of seconds. This effect will be negligible for most radio frequency systems, but it may be significant for radars with highly directional beams that pass fairly near the fireball. In the nuclear cloud and its stem, refraction of radar signals and clutter may be more significant than absorption.

For bursts at high altitude, particularly for bursts above 60 km, considerable disturbance of the ionosphere occurs which will change its reflective and refractive characteristics. The effect of this disturbance on radio and radar systems, in general terms, is to cause various signal distortions and absorption in the lower frequency bands over many hundreds of kilometres lasting from minutes to hours. In the VHF and UHF bands, signal interference will last from seconds to minutes with spatial extent of a few kilometres to tens of kilometres. The range and duration of signal degradation are dependent upon the yield and altitude of the burst. Such high altitude bursts will not likely inflict damage on the surface but could be used to disrupt air defence systems, degrade communications, and create confusion.

Electromagnetic Pulse (EMP) - Explosions of conventional high explosives produce electromagnetic signals so the generation of an electromagnetic pulse from a nuclear detonation was not unexpected. It was some years, however, before the extent and potentially serious nature of EMP effects on electrical and electronic systems was fully realized. Nuclear explosions of all types, from underground to high altitude, are accompanied by an EMP, although the intensity and duration of the pulse and the area over which it is effective vary considerably with the location of the burst point. Once again, the effects are most far-reaching for high altitude bursts.

The nuclear EMP is a time-varying, electromagnetic radiation which increases very rapidly to a peak. After reaching its maximum in a very short time, the electric field strength falls off and becomes quite small in a few tens of microseconds. In spite of the short duration of the pulse, it carries a considerable amount of energy, especially if the weapon has a yield in the megaton range. As it travels away from the burst point at the speed of light, the radiation can be collected by metallic and other conductors at a distance just as radio waves are picked up by antennas. Some typical EMP collectors are long runs of cable, piping or conduit, large antenna assemblies, power and telephone lines, and even railroad tracks. The energy of the collected radiation can then be converted into brief but strong electric currents with high voltages. Electrical and electronic equipment connected to or associated with the collector may thus suffer serious damage. The consequences could be serious for any system that relies on such equipment. Highly susceptible to EMP damage are low-power systems and equipment such as computers and systems employing transistors or semi-conductor rectifiers, alarm and intercom systems, telephone equipment, radio receivers and transmitters, and systems for life support and power control.

For a surface burst, the EMP threat to electrical and electronic systems extends only about as far as the range of the 15 kPa peak overpressure, i.e. about 10 km for a 1-Mt yield. This is still within the area of moderate blast damage so, for surface bursts, EMP does not necessarily add a great deal to the overall damage. For air bursts below 30 km, the range of the effect is greater but the EMP pulse is much weaker. For high altitude bursts (above 30 km), because of energy interactions with the upper edge of the atmosphere, the range of the EMP effect extends essentially to the all-around horizon from the burst altitude. For example, a megaton yield detonated 80 km high could produce damaging EMP out to a radius of 1 000 km on the surface. Thus, the high altitude burst is the only one which will produce severe EMP effects over a wide area, and this is at the expense of decreased overall damage on the ground. However, it still could be worthwhile for an aggressor in a widespread nuclear attack to devote one or several weapons to produce far-reaching EMP to interfere with defence communications.

EMP Personal Hazard - Except for locations close to a surface burst where other effects would dominate in any event, the EMP radiation from a nuclear burst is no more harmful to people than a flash of lightning at a distance. However, a person in contact with an effective collector of EMP energy, such as a long wire or a sizable metallic object, could receive a severe shock.

Speculative Effects

Publicity has been given to two theoretical effects that, in event of the all-out, widespread use of nuclear weapons, might upset some of the earth's basal environmental mechanisms -- effects on the ozone layer and "nuclear winter." Neither has been indicated by measurements from past nuclear detonations, but the uncertainties engendered from the possible occurrence of multiple, high-yield bursts do not allow an unambiguous conclusion to be reached.

Changes to the Ozone Layer - The ozone layer, located in the stratosphere at altitudes of 15 to 30 km, serves to filter out much harmful solar ultraviolet radiation before it reaches the earth. It is proposed that the extensive use of nuclear weapons could upset its equilibrium and cause an increase in adverse biological effects due to ultraviolet radiation. It is reckoned that the ozone layer would eventually recover, but it could take up to 25 years.

Climate Changes - "Nuclear winter" is the term that has been used to describe a theory concerning massive cooling of the atmosphere caused by huge quantities of dust and smoke being taken up from multiple nuclear detonations. This material, it is proposed, could be in sufficient quantities and suspended long enough to block radiant energy from the sun. Subsequent lowered atmospheric temperatures would then have a disastrous effect on food cultivation for a number of weeks or months. Further study by the theory's proponents indicate that the effect, should it occur, would more properly be called "nuclear autumn."

The possible influence that either of these effects would have on post-attack recovery is still questionable. They are, therefore, not considered in the following chapters dealing with casualty- and damage-estimation techniques.

CHAPTER III

PRELIMINARY CASUALTY AND DAMAGE ESTIMATIONS

Background

The aim of this chapter is to give emergency planners and damage assessment staffs a simple and expedient way to estimate overall damage and the general distribution of casualties resulting from nuclear explosions. The method described is based on draft material published in March 1961 by the (then) U.S. Office of Civil and Defence Mobilization in a publication entitled Nuclear Weapons Phenomena and Characteristics. The technique was further developed in the Canadian Forces Warning and Reporting System (CFWRS). It continues to be used in Central and Regional Emergency Government sites in each province to provide headquarters staffs with quick estimates of urban damage in the event of nuclear attack on Canada. Within the CFWRS, the procedure is usually referred to as "preliminary cas/dam estimation," but it is more accurately termed the "Zone A-B-C-D damage estimation technique."

Description of the Zone A-B-C-D Damage Estimation Technique

Composite Target - The technique is based on the concept that there is generally a certain distribution of types of damage to average buildings in a city around a nuclear detonation. The phrase "average buildings" used in connection with the Zone A-B-C-D technique, refers to the type of structures most commonly found in urban Canadian areas. These are:

- brick and wood frame houses;
- multi-storey brick apartment houses; and
- one storey light steel and wall frame industrial buildings.

Damage Zones - The damage criteria employed for this composite type of target are based on the ranges of certain peak overpressures in the blast wave as it progresses outward from ground zero. The extent of different damage zones -- labelled as Zones A, B, C and D -- is determined by the range of the following peak overpressures:

Zone of Damage	Peak Overpressure kPa*
A	50
B	17 to 50
C	10 to 17
D	7 to 10

*The operative overpressures in psi units are 7, 2.5, 1.5, and 1.0 psi.

Dividing types of damage into A, B, C and D zones derives from World War II categories of building damage in Great Britain. Figure 8 depicts distribution of the zones. There are four concentric circle-shaped areas:

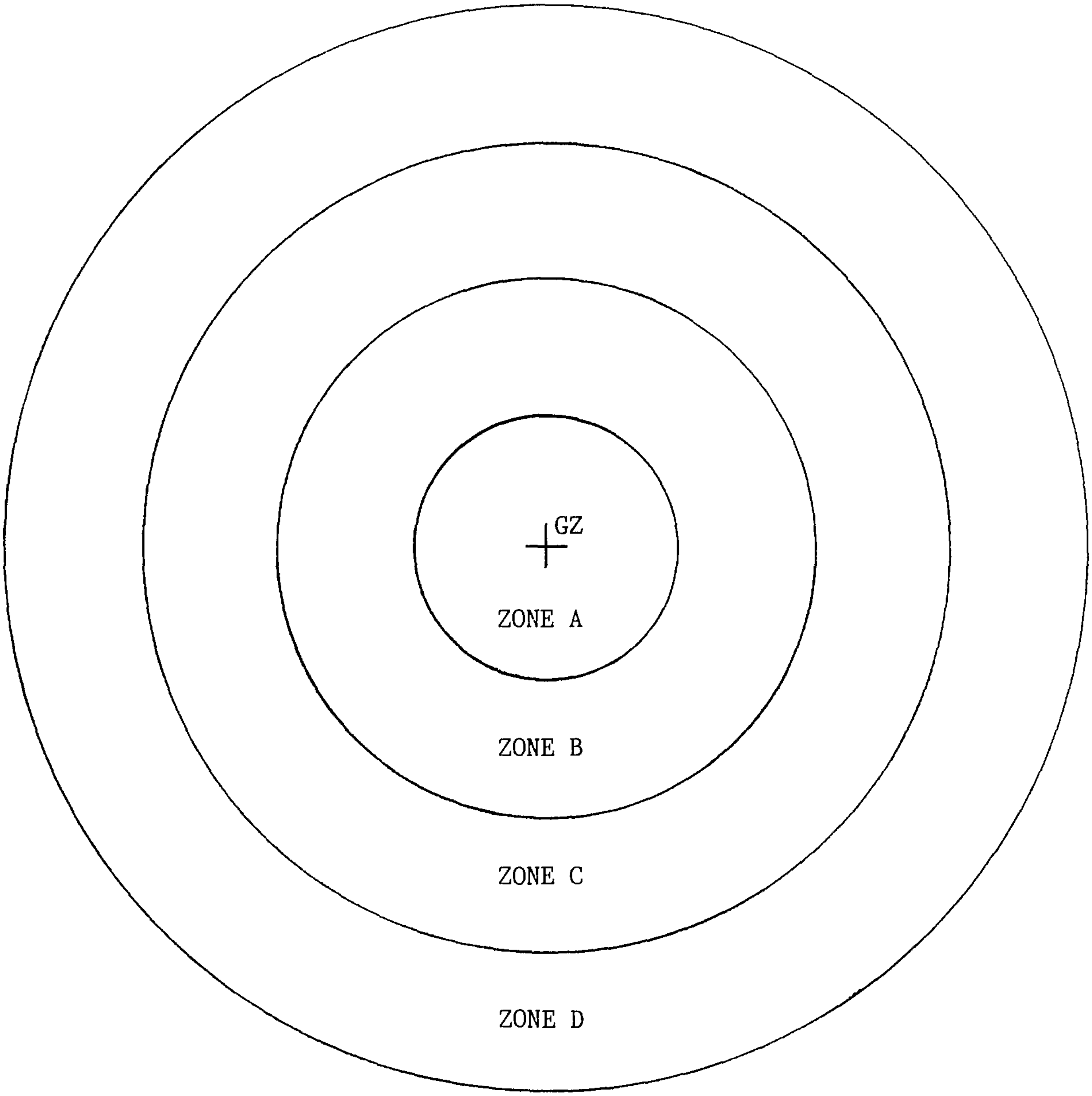
1) Surrounding ground zero, there will be an area in which destruction is virtually complete. This zone is called Zone A, or the **destroyed** area.

2) Outside the centre area of complete destruction, there is a doughnut-shaped area in which most buildings are damaged beyond repair. This is Zone B, the area of **heavy** damage.

3) Zone C, the area of **moderate** damage, is the circular area beyond the second area. Buildings in Zone C may be partially habitable but must be vacated during repairs.

4) The last and largest circular area, Zone D, is the area of **light** damage in which damaged buildings need not be vacated during repairs. Cases where the only damage amounts to broken glass in less than 10 percent of the windows are not included.

Beyond the four damage zones, essentially no significant damage occurs. The circular shape of the zones, however, is an idealized pattern which assumes that the terrain is fairly flat. Rugged terrain, ravines, hills, etc., may provide local shielding in certain areas; in others, it may enhance and extend the damage.



DAMAGE ZONE	DEGREE OF DAMAGE	DESCRIPTION
A	Destroyed	Virtually complete destruction.
B	Heavy	Damage is beyond repair.
C	Moderate	Buildings must be vacated for repairs.
D	Light	Buildings are usable.

Note: The concentric circles do not have equidistant radii.

Figure 8 Schematic Illustration of Distribution of A-B-C-D of Damage/Casualty Zones.

Table of Damage Radii - Annex A to this manual presents a sample worksheet designed as an aid to make preliminary casualty and damage estimations. Use of the worksheet will be described later but, for our purposes, note the "Table of Radii for A-B-C-D Damage/Casualty Zones" on the worksheet. It shows the radii of the damage zones in kilometres from ground zero for yields of 150 kt, 300 kt, 500 kt, 1.0 Mt, 10 Mt, 5 Mt, 15 Mt and 25 Mt. When the damage radii for a yield are applied in correct scale to a map of the target area, the estimated extent of damage is readily apparent.

Radii of damage are given for both air and surface bursts in the worksheet table. The surface burst data are for a "contact" burst which is one where the bomb is actually on the surface when it explodes. Air burst data are for "typical" air bursts which, for this table, are bursts at such an altitude that they would cause maximum blast damage to an **average city.** Thus, the term "typical air burst" is used in this case to distinguish a detonation which is not necessarily at the same height of burst as that for an "optimum air burst." An optimum height of burst is at the height which optimizes a particular bomb effect (blast, thermal, etc.), or which will cause greatest damage to a specifically targeted structure or resource. For the airburst data given on the Preliminary Casualty and Damage Estimation Worksheet, the assumed heights of burst range from as low as 400 m for the 150-kt yield to as high as 4 400 m for the 25-Mt yield.

Scaling Laws - The eight weapon yields given in the worksheet table of radii should suffice for most situations. This is especially true when one considers that, at least initially, the yields of nuclear warheads used in an attack on Canada most likely will be unknown and have to be estimated. Nevertheless, there is a mathematical formula, or "scaling law," by which the damage radii for other yields can be extrapolated from the radii given for the 1-Mt yield. The scaling procedure applicable to the "soft" composite urban target is called cube root scaling. Its use is detailed in the source publication mentioned in Chapter II entitled The Effects of Nuclear Weapons.

Casualty Estimates

Whereas structural damage is related most directly to the blast effect in damage estimation, the percentage of immediate casualties occurring (deaths and surviving injured) must consider blast, thermal and nuclear radiation effects around ground zero. There is no exact information available concerning the relative significance of each effect as a source of fatalities. In the nuclear bombings in Japan, many people who were fatally injured by blast were also burned, and this was also undoubtedly the fate of many who would have succumbed to the effect of nuclear radiation. Within the Zone A area of damage, it is probable that blast, burns and radiation could have been lethal separately in numerous instances. The total number of fatalities and surviving injured (and the most prevalent types of injuries) will be governed by the weapon yield, height of burst, target characteristics, nature of the terrain, weather and, very important, the disposition of the population at the time of attack, i.e. time of day, warning received, use of shelters, evacuation, and so forth.

A-B-C-D Casualty Zones - The method adopted in Canada for predicting numbers of casualties uses the same A-B-C-D zones determined for blast damage as the basis for casualty estimation. When estimating casualties the four concentric damage zones simply become "casualty zones." The percentage of fatalities and surviving injured expected within each casualty zone is shown in Table 6. The table compares casualty percentages for two conditions, population warned and population unwarned -- the assumption being that a warned populace will have taken cover. The value of disseminating timely attack warnings to the public is obvious. Generally, considering the relative difference in size of casualty zones, a warned and informed public quickly taking the best available nearby protection will sustain approximately half the casualties from immediate effects than does a populace that does not receive early warning of attack.

CASUALTY ZONE	FACTALITIES (%)		SURVIVING INJURED (%)	
	With Warning	Without Warning	With Warning	Without Warning
A*	75	90	15	10
B	30	50	20	35
C	5	15	25	40
D	1	2	9	18

*Note: Zone A fatalities are increased to 100 percent from a surface burst.

Table 6 Distribution of Percentage of Fatalities and Surviving Injured from Direct Effects around Ground Zero.

Surface Burst Casualties - The idealized circular zone-pattern and the percentages of casualties in Table 6 are changed slightly for surface bursts due to residual radiation caused by larger (heavy) fallout particles descending around ground zero within the first hour or so. The casualty pattern will be intensified more in the downwind hemisphere but, for casualty estimation purposes, it is sufficient to increase the percentage of fatalities in Zone A to 100 percent (warned and unwarned) to account for the extremely high radiation levels created close to surface bursts.

Casualty Situation with Time - Casualty multipliers in Table 6 are a snapshot of the casualty situation projected as it would be 60 days after the detonation. This projection is probably the most practical to use for most purposes. If needed, however, estimates for day 1, 7 and 14 can be determined from the 60-day projection figures. The procedure involves the application of the following percentage factors to the 60-day percentages:

Day 1

Dead - 100% of Zone A (fatal group only)
- 67% of Zones B, C and D (fatal group only)

Injured - 100% of injured (in all zones)
- 33% of Zones B, C and D (fatal group only);

Day 7

Dead - 100% of Zone A (fatal group only)
- 83% of Zones B, C and D (fatal group only)

Injured - 100% of Zone A (fatal group only)
17% of Zones B, C and D (fatal group only);

Day 14

Dead - 100% of Zone A (fatal group only)
- 91% of Zones B, C and D (fatal group only)

Injured - 100% of injured (in all zones)
- 9% of Zones B, C and D (fatal group only).

In summary, the above figures simply indicate that outside of Zone A not all the fatalities are killed outright. Only 67 percent of the expected 60th-day fatalities in Zones B, C and D will occur on the burst day, 83 percent as of one week, 91 percent as of two weeks, and, as of two months, all of the injured remaining are expected to survive.

Estimating the Extent of Fires

Sources of Fire - Although blast is responsible for most of the destruction caused by a nuclear detonation, fires may start in the area of blast damage from primary or secondary sources. Direct thermal radiations from the burst are the primary source, and secondary sources are fires resulting from destruction caused by the blast wave such as upset stoves, electrical short circuits, and broken gas lines. Both sources are considered in estimating the extent of fires, but most emphasis is given to secondary sources because of the many unknown variables which affect the ability of the thermal pulse to start fires directly in different seasons, weather, fuels, etc.

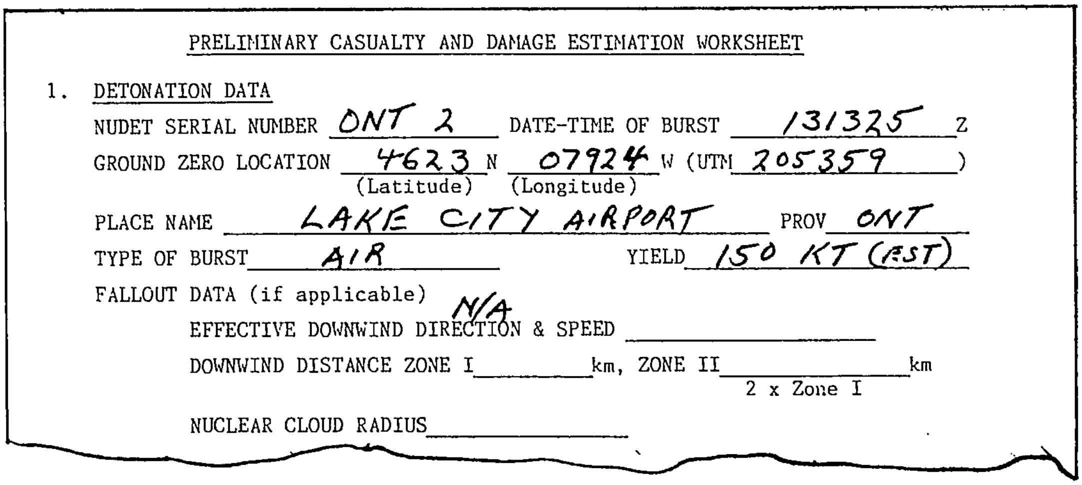
Multiple and Scattered Fires - The radii of two fire types -- multiple and scattered -- are indicated by the same A-B-C-D zones used to show damage and casualties. Assuming average conditions, the extent of fires will be as follows:

- Zones A and B - multiple fires throughout; and
- Zones C and D - scattered fires throughout.

Using the Preliminary Casualty and Damage Estimation Worksheet

Description - Annex A depicts a sample worksheet on which all necessary information from this chapter is summarized. The worksheet, which can be reproduced locally, is used to produce a quick appreciation of the overall impact of a nuclear detonation on a target area. It is divided into three sections. A completed sample showing the use of each section in turn and the resultant map display is described following.

Detonation Data Section -



PRELIMINARY CASUALTY AND DAMAGE ESTIMATION WORKSHEET

1. DETONATION DATA

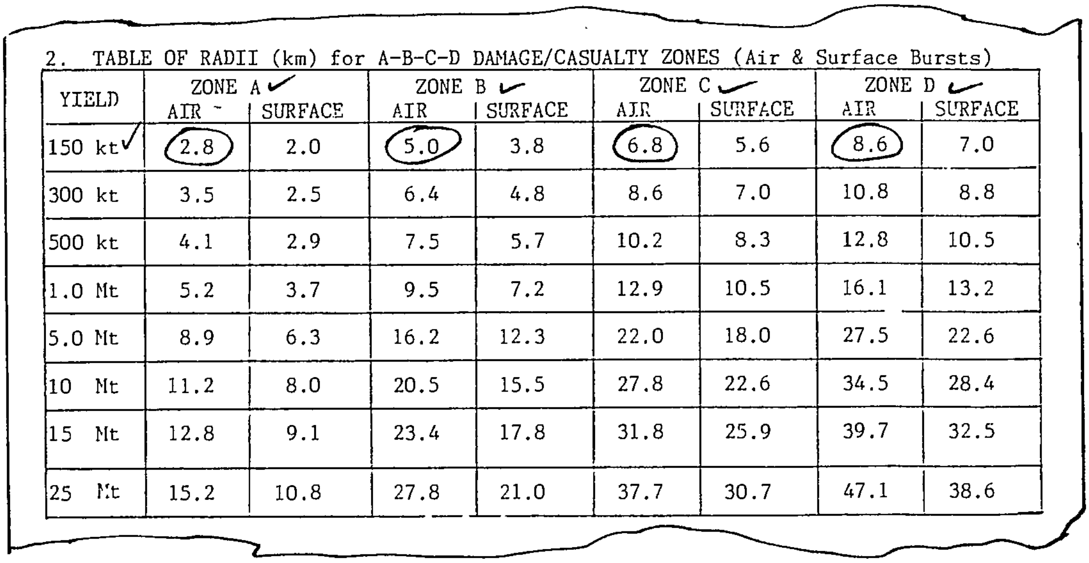
NUDET SERIAL NUMBER ONT 2 DATE-TIME OF BURST 131325 Z
GROUND ZERO LOCATION 4623 N (Latitude) 07924 W (Longitude) (UTM 205359)
PLACE NAME LAKE CITY AIRPORT PROV ONT
TYPE OF BURST AIR YIELD 150 KT (EST)
FALLOUT DATA (if applicable) N/A
EFFECTIVE DOWNWIND DIRECTION & SPEED ______
DOWNWIND DISTANCE ZONE I ______ km, ZONE II ______ km (2 x Zone I)
NUCLEAR CLOUD RADIUS ______

This section of the worksheet is used to record basic data. Most of the information on the occurrence of nuclear detonations will be received in the form of nudet reports via the CFWRS, although some pertinent items may also be gleaned from local observations. It is possible, too, that some of the essential information, such as the type of burst, yield, and even the exact location of ground zero, may not be available immediately. The damage assessor then will have to make prudent estimates on the type of attack that would likely be used on the target. Thoughtful appraisal can narrow the choices.

As a general guide, consider that the warhead's yield will be large enough, and the weapon delivered accurately enough, to destroy its target. It also is probable that an air burst would be the burst type of choice for greatest destruction for all but "hard" targets. Emergency operations personnel can give foresighted consideration to these factors during the pre-attack phase or sooner.

Fallout data items in the first section are applicable only to surface bursts. If the burst type is unknown, then the assessor may want to use a "worse-case" scenario by considering it an air burst for damage- and casualty-estimation purposes around ground zero and, at the same time, as a surface burst for downwind fallout purposes. This procedure is followed by the CFWRS to ensure that warning will always be given to the public of possible early fallout. Data on the effective downwind direction and speed, and the extent of fallout from Zone I, is available from Provincial Warning Centres and from CFWRS nudet reports. A detailed explanation of the data is given in Chapter VI under Fallout Prediction.

Table of Radii

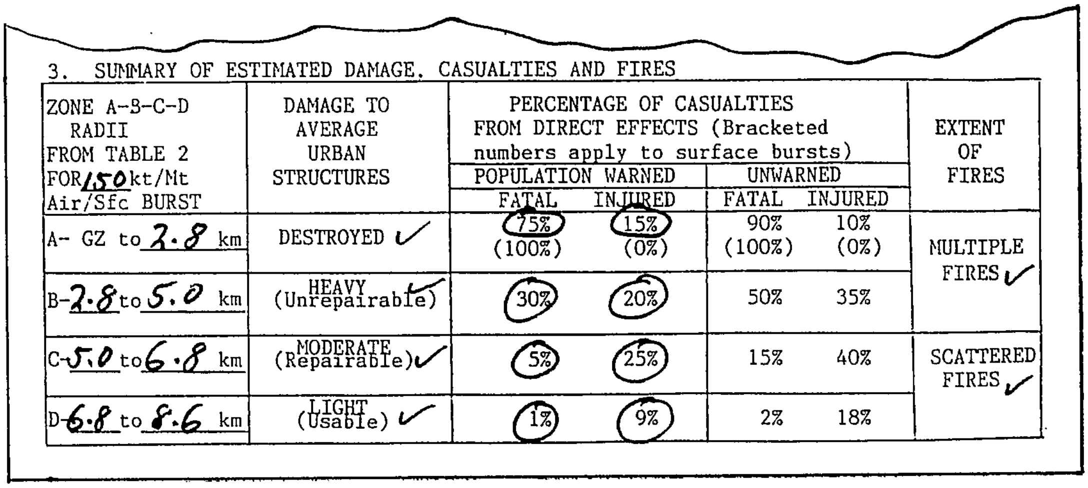


2. TABLE OF RADII (km) for A-B-C-D DAMAGE/CASUALTY ZONES (Air & Surface Bursts)

YIELD	ZONE A ✓		ZONE B ✓		ZONE C ✓		ZONE D ✓	
	AIR	SURFACE	AIR	SURFACE	AIR	SURFACE	AIR	SURFACE
150 kt ✓	2.8	2.0	5.0	3.8	6.8	5.6	8.6	7.0
300 kt	3.5	2.5	6.4	4.8	8.6	7.0	10.8	8.8
500 kt	4.1	2.9	7.5	5.7	10.2	8.3	12.8	10.5
1.0 Mt	5.2	3.7	9.5	7.2	12.9	10.5	16.1	13.2
5.0 Mt	8.9	6.3	16.2	12.3	22.0	18.0	27.5	22.6
10 Mt	11.2	8.0	20.5	15.5	27.8	22.6	34.5	28.4
15 Mt	12.8	9.1	23.4	17.8	31.8	25.9	39.7	32.5
25 Mt	15.2	10.8	27.8	21.0	37.7	30.7	47.1	38.6

Enter the table with the yield of the detonation and the type of burst to obtain the radii (circled), of the concentric zone rings around ground zero. The figures thus obtained are recorded in the summary table at the bottom of the worksheet.

Summary Section



3. SUMMARY OF ESTIMATED DAMAGE, CASUALTIES AND FIRES

ZONE A-B-C-D RADII FROM TABLE 2 FOR 150 kt/Mt Air/Sfc BURST	DAMAGE TO AVERAGE URBAN STRUCTURES	PERCENTAGE OF CASUALTIES FROM DIRECT EFFECTS (Bracketed numbers apply to surface bursts)				EXTENT OF FIRES
		POPULATION WARNED		UNWARNED		
		FATAL	INJURED	FATAL	INJURED	
A- GZ to 2.8 km	DESTROYED ✓	[✓ 75%] (100%)	[✓ 15%] (0%)	90% (100%)	10% (0%)	MULTIPLE FIRES ✓
B-2.8 to 5.0 km	HEAVY (Unrepairable) ✓	[✓ 30%]	[✓ 20%]	50%	35%	
C-5.0 to 6.8 km	MODERATE (Repairable) ✓	[✓ 5%]	[✓ 25%]	15%	40%	SCATTERED FIRES ✓
D-6.8 to 8.6 km	LIGHT (Usable) ✓	[✓ 1%]	[✓ 9%]	2%	18%	

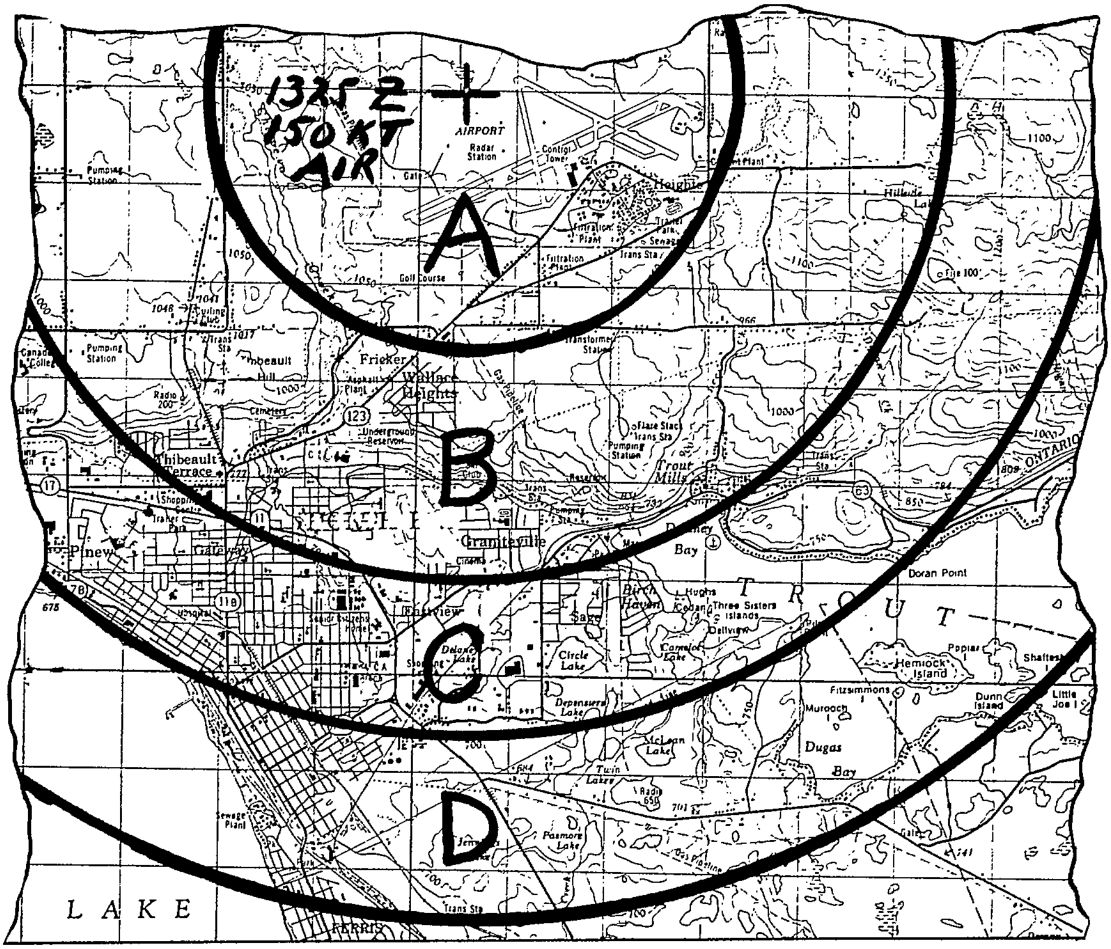
The radii figures obtained from the Table of Radii section are recorded in the first column of the summary section along with the yield and type of burst from which they derive. Next, the applicable casualty percentage figures should be circled, or otherwise highlighted, to indicate the casualty percentages which apply in each zone for either the warned or unwarned populace. This will be dependent upon whether the attack sirens, warning broadcasts, etc., were activated before the attack.

The worksheet is now complete and by reading the summary data from left to right the summary section presents, in turn, the size of the damage zones, type of damage in each, the applicable percentage of casualties and, on the far right, the extent of fires that can be expected in the zones. The estimated numbers of casualties can also be recorded -- superimposed over the percentage figures -- if they are available from a population distribution map. Preparation and use of these maps is discussed in Chapter V under Detailed Casualty Estimation.

Target Area Display Maps - When the worksheet is complete the information can be plotted on a large-scale map of the target area. Appropriate map scales for displaying damage assessment data are in the range 1:25 000 to 1:50 000. The first step is to locate and mark the ground zero position on the map. The location can be indicated with a "+" or any other such device. Alongside the ground zero symbol the following reference information should be plotted:

- date-time of burst (in Zulu time) and, if desired, the nudet report serial number;
- type of burst (<u>A</u>ir, <u>S</u>urface, <u>U</u>nknown); and
- the estimated yield.

Reference information can be plotted directly onto the map, however, to preserve the map and amend plotted data, it is advisable to use a method that does not indelibly mark the map if possible. Clear plastic map covers, erasable markers and transparent overlays are some of the methods used successfully in training exercises.



With the ground zero position as centre, Zone A-B-C-D damage rings are shown next and labelled on the target map. Transparent plastic damage ring templates may be used which can be produced in map scale beforehand for the radii of the yields given on the worksheet. Because templates tend to become unwieldly in size and number, it may be preferable to use a form of compass arm which pivots around ground zero to draw the damage rings directly onto a protected map or overlay.

With only the ground zero information plotted and the concentric zone rings showing the A-B-C-D damage divisions radiating out from it, the target area map clearly depicts an early appreciation of the situation. The estimated percentage (or numbers) of casualties in each zone might be plotted as well, but the imprecise nature of casualty estimates makes displaying them on situation maps unwarranted except, perhaps, for a special purpose such as for a casualty briefing. Supplemental detail may be added on the likely damage sustained by particular complexes, structures, bridges, resources, etc. Damage estimates of this nature are referred to as "detailed" and are the subject of the next chapter.

CHAPTER IV

DETAILED DAMAGE ESTIMATION

The purpose of this chapter is to describe detailed damage estimation procedures and present nuclear explosion damage-distance vulnerability data for different types of buildings, bridges, assorted equipments and resources.

Description

Detailed damage estimation is not necessarily the next step to the preliminary estimation procedure. The main difference between preliminary and detailed damage estimation is in the perception of the target. Whereas the preliminary procedure perceives the target as a whole area and assumes it is composed of a homogeneous mix of average urban residential buildings, the detailed approach to damage estimation perceives a target of individual structures and resources affected by the detonation and deals with damage to specific features. Different types of structures and objects will respond differently to the blast effect and, consequently, the amount of damage sustained by each at the same distance from ground zero will vary. Where construction information is available on significant buildings, resource complexes, crucial works, etc., their particular susceptibility to damage (physical vulnerability) can be taken into account before considering rescue and recovery operations. Target vulnerability information is presented in two annexes to this manual; Annex B -- Damage Criteria, and Annex C -- Physical Vulnerability Tables.

Annex B Damage Criteria Considerations

Structural Types - Annex B contains detailed descriptions of a number of structures, equipment and materials for which damage-distance tables have been prepared. The various types of features covered in the annex are presented under sub-headings in the following order:

- buildings
- shallow buried or earth covered structures
- bridges

- land transportation equipment
- parked aircraft
- ships
- communications and power lines
- forests
- selected urban elongated (line) features
- selected structural materials
- petroleum and oil storage tanks, and
- moderately deep underground structures.

An important step in emergency planning is to pre-identify key structures and vital points for which damage estimations may be required. Resource managers at each emergency government level should compile and maintain a listed inventory of significant structures and essential point resources that come within their spheres of responsibility. Inventories should indicate the map location co-ordinates for each feature and the type of structure or resource it **most closely resembles** described in Annex B. Pre-plotting vital points information on situation maps may also be desirable but a readily available list, electronic or otherwise, is more practical and probably easier to maintain if there are many periodic changes, additions and deletions needed to keep it current.

Classification of Damage - Damage to individual structures and objects is generally classified into three categories for detailed damage estimation purposes; severe, moderate, and light. For most of the structural types listed in Annex B, the specific nature of the damage caused in each category is described. These detailed damage descriptions will apply to the damage radii obtained from corresponding damage-distance tables in Annex C. Generally, the following broad definitions apply:

1) **Severe Damage** - A degree of damage that precludes further use of the structure or object for its intended purpose without essentially complete reconstruction. For a structure or building, collapse generally is implied.

2) **Moderate Damage** - A degree of damage to principal members that precludes effective use of the structure or object for its intended purpose unless major repairs are made.

3) **Light Damage** - A degree of damage to buildings resulting in broken windows, slight damage to roofing and siding, blowing down of interior partitions, and slight cracking of curtain walls in buildings. Minor repairs are sufficient to permit use of the structure or object for its intended purpose.

The similarity of the above damage classifications to the A-B-C-D zones of damage used for preliminary damage estimations is apparent. Indeed, the use of "types" A, B, C and D damage to structures was the predecessor of the current use of severe, moderate and light classifications in some civil defence publications. It was felt that the artificial distinction between degrees of damage for type A (destroyed) and type B (heavy) was not necessary since both are unrepairable. They were combined and now approximately equate to the "severe" classification. Former types C and D damage equate more or less to the moderate and light classifications, respectively. In Canada, the Zone A-B-C-D system has been retained for preliminary estimates because of the convenience of having a technique for estimating casualties, area of damage and the extent of fires in the target area combined into essentially one procedure.

Annex C Physical Vulnerability Tables

Yields - Annex C provides a summary of relevant nuclear detonation data for a selection of eight strategic-size weapon yields; 150 kt, 300 kt, 500 kt, 1 Mt, 5 Mt, 10 Mt, 15 Mt and 25 Mt. As alluded to earlier, because of the great number of warheads available and the improved accuracy of their delivery systems, most of the world's arsenal of strategic (intercontinental) warheads now have yields of 1 Mt or less so these are the yields that should be of greatest interest to emergency planners in Canada. A small inventory of the very large Mt-yield warheads still exists, however, and the warheads could still be employed in some scenarios.

Information is given in the tables for air and surface bursts and to facilitate use and easy comparison of the differences, the parameters for both are presented together in the form "air burst data/surface burst data." The air burst figures always precede those of the comparable surface burst whenever a "/" character separates two distance radii figures.

Content - The physical vulnerability information in Annex C is presented for each yield in turn under the following headings:

1) **Height of Burst for a Typical Air Burst** - Lower and upper altitude figures are given. Bursts between these levels are considered to be "low bursts" in military parlance. The lower figure has most significance because it is the minimum height of burst for negligible early fallout for that yield.

2) **Nuclear Cloud Dimensions** - Cloud radius, cloud top height and cloud bottom height are given for the stabilized cloud which is achieved about 10 minutes after detonation. The cloud radius figure is used in the fallout prediction procedure discussed in Chapter V.

3) **Distances at Which Flashburns Could Occur to Bare Skin** - Approximate radii for three degrees of skin burn severity are given. Assumptions are that exposure is to medium skin on a relatively clear day for the full duration of the yield's thermal pulse. First-degree burns are characterized by redness of the skin, like a mild sunburn; second-degree burns entail blistering of the skin; and third-degree burns involve charring of skin and under-tissues. Confidence in the ranges given falls off at distances over 12 km due to atmospheric scatter of thermal energy. Burn radii greater than 12 km, therefore, incline toward exaggeration and should be considered "worst case."

4) **Duration of the Thermal Pulse** - The duration given is the number of seconds by which time approximately 80 percent of the heat will have been emitted. This time is included to indicate the possible success of avoiding a portion of the thermal emissions from the fireball by taking immediate cover if exposed.

5) **Surface Burst Crater Dimensions** - Apparent crater radii, crater depth, height of the lip and radius of the ejecta (crater debris) are given for a contact surface burst (zero height/depth of burst) in dry soil or dry soft rock. For comparable dimensions in wet soil or wet soft rock, multiply the dry soil dimensions by 1.34; for crater dimensions in dry hard rock, multiply the dry soil dimensions by 0.8; and for wet hard rock, by 0.95.

6) **Sample Peak Overpressure Radii and Associated Blast Wave Wind Speeds** - Air burst/surface burst ranges of maximum peak overpressure are given in increments from 10 kPa to 500 kPa. The wind speed associated with each overpressure value is the same for all yields because wind speed is a direct function of the overpressure.

7) **Damage-distance Tables** - This is an extensive section for each yield which furnishes air burst/surface burst radii of blast damage for the same types of structures that are described and serial numbered (1 through 56) in Annex B - Damage Criteria. Structural types are listed in the same order.

Height of Burst Considerations - Often when nuclear effects parameters differ somewhat from one publication to another, and even within the same publication, the variance is because different heights of burst assumptions have been used. This applies to surface burst data, too, as even they have optimum heights (and depths) of burst that are still within the range of what is considered a surface burst. For civil damage estimation purposes these differences usually are only of academic interest.

One height of burst assumption used in calculations for the Damage-distance Tables in Annex C warrants explanation because the resulting differences in damage radii are significant. Nearly all measurements given in the tables are for detonations at "optimum height of burst" to produce greatest effect on the specific structure under consideration. However, because of a characteristic of the blast wave Mach effect, an exception was made in calculating the radii of light damage from air burst (about the range of 10 kPa peak overpressure). In this case, a more "typical" height of burst was assumed to avoid unrealistic exaggeration of light damage radii.

Sources - The basic source for computation of data given is the third edition (1977) of The Effects of Nuclear Weapons. Some credible information from earlier printings was retained as well. The Lovelace Nuclear Bomb Effects Computer (revised 1977) was also very useful to determine some of the parameters and to substantiate and extend results derived from scaling laws and the various graphs and nomograms found in the various effects of nuclear weapons publications.

Accuracy - The accuracy of data in the vulnerability tables is in the order of +/- 20 to 30 percent for average conditions. Greatest divergence will occur with very large yields and at the more extreme ranges.

CHAPTER V

DETAILED CASUALTY ESTIMATION

The purpose of this chapter is to discuss the availability and use of geostatistical population count data for casualty estimation purposes.

General

Estimates of the numbers of survivors and casualties are essential for immediate post-attack operations and recovery planning purposes. They are used as a basis to develop early estimates of requirements for food, water, housing, fuel and other essential needs of the surviving population following a nuclear detonation.

A-B-C-D Casualty Zones - The method for determining the **percentage** of direct effect casualties from A-B-C-D casualty zones is described in Chapter III, Preliminary Casualty and Damage Estimations. When the A-B-C-D casualty zones are depicted on a map which also shows how the resident population is distributed, then a reasonable estimate of the **number** of fatalities and surviving injured can be made by applying the percentage figures to the population counts within each casualty zone.

Statistics Canada Demographic Data

Provincial and local government offices are sometimes good sources of information for casualty estimation purposes, but the Statistics Canada census of population and housing is the basic source of population distribution data. As the national statistical agency, Statistics Canada produces a wealth of demographic information which is compiled and updated with each census. Besides population count data, Statistics Canada compiles dwelling counts, farm counts, labour force counts and other vital statistics which are available to emergency planners. This chapter is concerned primarily with population counts, but the dwelling counts and other data are produced for the same geographical patterns as those used to prepare population maps from which casualty numbers can be estimated.

Terminology Defining Statistical Areas - Statistics Canada's data are released in numerous formats in a wide range of reference publications which are available in most libraries. The publications can also be purchased through Statistics Canada Regional Reference Centres discussed later. Population data are presented in a number of "areal systems," defined as patterns of areas identified for statistical purposes. Most use the existing structure of local government as indicated by county boundaries, city limits, town lines, district borders, etc. Geographical divisions in this scale are well suited for nuclear attack casualty estimation purposes. To assist planners in dealing with Statistics Canada offices and their published materials, the following descriptions will give some familiarity with areal designations that will be encountered when assembling demographics for an area of interest:

1) **Census Subdivisions (CSD)** - CSDs are spatial divisions encompassing the first tier of local elected governments, e.g. city, town, village, borough, rural municipality.

2) **Census Divisions CD)** - CDs aggregate from CSDs. In Nova Scotia, Prince Edward Island, New Brunswick, Quebec, Ontario and British Columbia there are areas encompassing the second tier of municipal government, usually called a "county" or its equivalent (regional municipality, territorial district, etc.). In British Columbia they are called regional districts. In Newfoundland, Manitoba, Saskatchewan and Alberta geostatistical area equivalents have been created which are numbered. They are named in all other provinces.

3) **Census Metropolitan Areas (CMA)** - CMAs are continuous built-up areas having an urbanized core, of 100 000 or more population. They comprise one or more municipalities completely or partly inside the urbanized core and are usually known by the name of their largest city. As of the 1986 census, 25 CMAs have been created by Statistics Canada for which consolidated data are produced.

4) **Census Agglomerations (CA)** - CAs are geo-statistical areas comprising at least two adjacent municipal entities which have an urbanized core with the largest city having a population of less than 100 000. As of the 1986 census, 114 CAs have been created for which consolidated data are available.

5) **Census Tract (CT)** - CTs are permanent, small geostatistical areas of around 5 000 population created by Statistics Canada for large urban communities. Determining population distribution by the use of CT divisions is close to the ideal detail required for casualty estimation purposes. All census metropolitan areas, all census agglomerations with a central city having a population of 50 000 or more, and all other cities of at least 50 000 population are eligible for the CT program.

6) **Provincial Census Tract (PCT)** - PCTs extend the census tract concept beyond the larger urban areas to cover the entire country. The desired population size in a PCT is also targeted around 5 000, but PCTs can include several whole municipalities in the more rural areas.

7) **Enumeration Areas (EA)** - The EA is the basic building block of the census-taking operation and its size generally can be covered by one enumerator. EAs are probably in too small a scale to use in urban areas (population 500 to 1 000), however, EA divisions in rural areas could be useful because they consist of areas up to 100 farms.

Population count data can also be obtained for the areas of federal and provincial electoral districts, and even by postal code areas. The geographic divisions for these compilations are not as detailed as those made in the scale of census tracts and census subdivisions, but they can be used to make fast appreciations of the number of people at hazard in large predicted areas of downwind fallout.

Areal Maps - Maps are produced and available for all areal systems used by Statistics Canada. Sets of maps are published in fold-out book form which diagramatically displays census subdivisions, census divisions, census metropolitan areas and census agglomerations. Also, census tract diagrams are included in the relevant data publications in which population counts are found for each tract. As an example, Figure 9 depicts a census map for Halifax which shows the boundaries and tract numbers of each of the census tracts in the Halifax CMA. Population counts, dwelling counts, etc., are published for each tract. In the 1981 Census of Canada, population distribution ranged from as low as 1 500 in tract 009 in the central harbour area to as high as 8 000 in a residential tract (025.02). It can be seen, therefore, that although tract sizes aim for a populace of 5 000, the actual published figures must be consulted because of wide variations from that number.

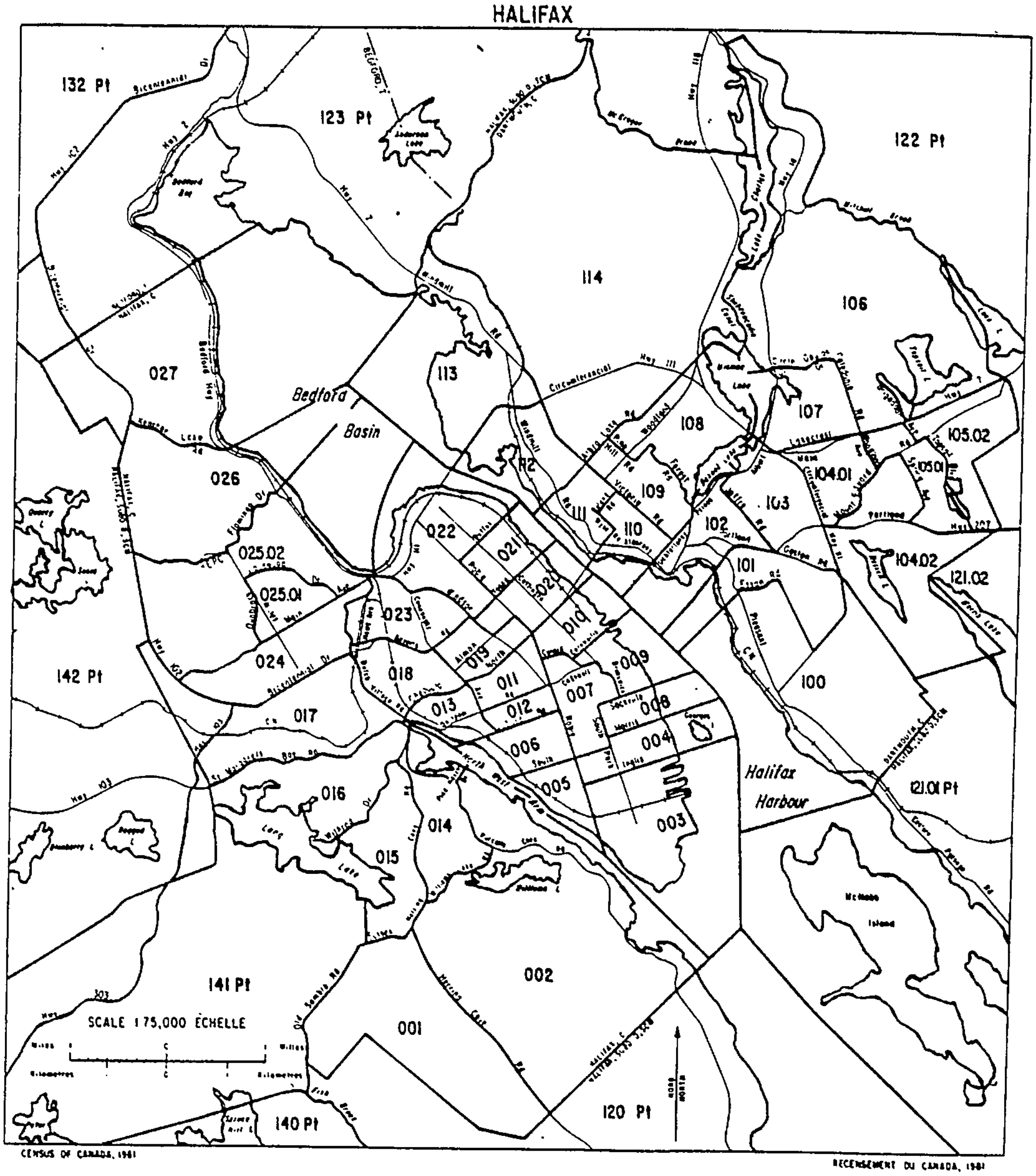


Figure 9 Example Statistics Canada Tract Map for a Census Metropolitan Area (Halifax, N.S.)

Statistics Canada Advisory Services - Ten Regional Reference Centres are located across Canada in which complete collections of current Statistics Canada publications and current, yet-to-be published material are maintained. The centres are staffed by knowledgeable inquiries officers who give assistance in locating and providing the most appropriate data and publications for a particular area of interest. Information on computer retrieval of demographic data is available also. For easiest initial contact, the telephone number of the nearest Statistics Canada Regional Reference Centre is found in all local telephone directories under the Government of Canada listings. Mail requests for information will also be honoured by the Regional Reference Centres and by the Ottawa office at:

Central Inquiries
Statistics Canada
R.H. Coats Building
Ottawa, Ontario
K1A 0T6

Library Sources - Public libraries are a convenient local source of census data. More than 300 local public libraries in Canada receive, free of charge, selected Statistics Canada census publications that cover their geographic area of interest. In addition, there are 52 full depository libraries holding all Statistics Canada publications. These are mainly university libraries, but the public libraries in several major municipalities are also full depository libraries. All legislative libraries hold a full inventory of Statistics Canada publications too, however, these libraries may not be open to the general public. Regional Reference Centres will provide advice on the location of library sources of Statistics Canada demographic publications nearest to your area.

Techniques for Presenting Population Data

Population Distribution Maps - Two techniques have been developed for aggregating population and showing the aggregates on maps or map overlays. The first is relatively simple to accomplsh once the necessary population data is obtained; the second technique is more complex but not necessarily better. They are:

1) **Unequal Value Dot Maps** - This technique employs dots, symbols, or the actual

population numbers and is also referred to as a point location method. In this technique, each dot (or number) represents the actual number of people in the area. Figure 10 depicts an example of a population distribution map which uses this technique.

2) **Equal Value Dot Maps** - In this technique, each dot represents the same number of people. The number of dots in an area then depicts the actual number of people. Figure 11 shows the map results of this technique.

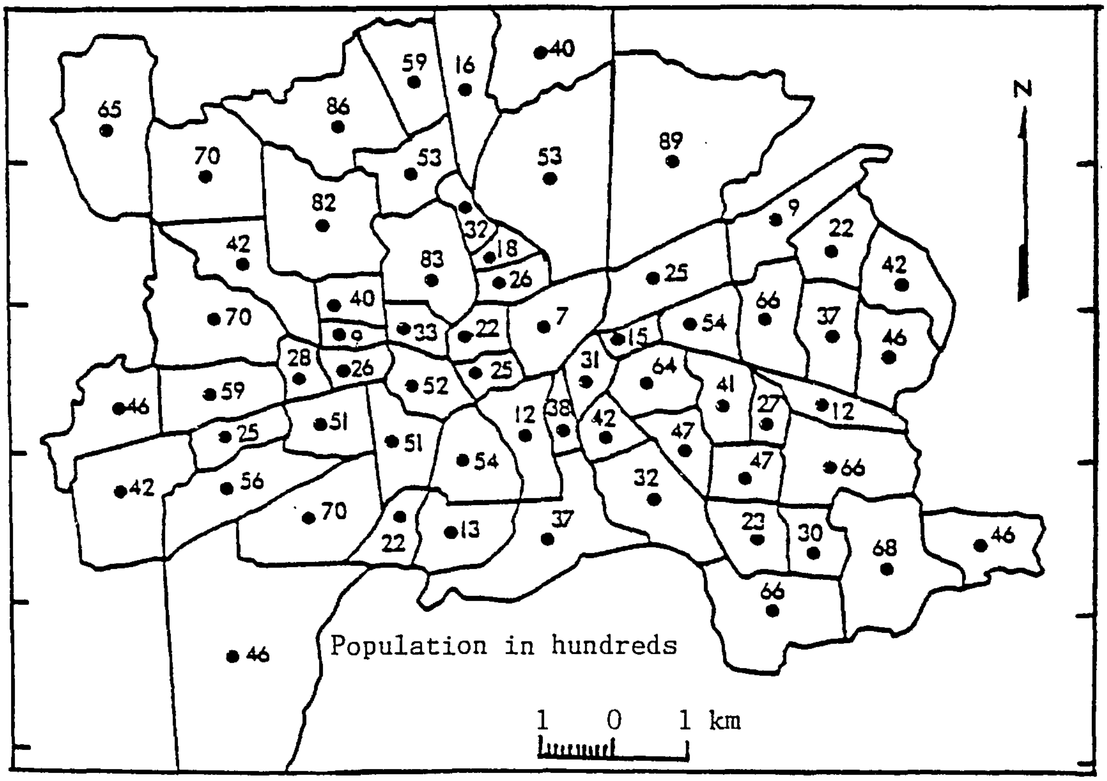


Figure 10 Example Unequal Value Dot Map (Distribution of residential population by Point Location Method.)

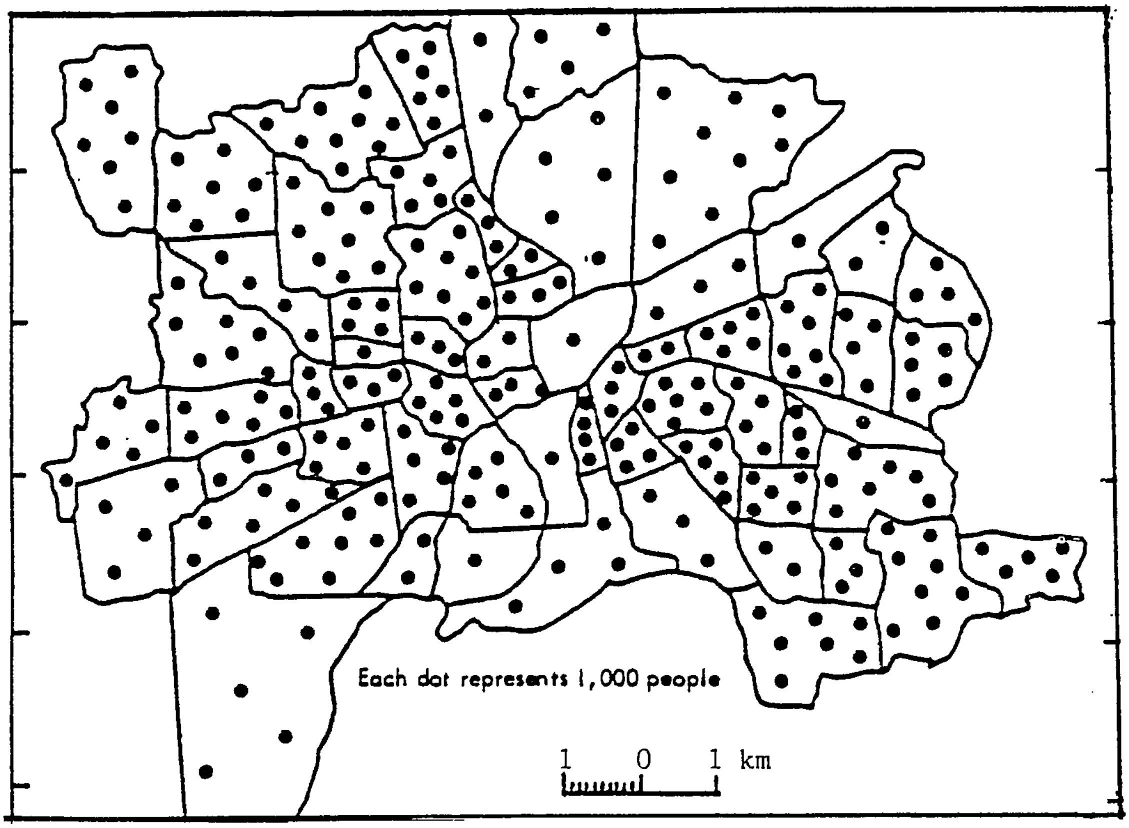


Figure 11 Example Equal Value Dot Map (Distribution of residential population. Dot value = 1000.)

Methods for Preparing and Using Population Distribution Maps

Point Location Method - This method employs the unequal dot technique and assumes that the entire population in the census tract, census subdivision or civil division is concentrated at a single point within its boundaries. It is especially well adapted for depicting the population distribution on Statistics Canada schematics or other maps showing many small geographical units. A problem that may be encountered in using the census maps is, however, that the map scales are quite varied. They range from large scales of 1:50 000 to smaller scales of 1:350 000. The example tract map shown as Figure 9 is in the scale of 1:75 000. To depict population data on maps for a large area, it may be necessary to collect information first on two or more census maps having different scales and then transfer it onto another map (or map overlay) to obtain the desired amount of area coverage in uniform scale.

At Municipal and Zone Emergency Government Headquarters levels, map scales of 1:25 000 and 1:50 000 are appropriate scales for casualty estimations. For Regional and Central Emergency Government Headquarters levels, scales up to 1:250 000 are still sufficiently detailed to make early gross estimates suited to the extensive areas monitored by higher headquarters. Of course, for smaller scale maps larger geostatistical population divisions are used, such as whole Census Divisions.

To plot population data on a map, the point (dot) location chosen within each sector to represent its concentrated population is selected by visual inspection. Indicate beside the dot its population value in hundreds (or thousands if the map is city-county-region scale). The position chosen for each of the dots is normally at the geographic centre of each division, however, if it is known that the population tends to concentrate more toward a certain area, the dots can be shifted off-centre. For more precision, two or more point locations can be selected in an area and the population total divided between them. This procedure is recommended when plotting on large/scale maps using large population divisions.

Calculating Casualty Numbers - Calculating estimated numbers of casualties from a completed point location map requires the following procedures:

1) Determine the ground zero location on the map. If the exact location of ground zero is not yet known, an assumption as to its most likely (or worst-case) position has to be made.

2) Draw the radii of the A-B-C-D casualty zones for the chosen yield around ground zero.

3) Total the populace in each zone by assigning the population value of each point location to the casualty zone in which it is located. Point locations that fall directly under a casualty zone radius line can be treated either as in the worst-case zone or, for more precision, split the population value between the two zones involved.

   It should be remembered also that census figures reflect a "night-time" distribution of the population. In the case of a "daytime" attack, additional refinement can be made by adding and subtracting approximations proportionately from zone to zone to account for population shifts from residential areas to core or industrial areas during working hours.

4) Multiply the A-B-C-D casualty zone totals by the appropriate casualty multipliers (percentages). The result is the estimated number of fatal and surviving injured persons for a warned/unwarned populace depending upon the casualty multipliers used. A warned population is one already in shelter posture, or one that has been informed of what immediate actions to take in event of an attack warning, with and the attack warning sounded by siren signal and/or via public broadcast by the Warning and Emergency Broadcasting Service.

The final figures on the estimated numbers of casualties can be conveniently recorded by superimposing them over the applicable percentages printed in Section 3 of the Preliminary Casualty and Damage Worksheet (Annex A).

Equal Value Dot Method - Preparing a population map employing equal value dots to represent population numbers scattered over an area is more time consuming, but the resulting depiction can be more objective than that of a point location map. Equal dot maps are best prepared as overlays to the basic map. Within each tract or subdivision, place dots, each representing the same number of people (500, 1,000, etc.) to indicate distribution of the population. Ideally, dots should be distributed to represent the true population distribution of an area but, to be practicable, they will normally be equally spaced within each division. If the dots merge so they cannot be counted, a smaller dot size should be used or dot value increased. Alternately, higher value symbols (triangles, squares, etc.) could be used conjointly to represent the more dense populations in core areas.

Calculating casualty estimates from an equal value dot map is accomplished in similar manner to the point location map method. A-B-C-D casualty zone radii are superimposed over the target area and the total number of persons in each zone is determined by counting the number of dots in the zones. Casualty percentage figures are then applied to the totals to obtain the estimated number of fatalities and surviving injured for each casualty zone.

Fallout Casualty Numbers

In case of a burst at or near the surface, there will be casualty-producing early fallout disbursed over very large areas many kilometres downwind from the detonation. The precise area that will be affected depends upon the weapon yield, the direction and speed of the winds from the nuclear cloud top down to the surface, downwind weather and a number of other factors. Because of the many variables involved, there is no method by which a valid estimate of the number of downwind radiation casualties can be made. Even after all fallout is down and the boundaries of the contaminated areas are known, the problem of estimating probable casualties is still formidable. Varying radiation intensities and decay rates, different degrees of protection afforded by shelters, and even a wide range of individual tolerances to the ionizing radiations emitted by fallout combine to make early estimates of the number of radiation sickness casualties very broad and sweeping approximations.

Estimating Numbers at Risk - What can be estimated with reasonable confidence is the total number of people within a broadly defined, cone-shaped, downwind area of hazard in which persons **could** be subjected to high intensity fallout. The same population-counting techniques described above can be used to determine the probable number of persons in the risk area. The method to define the cone-shaped area of hazard is given in detail in the next chapter. It will be seen that fallout hazard areas can extend several hundred kilometres downwind and contain huge numbers of people, many of whom may not actually experience any fallout. This reality very much limits the practical use of population estimates within the fallout hazard area.

Fallout Casualty Exercises - To script and conduct training exercises, and also to convey an appreciation of the nature of the fallout casualty estimation problem, Table 7 presents information on the probable condition of persons who actually experience a "medium risk" level of fallout. A medium risk level is defined as that amount of fallout which will produce a one-week unprotected radiation dose of 6 000 cGy. The table illustrates the consequences of being in shelters with Protection Factors from PF 5 through PF 500. It is important to note that some of the population in the fallout hazard area -- those closer to ground zero especially -- can be subjected to much higher unprotected doses than 6 000 cGy and many will experience lower levels of radiation or no radiation at all. The table conveys an appreciation of the nature and complexity of the fallout casualty estimation problem.

Table 7 can be used as a median for apportioning fallout casualties for training purposes. Assign a representative PF, or mix of PFs, to the total population in the area of fallout hazard. Casualties are then assumed for the entire population as stated in the table. It is emphasized that this procedure will not produce a valid estimate of the number of fallout radiation casualties for a "real world" situation.

Using Shelter Protection Factor	Potential In-shelter One-week Dose	Medical Care Needed	Able to Work	Probable Death Rate	Comments
PF 5	1200 cGy	Yes	No	100%	Deaths would occur in two weeks or less.
PF 10	600 cGy	Yes	No*	More than 50%	Deaths would occur in about one month.
PF 20	300 cGy	Yes	No*	Less than 50%	Deaths would occur in 30 to 60 days.
PF 30 PF 40 PF 60 PF 80	200 cGy 150 cGy 100 cGy 75 cGy	No	Yes	Less than 5%	Deaths would occur in 60 or more days.
PF 100 PF 200 PF 500	60 cGy 30 cGy 12 cGy	No	Yes	None	No symptoms.

(*Except during illness-free latent period.)

Table 7 Probable Condition of Survivors Subjected to a Medium Risk Level of Fallout. (A medium risk level is defined as 1-week unprotected radiation dose = 6000 cGy.)

CHAPTER VI

FALLOUT PREDICTION

Background

In Canada, the prime responsibility for fallout predictions and public fallout warnings is vested in the 10 Provincial Warning Centres (PWCs) located at Regional Emergency Government Headquarters sites throughout the country. The PWCs, together with the centrally located Federal Warning Centre, comprise the warning element of the Canadian Forces Warning and Reporting System (CFWRS). Briefly, their role is to provide the initial public warning of nuclear attack and to collect, collate and disseminate data on nuclear detonations affecting Canada. Because of their fallout warning function, the PWCs are the principal source of information needed to produce fallout prediction plots for display on operations centre situation maps.

The aim of this chapter is to describe the CFWRS fallout prediction method to enable civilian operations staffs in emergency government sites to prepare, present and interpret fallout predictions.

Zones of Hazard

Overview - Surface burst fallout predictions are produced by using predetermined effective winds to make a plot which shows areas where fallout could occur. A completed fallout plot delineates a cone-shaped area of hazard as shown in the example plot in Figure 12. The boundaries of the predicted fallout area are not dose rate contour lines, nor do they imply that all points within the enclosed areas will receive large quantities of fallout. The fallout cone is divided into two successive zones which are areas within which people could receive significant doses of fallout radiation. The zones of hazard are defined as:

1) Zone I is an area of immediate concern. It is a zone within which there will be areas where exposed, unprotected people may receive a dose of 150 cGy or greater (sickness-producing doses) in a relatively short period of time (less than four hours after fallout arrival). Major disruption to rescue operations and numerous radiation casualties could occur within this zone.

2) **Zone II** is an area of secondary hazard which extends downwind twice the distance of Zone I. It is a zone within which the total dose received by exposed, unprotected people is not expected to reach 150 cGy within a period of four hours after fallout arrival, but within which persons may receive a total dose of 50 cGy or more within the first 24 hours. Only a small percentage of the people in Zone II are likely to be subjected to heavy fallout.

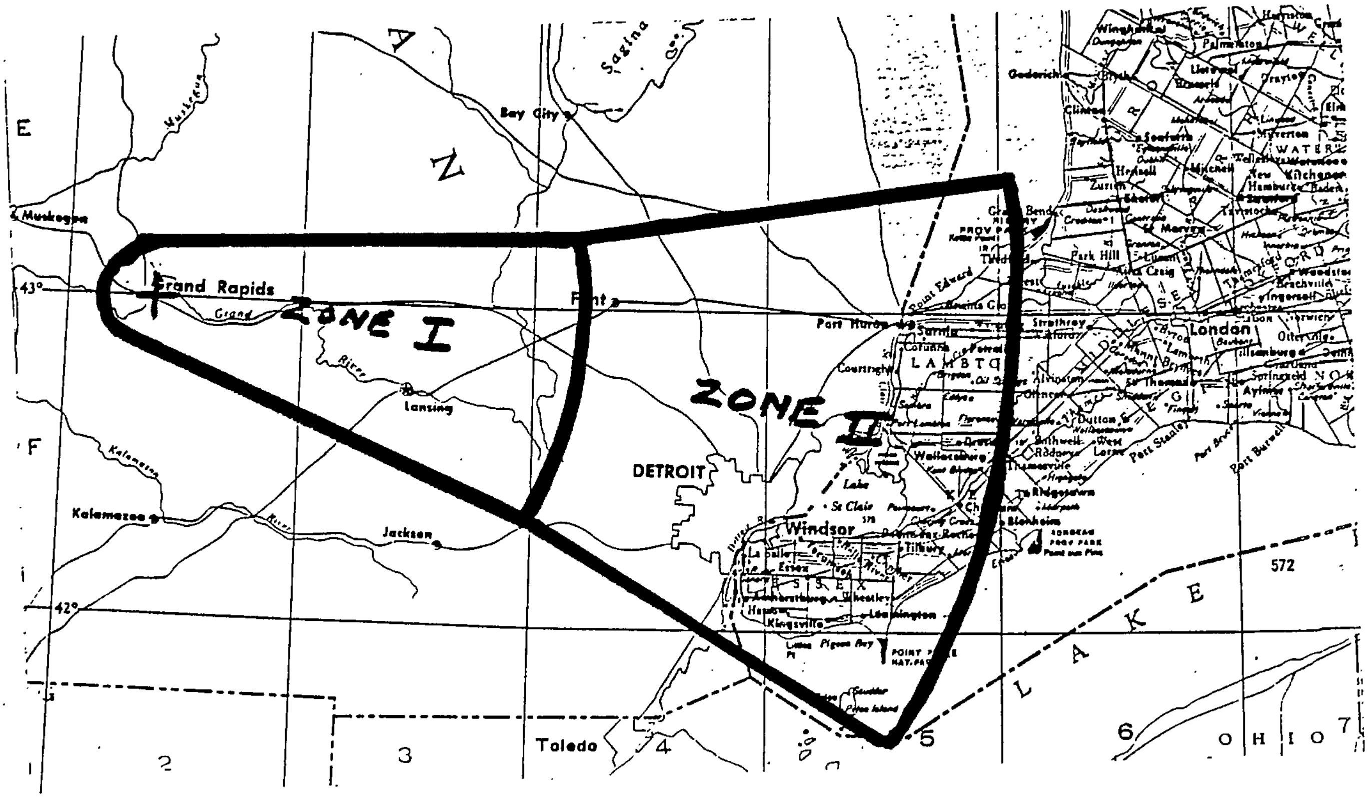


Figure 12 Example Fallout Predication Plot Showing the Two Zones of Hazard.

Reliability - The predicted fallout zones are larger than the actual area on the ground that will be covered by fallout. These zones represent areas of hazard, somewhere within which radioactive particles are predicted to fall. Because of the uncertainties of weather and nuclear burst input data, precise locations of fallout within the zones cannot be reliably predicted, but must be ascertained by monitoring and surveying after fallout has settled. The zones have been developed so there is a reasonably high assurance that expected fallout will not occur outside them. If it does it will be relatively light; exposed, unprotected people should not accumulate doses exceeding 50 cGy in the first 24 hours. The total lifetime dose outside the predicted zones should never reach 150 cGy.

Effective Winds

Description - In the CFWRS zone prediction method, fallout plots are produced by using a predetermined wind direction and speed which is attributed to each burst. This wind valuation, referred to as an **effective wind**, is a mean downwind vector accounting for all dynamic airflow forces affecting the fallout particles during their descent from the nuclear cloud. Effective winds for fallout predictions are always given as the direction from True North toward which the fallout will travel and the effective wind speed is usually given in knots (1 knot = 1.85 km/hr.). For example, an effective wind of "095/15" indicates that the fallout will travel in an easterly direction (toward 095°) at an overall speed of 15 knots. Since nuclear cloud sizes depend upon the yield of the detonation, each yield will have differing effective winds. Because effective winds derive from ever-shifting airflow patterns at all levels of the upper atmosphere, they also vary with time and by location.

Effective Downwind Fallout Messages - With all the variables inherent in determining effective winds, the early application of computer techniques to the problem was inevitable. Daily computer-generated effective winds for making fallout predictions are assembled and distributed by each of the 10 PWCs to any requesting agency. The method by which effective wind data is disseminated is best demonstrated by an example of a typical PWC Effective Downwind Fallout Message (EDM). Figure 13 shows a sample EDM from the PWC at Camp Borden. The message provides a 24-hour forecast of effective winds for four different weapon yields (more are available) for a number of locations (data points) throughout and adjacent to the Ontario region. The EDM format is:

Location A dddfff B dddfff C dddfff D dddfff

where: the **Location** to which the data applies is given by three-letter international identifiers; "ddd" is the effective downwind direction in degrees from True North toward which the fallout will travel; "fff" is the effective speed (force) in knots at which the fallout will travel. For example, interpreting the 1.0-Mt wind group for London, Ontario, in the first forecast period -- YXU C073022; the effective downwind direction is 073 degrees and the speed is 22 knots.

R 110545Z MAR 87
FM PWC BORDEN
TO (ONTARIO EDM SUBSCRIBERS)
BT
UNCLAS PWC 043
SIC JNG
SUBJ: EFFECTIVE DOWNWIND FALLOUT MESSAGE (EDM) FOR ONTARIO
24 HR FORECAST FOR A-300KT B-.5MT C-1.0MT AND D-5.0MT

FORECAST VALID AT 111200Z MAR 87 (EFFECTIVE FROM 110600Z TO 111800Z)

WMW	A099031	B099033	C097033	D093033
YVO	A090038	B090040	C089040	D087039
YXU	A070018	B072020	C073022	D073024
YYZ	A081019	B082021	C081023	D079025
YYB	A083030	B083032	C083033	D081033
YAM	A070032	B071033	C072034	D072034
YQT	A080033	B080035	C081035	D082035
YAG	A099033	B099035	C100035	D100035
YOW	A104025	B102027	C101028	D095028
YTR	A095020	B094022	C092023	D087025
YYU	A074042	B075044	C077044	D077043
WYW	A076039	B077041	C078042	D079041
YVV	A073024	B074026	C075027	D074028
YWG	A117042	B116945	C116045	D114044
IAG	A087017	B087019	C085021	D082023
RME	A117018	B113020	C109021	D099023
PBG	A120025	B117027	C114027	D106027

FORECAST VALID AT 120000Z MAR 87 (EFFECTIVE FROM 111800Z TO 120600Z)

WMW	A068036	B068038	C069039	D069038
YVO	A065043	B066045	C067045	D067043
YXU	A064026	B066028	C067029	D068030
YYZ	A064028	B065030	C067031	D067032
YYB	A067038	B068040	C069040	D069039
YAM	A083036	B083037	C084038	D084038
YQT	A101044	B101046	C102046	D102045
YAG	A112048	B112051	C112051	D111050
YOW	A068032	B069035	C069035	D069035
YTR	A063030	B064032	C065033	D065034
YYU	A072043	B073044	C074044	D074043
WYW	A097042	B097044	C097045	D097044
YVV	A068033	B069035	C070035	D070035
YWG	A119050	B118052	C117053	D114052
IAG	A062026	B064028	C065029	D066030
RME	A068022	B068024	C069026	D068028
PBG	A076026	B075028	C075030	D073031

Figure 13 Example of an Effective Downwind Fallout Message (EDM)

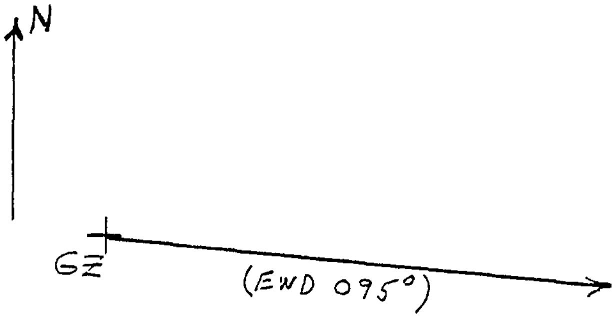
The locations used in EDMs should not necessarily be construed as likely targets. Rather, they are a selected spread of prominent places for which, should a nuclear detonation occur anywhere in the region, the effective wind from the nearest given data point to the burst can be used for fallout prediction. Each PWC issues EDMs for its province/region so that, no matter where the ground zero might occur, there are always predetermined effective wind data available to plot the downwind areas of hazard. EDMs are disseminated to users on a continuing daily basis or periodically for training purposes. Arrangements can be made between users and PWCs to provide appropriate EDMs by teletype or telephone, or in any manner, format and frequency agreed to by the issuing PWC.

Fallout Plotting Procedure

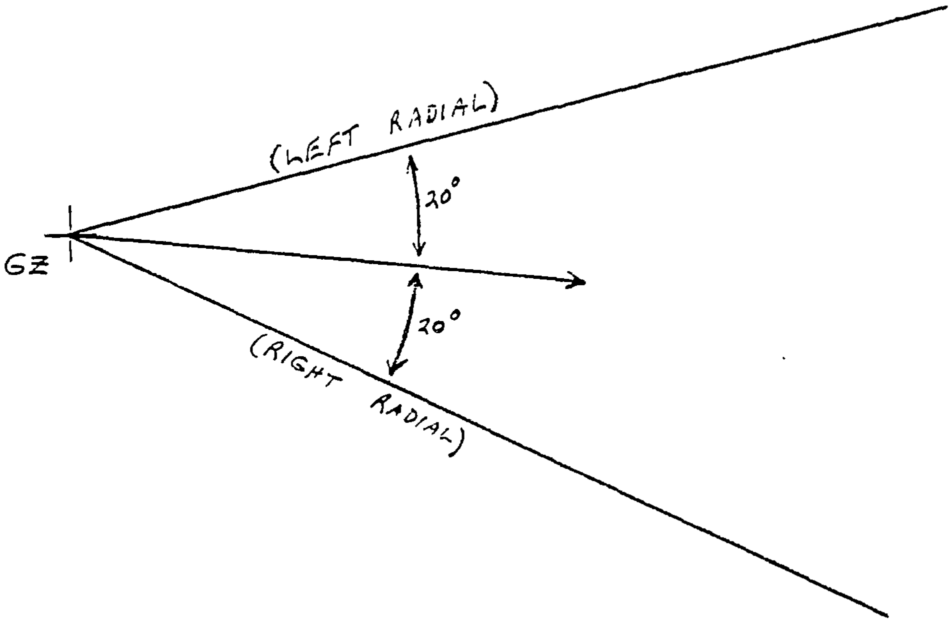
Fallout Burst Assumptions - Before commencing a fallout prediction plot, it is necessary to consider what yield to assume since it is unlikely that the yield of the weapon would be known. For fallout prediction purposes, the convention most followed is that, if the weapon yield is unknown, assume a yield of 1.0 Mt. This assumption has been reasonable to follow for public warning purposes because, if not "worse-case," it is sufficiently pessimistic to ensure widespread coverage of downwind fallout warnings. For the same reason, PWCs initially assume all bursts as having a 100 percent fission yield and all unknown types of burst as fallout-producing surface bursts until known otherwise. Nothwithstanding public warning considerations, wind data for a range of yield sizes are included in EDMs. The choice of yields is given for those cases when the approximate yield has been determined or, if not, when more precision is desired and prudent assumptions are made by relating the nature of the target to the probable yield necessary to destroy it.

Plotting Steps - There are several techniques and expedient short cuts that are often devised by plotters in preparing fallout prediction plots. For demonstration purposes, the following is the basic procedure to complete a fallout plot from EDM data (1-Mt yield with effective wind 095/15 is used in the example):

Step 1: Indicate the ground zero (GZ) location with a "+" on the map or, more practically, on a transparent map overlay. With a protractor and ruler, draw a line from GZ corresponding to the bearing of the effective wind direction (EWD).

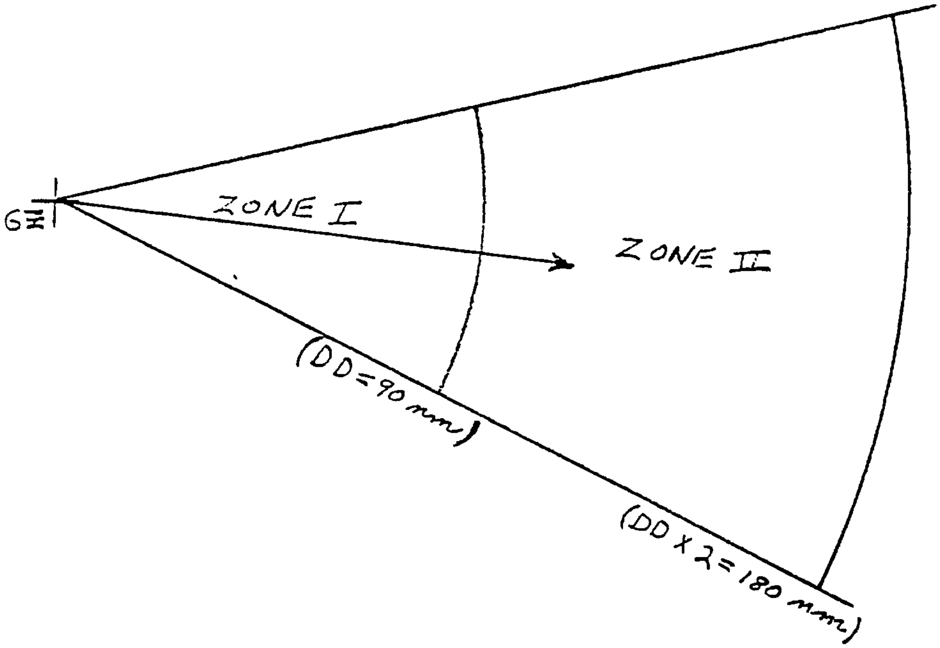


Step 2: Draw two radial lines from GZ; one 20 degrees to the left of the EWD line and the other 20 degrees to the right.



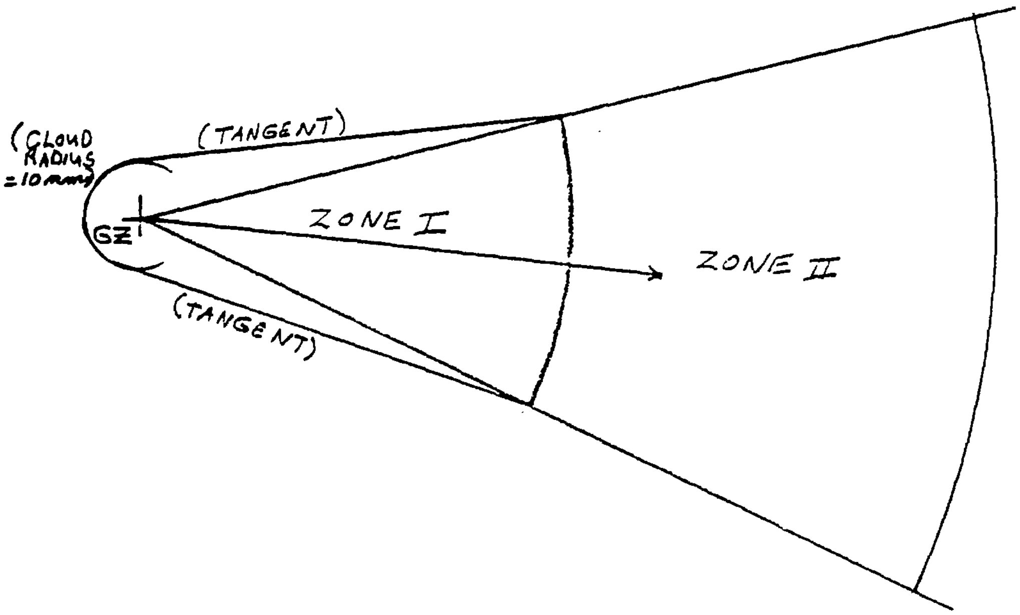
Step 3: Between the left and right radial lines, strike an arc from GZ with radius equal to the Zone I downwind distance (DD). This distance is dependent upon the effective downwind speed. Figure 14 presents a graph to determine the DD of Zone I at different effective speeds for various weapon yields.

Draw a second arc at twice the DD from GZ. This second arc represents the downwind distance of Zone II.



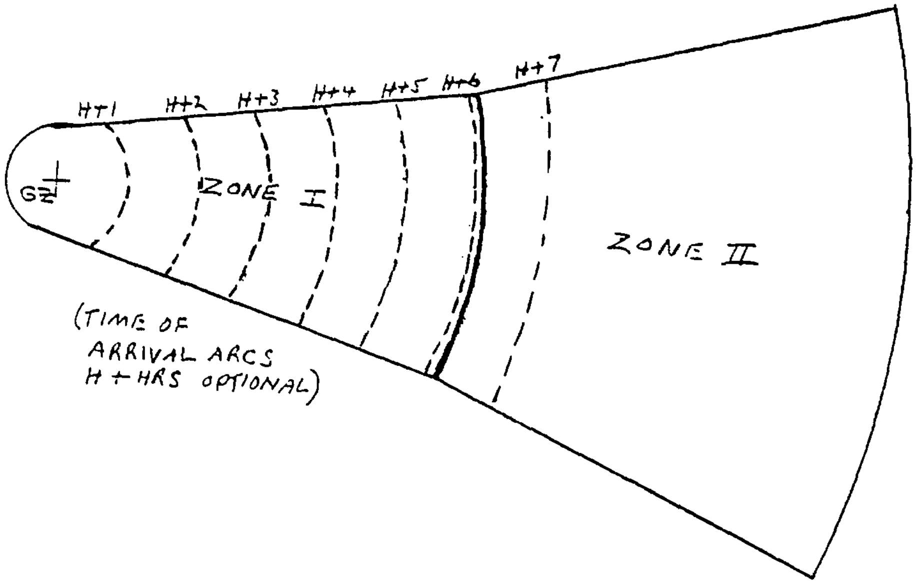
Step 4: Draw a semicircle on the upwind side of GZ with radius equivalent to that of the stabilized nuclear cloud. (Cloud dimensions are given in Physical Vulnerability Data which prefaces the damage-distance tables for each yield in Annex C.)

Draw two tangents from the GZ semicircle to the points on the left and right radials where they intersect the Zone I arc.



Step 5: Erase unnecessary plotting lines. (Retain the outside boundary lines and the Zone I and II arc lines.) The plot is now complete, however, arrival arcs can be added if desired. Using successive multiples of the effective wind speed as radius from GZ, strike concentric downwind arcs and label them as isochrones which indicate the expected downwind progression of the fallout with time.

Alternately, the likely time of arrival at a specific downwind location can be indicated; simply divide the distance from GZ by the effective wind speed to determine the number of hours to arrival.



(TIME OF ARRIVAL ARCS H + HRS OPTIONAL)

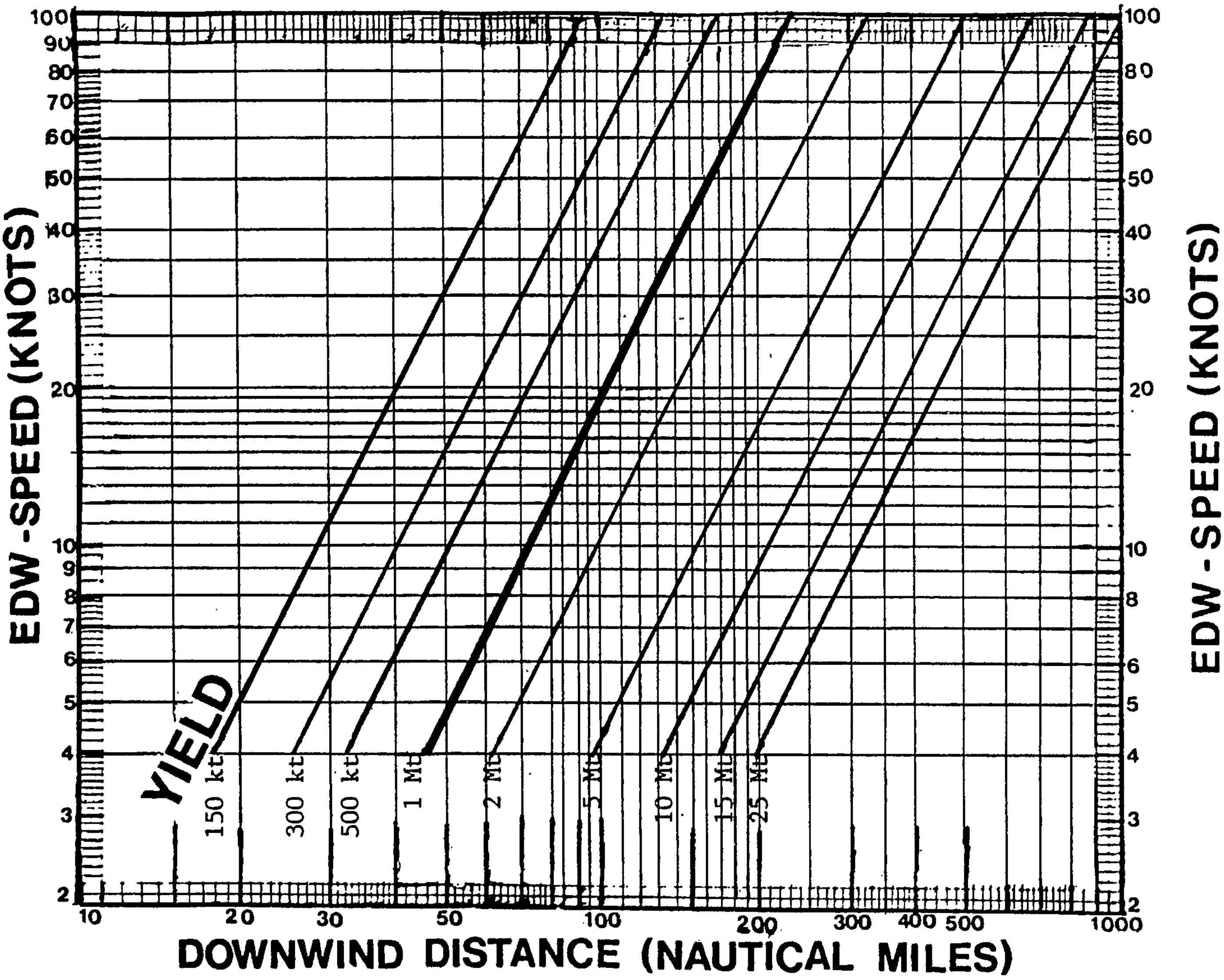


Figure 14 Zone I Downwind Distance (nm) versus Yield and Effective Downwind Speed (knots).

Notes: *Graph is for full fission yields. For 50/50 fission-fusion fraction reduce downwind distances by 20%.

*1 nautical mile = 1.85 km

Special Situations: There are two special cases when upper wind patterns are such that modifications to the normal fallout plot are necessary.

1) **Very Low Wind Speed** - When an effective downwind speed is less than 4 knots, the wind is deemed to be light and variable. In this situation, fallout may occur at any location around ground zero and, therefore, the predicted area of hazard is a complete circle around GZ. The circle radius for each yield is equivalent to the DD for a four-knot wind and, in these cases, the EDM will always give the radius to use in a three-figure DD group instead of a normal direction/speed group. For example, light and variable winds for a 1-Mt yield would be shown on the EDM as "048" which means that the Zone I hazard area completely surrounds GZ out to a radius of 48 nautical miles and Zone II is double that distance. Time-of-arrival arcs cannot be determined in this situation.

2) **Expanded Cone of Hazard** - In some instances, the upper air wind vectors are such that the angle between the left and right radial lines of the plot should be wider than the standard 40 degrees (20° on either side of the EWD bisector). When this situation occurs, the effective downwind direction/speed group will be followed by a bracketed figure to indicate the increased expansion angle. For example, an effective wind group "140008 (70)" indicates a direction/speed of 140 degrees/8 knots and the cone of hazard should be expanded to 70 degrees (35° on either side of the EWD bisector).

Effects of Precipitation - When airborne fallout particles fall into rain clouds, the particles tend to be scavenged out by the rain to create "hot-spots" of radiation where the rain reaches the surface. An equivalent reduction in fallout radiation could then be expected further downwind. Snowfall, on the other hand, generally will not have as great an effect because dry snowflakes descend at approximately the same rate as median-size fallout particles.

For yields greater than 100 kt, the significance of precipitation scavenging is relatively low compared to that of smaller yields because fallout from strategic-size detonations originates from nuclear clouds formed well above layered rain clouds. If the particles fall through a region of towering thunderstorms, however, a considerable portion of the fallout could be pulled down early in accompanying heavy rain showers.

Operations Centre Procedures

Displaying fallout prediction plots and subsequent intensity data on operations centre situation maps is necessary to give response directors and resource managers a clear picture of the fallout hazard areas. Procedures should be developed which suit the needs and facilities available at each level of emergency government. The following suggested modus operandi is given to develop standing operating procedures for the early stages of an attack.

Pre-attack Phase - Obtain EDMs from PWCs and maintain a map plot of current downwind direction arrows for each EDM data point (plotting Step 1). The effective wind speed should be indicated with each arrow. Use the winds for the 1-Mt yield unless, as mentioned earlier, the likelihood of different yields for different target areas has been prudently considered. EDMs will be issued by PWCs twice daily during this phase. Each issue, therefore, comprises a 24-hour forecast which is updated every 12 hours. A situation map, with up-to-date effective winds plotted on it, clearly shows the predicted fallout stream.

There is another technique that can be added in the pre-attack phase to demonstrate a quantitative assessment of fallout risk at specific locations. The technique is most appropriate at municipal and zone levels where officials will be particularly concerned with the likely risk of fallout that might reach their own communities. The procedure is to apply a completed fallout plot to the community of interest but apply it in reverse, i.e. orient the plot to the reciprocal of the downwind direction (or upwind) from the community. The area of hazard then represents an area within which detonations must occur before the community will be in jeopardy of receiving fallout. This risk assessment might also be visualized from the plotted wind arrows, but the reversed fallout plot shows greater dimension in that the relationship between any upwind GZs that might occur, the Zone I or II hazard area they may fall into, and time-of-arrival isochrones, all correspond directly to the fallout risk at the community of interest. The plot also will be ready for possible use in the attack period.

Attack Period - As nuclear detonation (nudet) reports are received, plot the ground zero locations and reference information (time of burst, type of burst, etc.) on the situation map. For surface and unknown type bursts, show the predicted areas of fallout hazard either directly on the map or, preferably, with transparent overlays. An excellent technique for displaying predicted fallout areas on situation maps is to use tinted acetate cutouts that are trimmed to the size and shape of the hazard areas. Orient them with the wind arrows and adhere them to the map with photo mount spray. As suggested above, fallout plot cutouts can even be prepared and used during the pre-attack phase, especially for those locations such as cross-border missile silo fields, considered high-risk surface burst targets.

Confirmation that reported bursts were actually fallout-producing surface bursts will be evidenced when radiological monitoring (radmon) reports are received from downwind locations. Representative intensities should be plotted on the situation map and, as the actual size and shape of the fallout area becomes apparent, the prediction display can be reshaped and adjusted. If increasing fallout radiation is not detected by downwind radiation monitors within the first few hours, the fallout plot can be removed -- the detonation was in all probability not a surface burst.

As more radmon reports are received from the contaminated areas, the prediction aspects of fallout distribution are superseded by hard data. As this occurs, separate iso-intensity maps should be prepared to better present the actual radiation picture.

CFWRS Warning and Reports

In any discussion about fallout prediction, mention must be made of basic attack data that can be obtained from the public fallout warning broadcast made through the Emergency Broadcast System (EBS). The basic content and format of CFWRS nudet and radmon reports should be familiar as well so that recipients can interpret and extract needed information. Some information might be acquired from local observers, but the prime source of timely and accurate data likely will be via EBS warning broadcasts and nuclear reports disseminated by the CFWRS. Both are described below.

Fallout Warning Broadcasts - A variety of prerecorded and formatted emergency broadcast messages have been prepared in the event of nuclear attack. They include survival instruction messages, a warning of imminent attack and messages to inform the public of the likelihood of fallout in their area. Fallout warning broadcasts could provide some operations centres with first knowledge of the hard data necessary to complete their own prediction plot. For example, following is the format of an EBS warning broadcast which is designed as a first alert to the public on the occurrence of a nuclear detonation which might result in fallout:

PRELIMINARY FALLOUT WARNING EMERGENCY BROADCAST - EB 4

> "Here is an emergency broadcast. I repeat, here is an emergency broadcast. A nuclear weapon has exploded in the __(location)__ area at __(time a.m./p.m.)__. Everyone within 20 kilometres of __(ground zero name)__ must take shelter against radioactive fallout which will start to fall on the area within 20 minutes. A much larger area will be affected eventually as the winds cause radioactive fallout to drift __(downwind direction)__ from __ground zero__ toward __(prominent place downwind)__ at about __(effective windspeed)__ kilometres per hour. The estimated times at which the radioactive fallout may affect the localities __(downwind direction)__ of __(ground zero)__ will be broadcast in a few minutes. The situation will be easier to follow if you have a road map."

The time of burst, ground zero location and even the effective wind direction and speed will be found in fallout warning broadcasts. The next broadcast will repeat this information and add the estimated arrival times of fallout at a selection of prominent downwind communities.

The format is as follows:

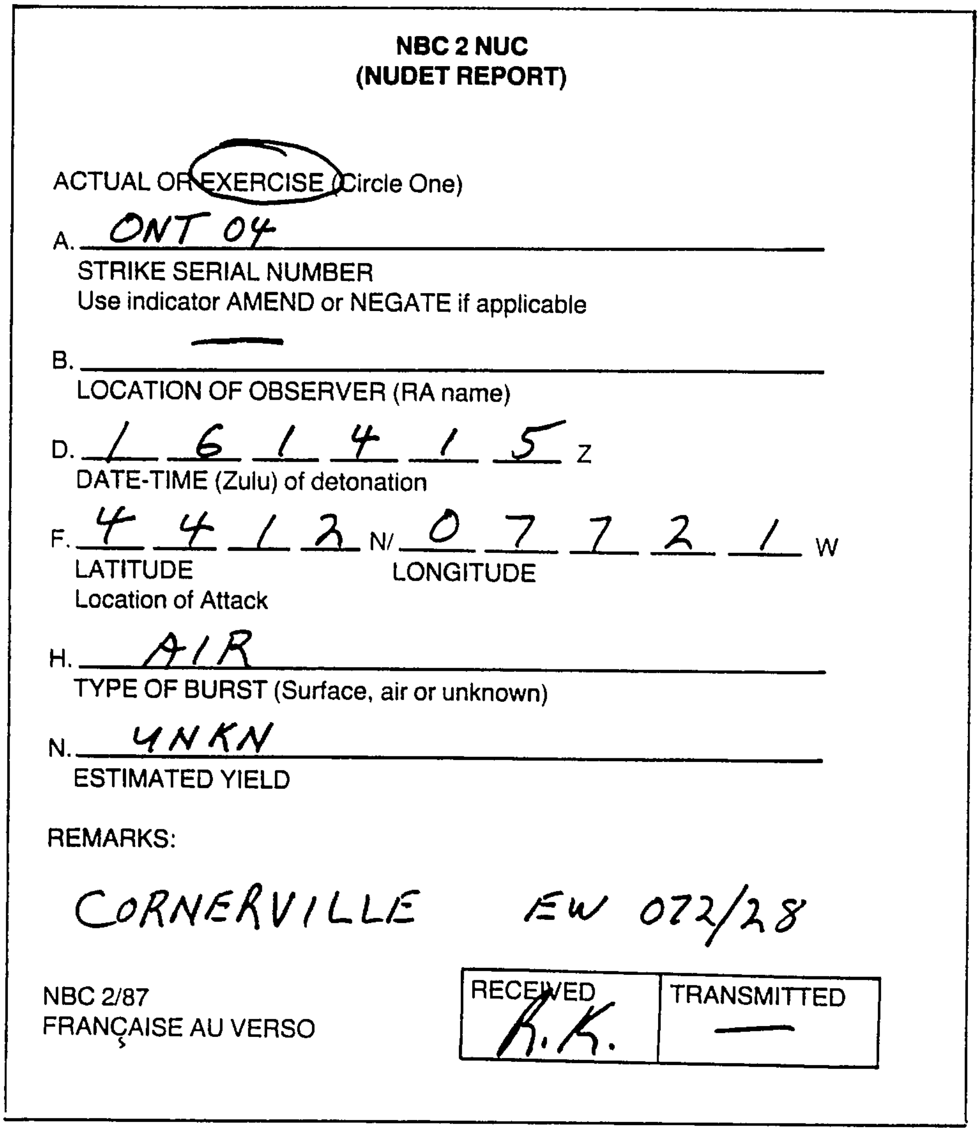
FALLOUT WARNING EMERGENCY BROADCAST - EB 5

> "Here is an emergency broadcast. I repeat, here is an emergency broadcast. As a result of a nuclear attack on the __(location)__ area, radioactive fallout may now be coming down on all localities within __(cloud radius)__ kilometres of __(ground zero name).__ A large area __(downwind direction__ of __(ground zero)__ will also be affected because radioactive fallout is drifting __(direction)__ at approximately __(effective wind speed)__ kilometres per hour. I will now give estimated __(state time zone)__ times that radioactive fallout could arrive at various localities within the area.
>
> __(localities)__ by __(time a.m./p.m.)__
>
> __(localities)__ by __(time a.m./p.m.)__
>
> (Listed localities will be prominent locations in Zone I.)

If you are within the area described, you must take shelter against fallout well before the time forecast for your locality. Forecasts for communities further to the ___(downwind direction)___ will be announced shortly. A change in weather con ditions may affect the direction and speed that the radioactive fallout will travel. Monitoring stations are tracing the actual path of fallout. Any changes in the area likely to be affected and the forecast times of arrival will be reported to you over this station. Radioactive fallout may also affect the area bounded by ___(rough boundary to limit of Zone II)___. Times of arrival for this area will be announced when the actual path of the radioactive fallout has been confirmed. No radioactive fallout should occur there before ___(time a.m./p.m.)___."

Nudet Reporting - The CFWRS is responsible as well for detecting and reporting on any nuclear detonations affecting Canada. Data is collected from a number of sources including visual sightings and surveillance radar and satellite detection systems. Nudet reports can be passed in various formats depending on the medium of transmission, but they all include the same common items of essential information and they are normally reported in the same sequence.

As an example, Figure 15 shows a completed nuclear detonation report on a CFWRS nudet report form. The report is in a standard NATO format which uses a system where each item of event information is identified by an assigned letter of the alphabet. For example, the "D" (or Delta) line will always give the event time, "H" (Hotel) always identifies type of burst data, and so on. These letter codes need not be memorized. Nudet reports will be in plain language, but the line-identifiers are convenient to use when reporting by the telephone and radio. These forms are available to all emergency headquarters and reporting activities from the serving PWC.



NBC 2 NUC
(NUDET REPORT)

ACTUAL OR [✓ EXERCISE] (Circle One)

A. ONT 04
STRIKE SERIAL NUMBER
Use indicator AMEND or NEGATE if applicable

B. —
LOCATION OF OBSERVER (RA name)

D. 1 6 1 4 1 5 Z
DATE-TIME (Zulu) of detonation

F. 4 4 1 2 N/ 0 7 7 2 1 W
LATITUDE LONGITUDE
Location of Attack

H. AIR
TYPE OF BURST (Surface, air or unknown)

N. UNKN
ESTIMATED YIELD

REMARKS:

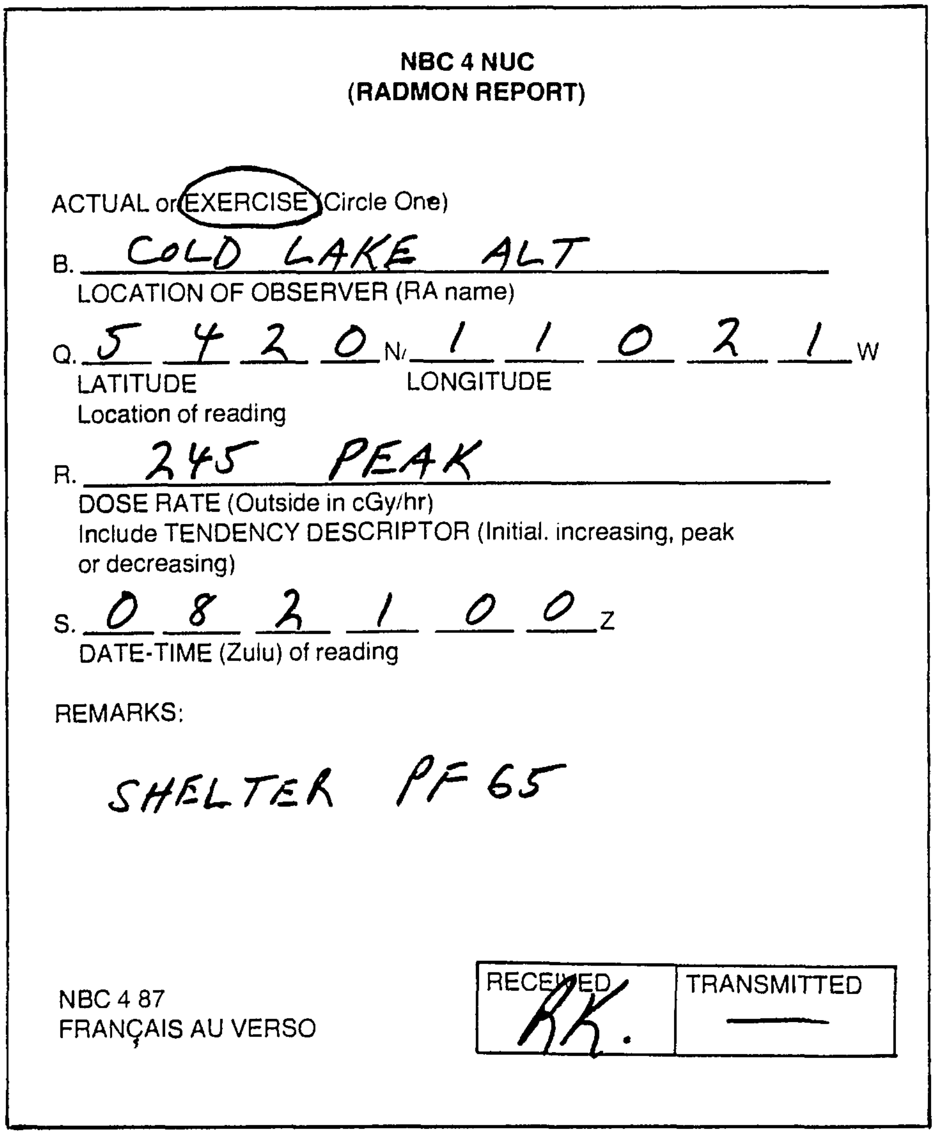
CORNERVILLE EW 072/28

NBC 2/87
FRANÇAISE AU VERSO

RECEIVED	TRANSMITTED
R.K.	—

Figure 15 Example of CFWRS Nudet Report Form.

The essential information to look for in radiation reports is the measured radiation intensity (outside dose rate), time of reading and the location. Radmon reports may also include trend data to indicate whether the radiation has just started, is increasing, has peaked or is decreasing in intensity. Remarks could include an indication of protection factors in the reporting post, accumulated doses, casualties, etc.



NBC 4 NUC
(RADMON REPORT)

ACTUAL or [✓ EXERCISE] (Circle One)

B. COLD LAKE ALT
LOCATION OF OBSERVER (RA name)

Q. 5 4 2 0 N/ 1 1 0 2 1 W
LATITUDE LONGITUDE
Location of reading

R. 245 PEAK
DOSE RATE (Outside in cGy/hr)
Include TENDENCY DESCRIPTOR (Initial. increasing, peak or decreasing)

S. 0 8 2 1 0 0 Z
DATE-TIME (Zulu) of reading

REMARKS:

SHELTER PF 65

NBC 4 87
FRANÇAIS AU VERSO

RECEIVED	TRANSMITTED
RK.	—

Figure 16 Example of CFWRS Radmon Report Form

The civilian Provincial/Municipal Radiological Defence (RADEF) System will use their own log forms and report formats. RADEF procedures are thoroughly detailed in the Emergency Preparedness Canada RADEF manual. The content of RADEF reports is fundamentally the same as that of CFWRS radmon reports. Indeed, when the civilian RADEF System is activated, the CFWRS will operate in concert with them to provide continuous reports on current radiation intensities in fallout contaminated areas.

CHAPTER VII

WORKING WITH MAPS

Introduction

An inevitable requirement of damage and casualty assessment and fallout prediction is the ability to work with maps. To find the positions of resources on maps, locate structures and topographical features, and even to pinpoint the ground zero locations of nuclear detonations, a basic acquaintance with cartographic devices and grid reference systems used on maps is needed. Most people already have some skill from using road maps and other map products. Readers who may become involved in national survival and recovery operations will find the following supplementary discussion on map usage helpful to make damage assessments and maintain situation map displays in operations centres.

The purpose of this chapter is to provide useful information on map scales and hints to use the common latitude-longitude graticule system. Also covered is the use of the Universal Transverse Mercator (UTM) grid reference system which is imprinted on many large-scale maps appropriate for damage assessment purposes. A brief word on where to obtain maps is also given.

Map Scales

A map is a proportional representation of the earth's surface and its pattern. This proportion is called "scale" and for maps it means the ratio of a distance on a map to the actual distance on the ground. Scales on maps are usually represented in one of three ways:

1) **Representative Fraction** - The proportion between the length of a line on the map and the corresponding length of the earth's surface is given in the form of a fraction. For example:

   Scale 1/250 000 or 1:250 000

2) **Verbal Scale** - In the following example, a measured distance on the map corresponds to a number of kilometres:

   Scale 1 cm to 2.5 km

Maps are also referred to in relative terms as **large scale** and **small scale.** The division between the two is not necessarily abrupt or absolute and can be considered as within a range of **medium scales** between 1:100 000 and 1:500 000. Large-scale maps have representative fractions of larger value and are able to portray more detail. Small-scale maps have smaller-value representative fractions (though bigger numbers) and depict less detail but greater overall area.

3) **Graphic Distance Scales** - Most readers will already be familiar with the bar distance scale given on most maps to measure distances. Bar scales are usually located in or near the map border along with the representative fraction. The bar scale can be used to measure distances on the map fairly accurately but, as described later, the use of the grid co-ordinate lines printed over the entire face of the map is a more expedient method of making distance measurements for damage radii and fallout prediction plots.

Appropriate Map Scales - Large-scale maps, in the range of 1:2M and 1:1M, are used to plot fallout hazard areas because they cover the large areas over which fallout can be carried downwind from a nuclear explosion. Maps of 1:2M scale are particularly suited to assess and display the overall attack situation across the entire nation. Maps of 1:1M scale and, in some instances, 1:500 000 scale, are more appropriate to estimate and display hazard areas at provincial or regional levels.

Small-scale 1:50 000 maps are readily available and have the amount of detail needed for damage estimation purposes. Military maps of many Canadian cities also are available in 1:25000 scale also. They are excellent for finer detail, but the number of map sheets required to cover a large city makes them unwieldy in some situations.

The proper scale to use depends on the area coverage needed and the type of detail required. In some settings, too, the amount of space and facilities available to work with and display the maps is also a consideration. Table 8 provides a summary of equivalancy information on map scales and suggests appropriate uses for each.

	Representative Fraction: 1 to	cm to 1 km	km to 1 cm	Statute Miles to 1 inch	Uses
Small Scale	3M	-	30	47	Strategic displays.
	2M	-	20	32	Nudet plotting and fallout prediction.
	1M	-	10	16	
Medium Scale	500 000	-	5	8	Strategical to tactical alternative for all uses.
	250 000	-	2.5	4	
	100 000	1	1	1.5	
Large Scale	50 000	2	.5	.75	Tactical uses.
	25 000	4	.25	.4	Damage and casualty estimation and display

Table 8: Appropriate Map Scales

The Latitude-Longitude Graticule System

Description - In Canada, location reporting in nuclear reports is almost always expressed as co-ordinates of the "parallels of latitude" and the "meridians of longitude." As shown on the map of Canada, Figure 17, the parallels of latitude are the curved horizontal lines which are graduated in degrees (°) North from the equator. The vertical lines, which converge toward the poles, are the meridians of longitude. They are graduated in degrees West from the prime meridian (0°) which runs through Greenwich, England. Each whole degree can be further broken down into 60 minutes ('). Thus, any location on a map of North America can be expressed in terms of its co-ordinated position in whole degrees and minutes of latitude/longitude. (On larger-scale maps, each minute of latitude or longitude may be further subdivided into 60 seconds (").

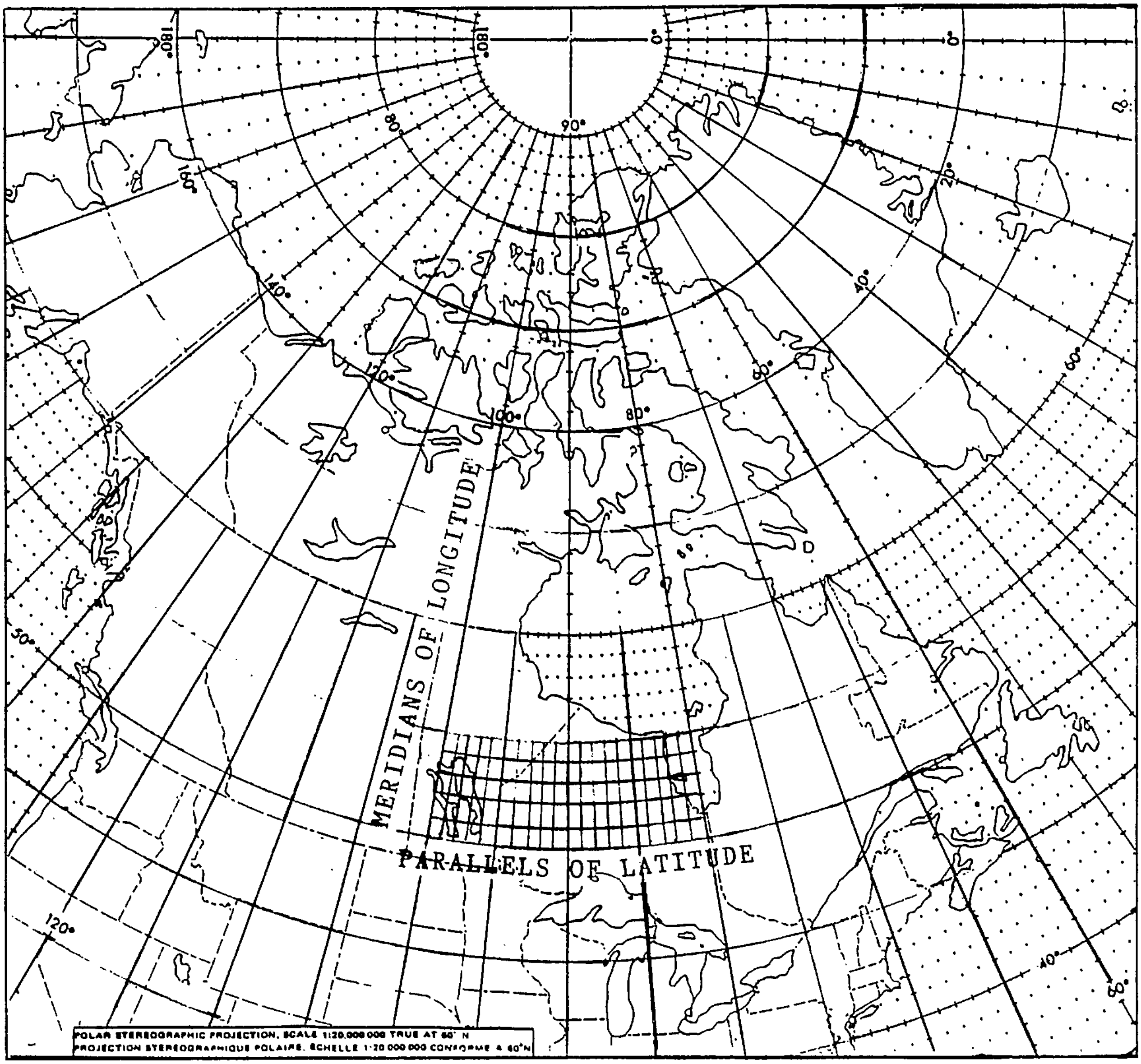


Figure 17 Map of Canada Demonstrating Parallels of Latitude (North) and Meridians of Longitude (West)

Using Latitude/Longitude Co-ordinates - As an example, the location of Ninette, Manitoba, is shown as an X on the graticule depiction given as Figure 18. Its co-ordinate position is latitude 49° 25' North and longitude 99° 40' West which would be written as 4925N/-09940W. Note that latitude is always given first in four figures and the longitude follows in five figures. A simple method to pinpoint the location on a map is to find the whole-degree (49°/99°) intersection first (horizontal lines, then vertical lines); then the minutes (25'/40'), up and across to the left. Most maps will not have all minute and degree graduations printed and interjacent lines must be visualized. Often the degree graduations along the borders are in more detail than are found across the face of the map. Remember that in the latitude/longitude systems each degree is like an hour; it is divided into 60 minutes and therefore 15, 30 and 45 minutes are found between the degree lines at quarter, half and three quarters of the way to the next degree line, respectively.

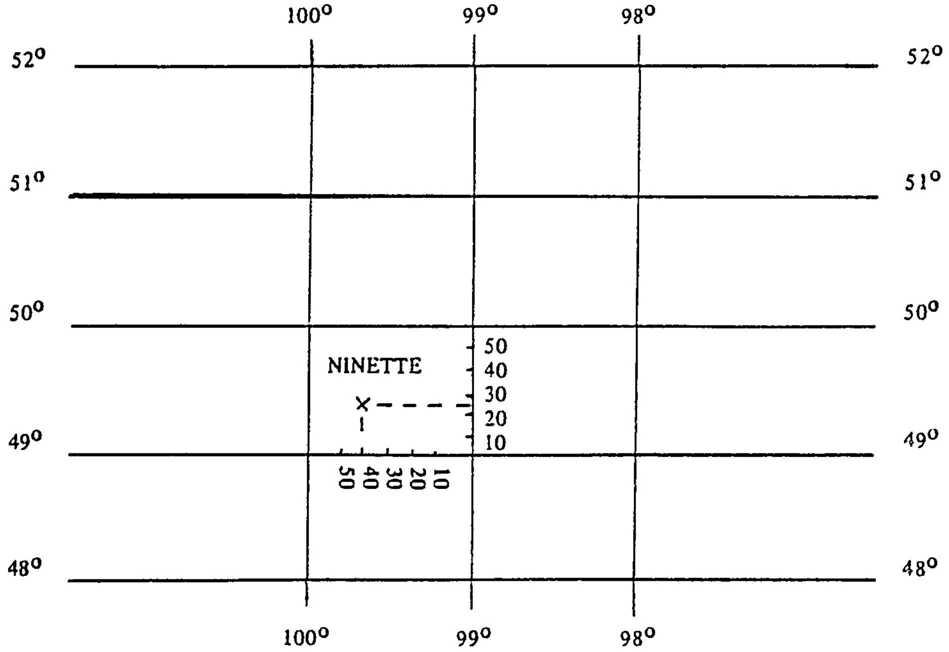


Figure 18 Locating a Position by Parallels of Latitude and Meridians of Longitude. (Example: Ninette (x) 4925N/09940W.)

Measuring Distances by Means of the Latitude Lines - A nautical mile is the length of one minute of latitude on the earth's surface. This fact also holds true when scaled down to map size so an expedient method of measuring distances on maps is to use the latitude lines as a distance scale. Demonstrating with the latitude/longitude graticule depiction in Figure 18 as an example, Ninette, Manitoba, is 25 nautical miles (25 minutes) from the Canada/U.S. border (49th parallel): also, its distance from the 48th parallel of latitude is 85 nautical miles (60 + 25); and so on, the distance between each whole degree of latitude representing 60 nautical miles on the map.

Distance measurements can **only** be taken off **the latitude scale,** but those measured lengths are then valid all across the map at the same general latitude. For precise measurement, with dividers or a ruler, use the scale on the vertical borders of the map where the latitude divisions are clearly marked. Note also that distance measurements taken from the latitude lines are in **nautical miles.** This is very convenient when doing fallout prediction plots because effective wind speeds are usually given in knots, therefore it is easy to mark off the hourly downwind progress of fallout to determine arrival times. The downwind distance of Zone I is also given in handy nautical mile units. For a **rough** conversion of nautical miles to kilometres, simply double the nautical miles. Unless the map also has a UTM grid (described below), precise kilometre measurements must either be taken off the bar scale, or use the following conversions:

- nautical miles x 1.85 = km
- km x .54 = nautical miles

UTM Grid Reference System

Description - The Universal Transverse Mercator system, or UTM, is an ingeniously projected grid system of perfectly squared horizontal and vertical lines on topographical maps. There is so little distortion that the edges of adjacent map sheets will always match. The equally spaced east-west and north-south lines of the UTM grid provide a reference system on most large-scale UTM maps in 1 000-metre (1 km) squares -- ideal for damage-assessment purposes. Locations on these maps are accurately pinpointed to within 10 metres by means of a six-figure grid reference number which expresses the latitudinal part of the grid as "eastings" and the longitudinal part as "northings." For example, in UTM grid reference 454075, the first half of the reference is the easting (454) and the last half is the northing (075). Eastings and northings are used on a map in latitude/longitude-like fashion except that UTM references are in reverse order, i.e. eastings (vertical lines) first, and northings (horizontal lines) second.

Using UTM Grid References - Figure 19 is a section of a 1:25 000-scale UTM grid map which has 1-km grid squares over its face. To find the location of the example grid reference, 454075, first go to easting line 45 then move up to northing line 07. The intersection is the southwest corner of grid square 4507. Now, imagine that the bottom side of the grid square is divided into tenths and go easting 4 divisions (454) and, in similar manner, northing 5 divisions (075). The co-ordinate point is the location of UTM grid reference 454075 (30-m radio tower) and, if you did the eastings and northings properly, you will find there is another radio tower at grid reference 456072; oil storage tanks at 454066; and another oil storage tank at grid reference 441056.

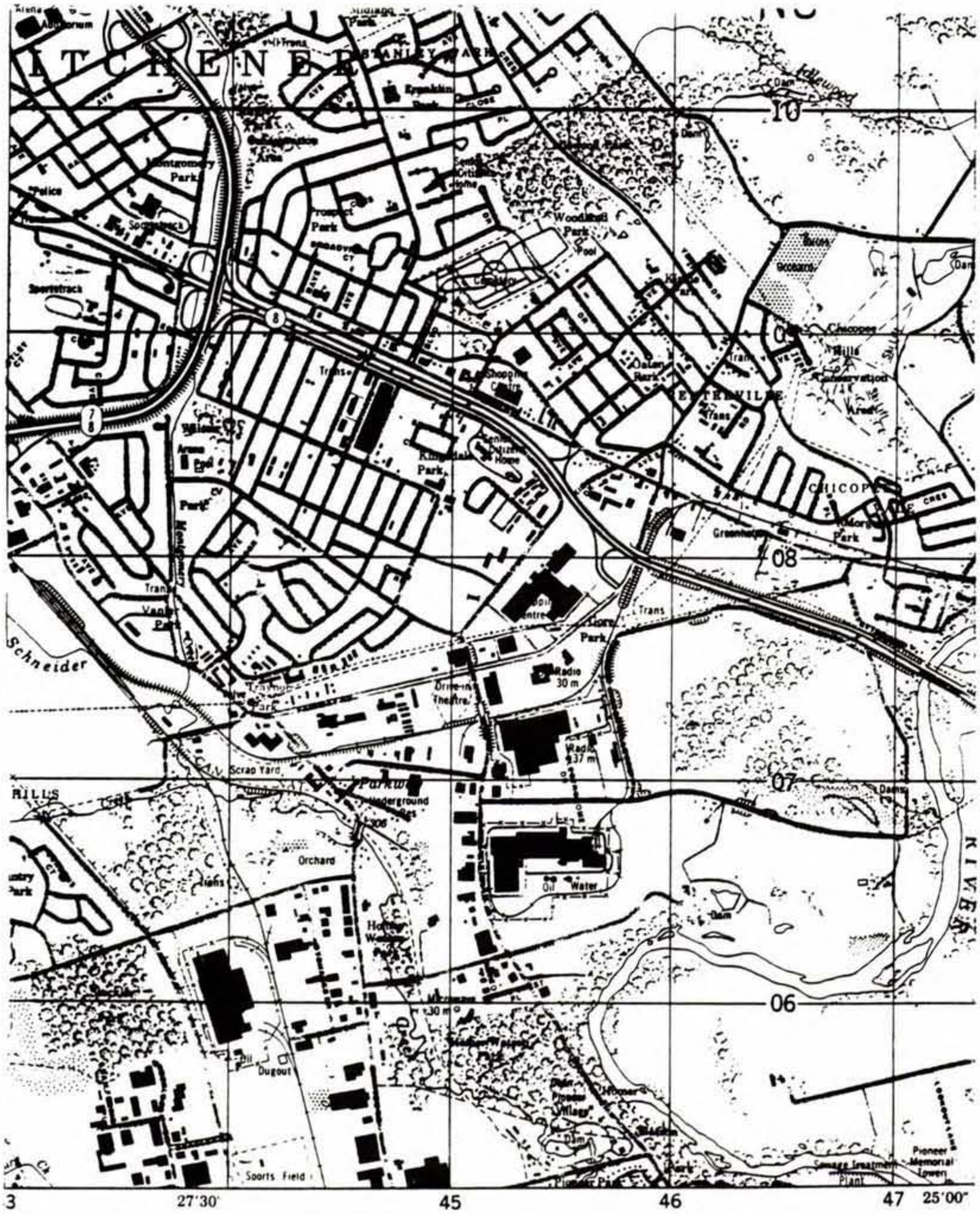
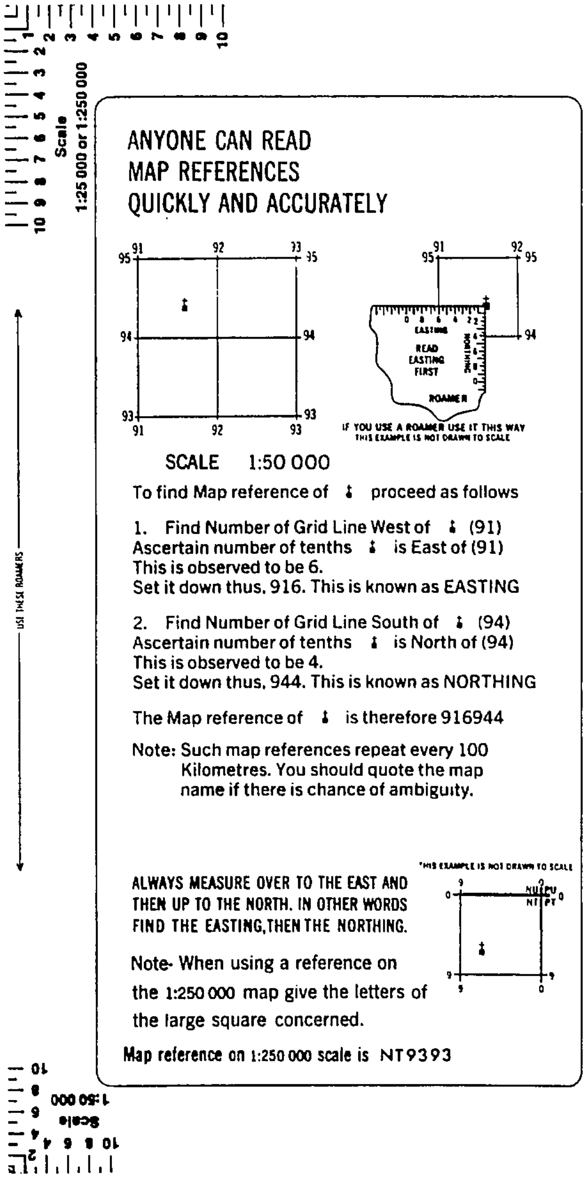


Figure 19 Example of a 1:25 000 Scale UTM Grid Map (1 km squares) (MCE 318 Canada Map Office 17T NU)

Roamers - A roamer is a device to measure the exact position within a grid square instead of estimating it. Figure 20 depicts a leaf from an Energy, Mines and Resources pamphlet entitled How to Use a Map. The use of a roamer is shown along with instructions on reading map references from 1:50 000- and 1:250 000-scale maps. Manufactured roamers made of clear plastic material are available but, as shown at the corners of the depiction, expedient roamers can be made by simply marking graduations (taken from the map's bar scale) onto the corner of a sheet of paper or cardboard.



ANYONE CAN READ
MAP REFERENCES
QUICKLY AND ACCURATELY

IF YOU USE A ROAMER USE IT THIS WAY
THIS EXAMPLE IS NOT DRAWN TO SCALE

SCALE 1:50 000

To find Map reference of ⍋ proceed as follows

1. Find Number of Grid Line West of ⍋ (91)
Ascertain number of tenths ⍋ is East of (91)
This is observed to be 6.
Set it down thus, 916. This is known as EASTING

2. Find Number of Grid Line South of ⍋ (94)
Ascertain number of tenths ⍋ is North of (94)
This is observed to be 4.
Set it down thus, 944. This is known as NORTHING

The Map reference of ⍋ is therefore 916944

Note: Such map references repeat every 100 Kilometres. You should quote the map name if there is chance of ambiguity.

THIS EXAMPLE IS NOT DRAWN TO SCALE

ALWAYS MEASURE OVER TO THE EAST AND THEN UP TO THE NORTH. IN OTHER WORDS FIND THE EASTING,THEN THE NORTHING.

Note- When using a reference on the 1:250 000 map give the letters of the large square concerned.

Map reference on 1:250 000 scale is NT9393

Figure 20 Extract from Energy, Mines and Resources Canada pamphlet "How to Use a Map".

Complete UTM Map References - It should be mentioned that the full UTM grid reference for the first example location is actually 17T NU 454075. The 17T is a grid zone designator which identifies a very large quadrangle (8° of latitude x 6° of longitude) encompassing the southern Ontario area. The NU defines a smaller 100-km^2 quadrangle containing the city of Kitchener and a map section of this area is shown in Figure 19. A full UTM code designates a unique point on the earth and can be termed universal, but when UTM is used on large-scale local maps, where everyone knows the local area, only the last six digits of the grid reference are used. Indeed, on 1:25 000 maps and, to some extent, 1:50 000-scale maps, border legends usually determine the applicable Zone and 100 km^2 designators.

Measuring Distances from UTM Grid Lines - Distances can be taken off UTM gridded maps in the same way that the latitude scale is used. There are several differences, however, that make the UTM grid more convenient. First, the grid will be clearly printed over the whole map; second, accurate measurements can be taken from both horizontal and vertical grid lines; and finally, the grid squares are in kilometric sizes. The kilometre scale is ideal to locate resources on maps and is the preferred scale of measurement for damage estimation purposes. As a demonstration of how obvious distances are on a UTM grid map, refer again to the example map, Figure 19, which has 1-km grid squares. Simple inspection indicates that the map covers an area about 4.3 km by 5.5 km. As an example of making measurements using dividers or a ruler, take off the distance between the centre of the highway cloverleaf intersection (top left corner) and the 30-m radio tower at grid reference 454075. Lay the distance anywhere along either the vertical or horizontal grid lines and it will be found that the distance thus measured is about 2.3 km. (The "spread-finger" measuring technique also works well.)

Using UTM and Latitude/Longitude Together - Laying out damage radii around a latitude/longitude ground zero location is easily accomplished on UTM maps. All maps featuring the UTM grid reference system also show the latitude and longitude graticule, usually in some abbreviated fashion around the map border. Although there are mathematical methods to convert from one reference system to the other, ground zero locations given by their latitude/longitude co-ordinates can still be positioned on UTM maps by using the degree co-ordinate marks around the edges.

GEOREF - There is another map referencing method which is sometimes confused with UTM. The World Geographic Reference System, abbreviated GEOREF, was once used extensively in air defence reporting and is still found on many world-scale maps. GEOREF uses a descending order of latitude-longitude quadrangles which are identified by lettered designators to define an area on the earth's surface. GEOREF maps normally have detailed grid referencing instructions printed in their legends. This brief mention is only given so readers are aware that GEOREF, if encountered, is not the same as the UTM grid reference system.

Source of Maps

Maps suitable for damage assessment and fallout-prediction purposes can often be obtained from provincial and municipal sources, but the prime source is the federal department responsible for production of Canadian topographical maps -- the Surveys and Mapping Branch of Energy, Mines and Resources Canada. Many of their maps are available from local map dealers who are sales agents for Surveys and Mapping Branch products -- look in the Yellow Pages of the telephone directory under Maps. Map purchases, catalogues, lists of map dealers, general information on maps and sources of specialized resource maps will also be handled by mail, or phone:

Canada Map Office,
615 Booth Street,
Ottawa, Ontario.
K1A 0E9

ANNEX A

PRELIMINARY CASUALTY AND DAMAGE ESTIMATION WORKSHEET

This annex presents a sample worksheet which is designed as an aid for making preliminary casualty and damage estimations. A detailed explanation on its content and use in given in Chapter III of the manual.

Working copies of the form may be reproduced locally by photo-copier or other available means.

ANNEX A

PRELIMINARY CASUALTY AND DAMAGE ESTIMATION WORKSHEET

DETONATION DATA

Nudet Serial Number ______________ Date-Time of Burst ______________

Ground Zero Location ______________ N ______________ W (UTM ______________
(Latitude) (Longitude)

Place Name ______________________________ Province ______________

Type of Burst ______________________ Yield ______________

Fallout Data (if applicable)

Effective Downwind Direction and Speed ______________________

Downwind Distance Zone I ________ km, Zone II ______________ km
2 x Zone I

Nuclear Cloud Radius ______________

TABLE OF RADII (km) for A-B-C-D DAMAGE/CASUALTY ZONES (Air and Surface Bursts)

Yield	Zone A		Zone B		Zone C		Zone D	
	Air	Surface	Air	Surface	Air	Surface	Air	Surface
150 kt	2.8	2.0	5.0	3.8	6.8	5.6	8.6	7.0
300 kt	3.5	2.5	6.4	4.8	8.6	7.0	10.8	8.8
500 kt	4.1	2.9	7.5	5.7	10.2	8.3	12.8	10.5
1 Mt	5.2	3.7	9.5	7.2	12.9	10.5	16.1	13.2
5 Mt	8.9	6.3	16.2	12.3	22.0	18.0	27.5	22.6
10 Mt	11.2	8.0	20.5	15.5	27.8	22.6	34.5	28.4
15 Mt	12.8	9.1	23.4	17.8	31.8	25.9	39.7	32.5
25 Mt	15.2	10.8	27.8	21.0	37.7	30.7	47.1	38.6

SUMMARY OF ESTIMATED DAMAGE, CASUALTIES AND FIRES

Zone A-B-C-D from Table of Radii for 150 kt/Mt Air/ Surface Burst	Damage to Average Urban Structures	Percentage of Casualties from Direct Effects (Bracketed numbers apply to surface bursts)				Extent of Fires
		Population Warned		Unwarned		
		Fatal	Injured	Fatal	Injured	
A- GZ to ___ km	Destroyed	75% (100%)	15% (0%)	90% (100%)	10% (0%)	Multiple fires
B-___ to ___ km	Heavy (unrepairable)	30%	20%	50%	35%	
C-___ to ___ km	Moderate (repairable)	5%	25%	15%	40%	Scattered fires
D-___ to ___ km	Light (usable)	1%	9%	2%	18%	

ANNEX B

DAMAGE CRITERIA

This annex contains descriptions of 56 structural types and describes in some detail the damage effects sustained by them for severe, moderate and light damage classifications. These damage criteria are used in conjunction with the damage-distance tables for various yields found in Annex C. A complete explanation on the content and use of this annex is given in Chapter Iv.

Index - The structural types are serial numbered and presented in the following order:

Structural Type	Serials	Annex B Page(s)
Buildings	1 to 12	2,3,4
Shallow Buried or Earth-Covered Structures	13 to 14	4
Bridges	15 to 23	4,5,6
Land Transportation Equipment	24 to 31	6
Parked Aircraft	32 to 33	7
Ships	34	7
Communications and Power Lines	35 to 37	7
Forests	38,39	8
Selected Urban Elongated (Line) Features	40 to 47	8,9
Selected Structural Materials	48 to 53	9
Petroleum and Oil Storage Tanks	54	9
Moderately Deep Underground Structures	55,56	10

DESCRIPTION OF DAMAGE

SERIAL & STRUCTURAL TYPE	SEVERE	MODERATE	LIGHT
Buildings			
(Note: Building serials 1 to 5 are primarily affected by diffraction loading and serials 6 to 12 by drag loading.)			
1. Multi-storey reinforced concrete building with reinforced concrete walls, blast resistant design for 200 kPa Mach region pressure from 1 Mt, no windows.	Walls shattered, severe frame distortion, incipient collapse.	Walls breached or on the point of being so, frame distorted, entrance ways damaged, doors blown in or jammed, extensive spalling of concrete.	Some cracking of concrete walls and frame.
2. Multi-storey reinforced concrete building with concrete walls, small window area, three to eight storeys.	Walls shattered, severe frame distortion, incipient collapse.	Exterior walls severely cracked. Interior partitions severely cracked or blown down. Structural frame permanently distorted, extensive spalling of concrete.	Windows and doors blown in, interior partitions cracked.
3. Multi-storey wall-bearing building, brick apartment house type, up to three storeys.	Collapse of bearing walls, resulting in total collapse of structure.	Exterior walls severely cracked, interior partitions severely cracked or blown down.	Windows and doors blown in, interior partitions cracked.
4. Multi-storey wall-bearing building, monumental type, up to four storeys.	Collapse of bearing walls, resulting in collapse of structure supported by these walls. Some bearing walls may be shielded by intervening walls so that part of the structure may receive only moderate damage.	Exterior walls facing blast severely cracked, interior partitions severely cracked with damage toward far end of building possibly less intense.	Windows and doors blown in, interior partitions cracked.
5. Wood frame building, house type, one or two storeys.	Frame shattered resulting in almost complete collapse.	Wall framing cracked. Roof severely damaged, interior partitions blown down.	Windows and doors blown in, interior partitions cracked.

	DESCRIPTION OF DAMAGE		
SERIAL & STRUCTURAL TYPE	SEVERE	MODERATE	LIGHT
6. Light steel frame industrial building, single storey, with up to 5-tonne crane capacity; low strength walls which fail quickly.	Severe distortion or collapse of frame.	Minor to major distortion of frame; cranes, if any, not operable until repairs made.	Windows and doors blown in, light siding ripped off.
7. Heavy steel-frame industrial building, single storey, with 25.5 to 51-tonne crane capacity; lightweight, low strength walls which fail quickly.	Severe distortion or collapse of frame.	Some distortion to frame; cranes not operable until repairs made.	Windows and doors blown in, light siding ripped off.
8. Heavy steel frame industrial building, single storey, with 61 to 102 tonne crane capacity; lightweight low strength walls which fail quickly.	Severe distortion or collapse of frame.	Some distortion to frame; cranes not operable until repairs made.	Windows and doors blown in, light siding ripped off.
9. Multi-storey steel frame office-type building, 3 to 10 storeys. Lightweight low strength walls which fail quickly, earthquake resistant construction.	Severe frame distortion, incipient collapse.	Frame distorted moderately, interior partitions blown down.	Windows and doors blown in, light siding ripped off, interior partitions cracked.
10. Multi-storey steel frame office-type building, 3 to 10 storeys. Lightweight low strength walls which fail quickly, non-earthquake resistant construction.	Severe frame distortion, incipient collapse.	Frame distorted moderately, interior partitions blown down.	Windows and doors blown in, light siding ripped off, interior partitions cracked.
11. Multi-storey reinforced concrete frame office-type building, 3 to 10 storeys; lightweight low strength walls which fail quickly, earthquake resistant construction.	Severe frame distortion, incipient collapse.	Frame distorted moderately, interior partitions blown down, some spalling of concrete.	Windows and doors blown in, light siding ripped off, interior partitions cracked.

	DESCRIPTION OF DAMAGE		
SERIAL & STRUCTURAL TYPE	SEVERE	MODERATE	LIGHT
12. Multi-storey reinforced concrete frame office-type building, 3 to 10 storeys; lightweight low strength walls which fail quickly, non-earthquake resistant construction.	Severe frame distortion, incipient collapse.	Frame distorted moderately, interior partitions blown down, some spalling of concrete.	Windows and doors blown in, light siding ripped off, interior partitions cracked.
Shallow Buried or Earth-Covered Structures (air blast)			
13. Light, corrugated steel arch, surface structure (10-gauge corrugated steel with a span of 6-8 m), central angle of 180°; 1.5 m earth cover. (Arched structures reinforced with ribs are more robust depending on the number of ribs.)	Collapse at 300-400 kPa peak overpressure.	At about 350 kPa peak overpressure, large deformations of end walls and arch, also major entrance door damage.	At 200-275 kPa peak overpressure, damage to ventilation and entrance door.
14. Buried concrete arch, 20 cm thick with a 5-m span and central angle of 180°; 1.2 m earth cover at the crown.	Collapse at 1,500-2,000 kPa peak overpressure.	At 700-1,500 kPa peak overpressure, large deformations with considerable cracking and spalling.	At 800-1,100 kPa peak overpressure, cracking of panels, possible entrance door damage.
Bridges (drag-sensitive targets)			
15.a) Highway truss bridges, 4-lane, spans 60 to 120 m; b) Railroad truss bridges, double track ballast floor spans 60 to 120 m.	Total failure of lateral bracing or anchorage, collapse of bridge.	Substantial distortion of lateral bracing or slippage on supports, significant reduction in capacity of bridge.	Capacity of bridge not significantly reduced, slight distortion of some bridge components.
16.a) Highway truss bridges, 2-lane, spans 60 to 120 m; b) Railroad truss bridges, single track ballast or double track open floors, spans 60 to 120 m; c) Railroad truss bridges, single track open floor, span 120 m.	Total failure of lateral bracing or anchorage, collapse of bridge.	Substantial distortion of lateral bracing or slippage on supports, significant reduction in capacity of bridge.	Capacity of bridge not significantly reduced, slight distortion of some bridge components.

DESCRIPTION OF DAMAGE

SERIAL & STRUCTURAL TYPE	SEVERE	MODERATE	LIGHT
17. Railroad truss bridges, single track open floor, span 60 m.	Total failure of lateral bracing or anchorage, collapse of bridge.	Substantial distortion of lateral bracing or slippage on supports, significant reduction in capacity of bridge.	Capacity of bridge no significantly reduced slight distortion of some bridge components.
18. Highway girder bridges, 4-lane through, span 25 m.	Total failure of lateral bracing or anchorage, collapse of bridge.	Substantial distortion of lateral bracing or slippage on supports, significant reduction in capacity of bridge.	Capacity of bridge no significantly reduced slight distortion of some bridge components.
19.a) Highway girder bridges, 2-lane deck, 2-lane through, 4-lane deck, span 25 m; b) Railroad girder bridges, double-track deck, open or ballast floor, span 25 m; c) Railroad girder bridges, single or double track through, ballast floors, span 25 m.	Total failure of lateral bracing or anchorage, collapse of bridge.	Substantial distortion of lateral bracing or slippage on supports, significant reduction in capacity of bridge.	Capacity of bridge no significantly reduced slight distortion of some bridge components.
20.a) Railroad girder bridges, single track deck, open or ballast floors, span 25 m; b) Railroad girder bridges, single or double track through, open floors, span 25 m.	Total failure of lateral bracing or anchorage, collapse of bridge.	Substantial distortion of lateral bracing or slippage on supports, significant reduction in capacity of bridge.	Capacity of bridge not significantly reduced, slight distortion of some bridge components.
21.a) Highway girder bridges, 2-lane through, 4-lane deck or through, span 60 m; b)Railroad girder bridges, double track deck or through, ballast floor, span 60 m.	Total failure of lateral bracing or anchorage, collapse of bridge.	Substantial distortion of lateral bracing or slippage on supports, significant reduction in capacity of bridge.	Capacity of bridge not significantly reduced, slight distortion of some bridge components.

DESCRIPTION OF DAMAGE

SERIAL & STRUCTURAL TYPE	SEVERE	MODERATE	LIGHT
22.a) Highway girder bridges, 2-lane deck, span 60 m; b) Railroad girder bridges, single track deck or through, ballast floors, span 60 m; c) Railroad girder bridges, double track deck or through, open floors, span 60 m.	Total failure of lateral bracing or anchorage, collapse of bridge.	Substantial distortion of lateral bracing or slippage on supports, significant reduction in capacity of bridge.	Capacity of bridge not significantly reduced, slight distortion of some bridge components.
23. Railroad girder bridges, single track deck or through, open floors, span 60 m.	Total failure of lateral bracing or anchorage, collapse of bridge.	Substantial distortion of lateral bracing or slippage on supports, significant reduction in capacity of bridge.	Capacity of bridge not significantly reduced, slight distortion of some bridge components.
Land Transportation Equipment (unprotected)			
24, 25. Motor transport vehicles (cars, trucks, etc.) and truck-mounted engineering equipment.	Gross distortion of frame, large displacements, outside appurtenances (doors and hoods) torn off, need rebuilding before use.	Turned over and displaced, badly dented, frames sprung, need major repairs.	At about 15 kPa, glass broken, dents ir body, possibly turned over, immediately usable.
26. Construction equipment (bulldozers and graders).	Extensive distortion of frame and crushing of sheet metal, extensive damage to caterpillar tracks and wheels.	Some frame distortion, overturning, track and wheel damage.	At about 15 kPa, slight damage to cabs and housing, glass breakage.
27, 28, 29. Railroad rolling stock (box, flat, tank and gondola cars).	Car blown from track and badly smashed, extensive distortion some parts usable.	Doors demolished, body damages, frame distorted, could possibly roll to repair shop.	At about 15 kPa, some door and body damage, car can continue in use.
30, 31. Railroad locomotives (diesel or steam).	Overturned, parts blown off, sprung and twisted, major overhaul required.	Proably overturned, can be towed to repair shop after being righted, need major repairs.	At about 15 kPa, glass breakage and minor damage to parts immediately usable.

DESCRIPTION OF DAMAGE

SERIAL & STRUCTURAL TYPE	SEVERE	MODERATE	LIGHT
Parked Aircraft (unprotected, random orientation)			
32. Transport airplanes and helicopters.	Major (or depot level) maintenance required to restore aircraft to operating status. (20 kPa)	Field maintenance required to restore aircraft to operating status. (10 to 14 kPa)	Flight of aircraft not prevented although performance may be restricted. (7 kPa)
33. Light aircraft.	Major (or depot level) maintenance required to restore aircraft to operating status. (14 kPa)	Field maintenance required to restore aircraft to oerating status. (7 kPa)	Flight of aircraft not prevented although performance may be restricted. (5 kPa)
Ships (from air blast)			
34. Merchant shipping.	Ships either sunk, capsized or damaged to extent of requiring rebuilding.	Ships immobilized, need extensive repair especially to shock-sensitive components or their foundations, e.g. propulsive machinery, boilers and interior equipment.	Ships may still be able to operate although there will be damage to electronics, electrical and mechanical equipment.
Communications and Power Lines			
(Note: Damage of 35 and 36 is predicated upon whether supporting poles are blown down or not, hence damage to lines will be severe or very light.)			
35. Telephone and power lines (oriented radially from the burst).	Poles blown down. Extensive repairs needed.	N/A	Little repair needed.
36. Telephone and power lines (oriented transversely from the burst).	(Damage criteria same as for 35. In general, lines extending radially from ground zero are less susceptible to damage than are those running at right angles to this direction.)		
37. Radio and television transmitting towers, 60 to 150 m.	Towers demolished or flat on ground.	Towers partially buckled but held by guy lines. Ineffective for transmission.	Guy lines somewhat slack but tower able to transmit.

DESCRIPTION OF DAMAGE

SERIAL & STRUCTURAL TYPE	SEVERE	MODERATE	LIGHT
Forests (blast wave wind effect)			
38, 39. Unimproved coniferous forests and average deciduous forests.	At 210-225 km/h, up to 90% of trees blown down; remainder denuded of branches and leaves. Area impassable to vehicles and very difficult on foot.	At 145-160 km/h, about 30% of trees blown down; remainder have some branches and leaves blown off. Area passable to vehicles only after extensive clearing.	(Only applies to deciduous forest stands.) At 95-130 km/h, very few trees blown down; some leaves and branches blown off. Area passable to vehicles.
Selected Urban Elongated (Line) Features			
(Note: Highways, rail tracks, water mains, etc., are not, in themselves, greatly affected by air blast. Depending on the target area, their usefulness is degraded mainly by blockage from scattered debris and damage from falling rubble.)			
40. Highways struts and airport runways.	Impassable.	Many parts blocked by debris. Requires clearing before use.	Some parts blocked by debris. Requires clearing before use.
41. Elevated roads and short span bridges.	Some destroyed, approaches blocked by rubble and disabled vehicles. Decks of steel plate girder bridges may shift laterally.	Approaches blocked but generally usable.	Slight damage. Usable.
42. Railroad yards and tracks.	Tracks blocked by damaged rolling stock and rubble.	Some parts blocked by debris.	Some parts blocked by debris.
43. Water mains.	Some mains broken especially near ground zero and on bridges.	Little damage.	Little damage.
44. Elevated water tanks.	Mostly destroyed or damaged beyond use. Some substantial towers may be usable.	Tanks supported by frames may fall.	Slight damage. Usable.
45. Sewers and storm sewers.	Some mains broken especially near ground zero.	Little damage.	Little damage.

DESCRIPTION OF DAMAGE

SERIAL & STRUCTURAL TYPE	SEVERE	MODERATE	LIGHT
46. Gas mains.	Some mains broken especially near ground zero and on bridges.	Little damage.	Little damage.
47. Underground electric power lines.	Intact except where lines join overhead lines or enter transformer or power stations. Some may short if conduits flood.	Little damage. Some short circuits if conduits flood.	Little damage. Some short circuits if conduits flood.

CONDITIONS OF BREAKAGE OR FAILURE

Selected Structural Materials

(Note: The pressures (kPa) given for failure of structural materials are approximate side-on peak overpressures on panels that face ground zero. For panels oriented for little or no reflected overpressure, the side-on pressures must be doubled.)

48. Glass windows large and small.	At 3 to 7 kPa, most windows will shatter with occasional frame failure.
49. Corrugated asbestos siding.	At 7 to 14 kPa; shattering.
50. Corrugated steel or aluminum paneling.	At 7 to 14 kPa, connection failure followed by buckling.
51. Brick wall panel, 20 or 30 cm thick (not reinforced).	At 20 to 70 kPa, shearing and flexure failures.
52. Wood siding panels, standard house construction.	At 7 to 14 kPa, failure usually occurs at the main connections allowing a whole panel to be blown in.
53. Concrete or cinder-block wall panels, 20 or 30 cm thick (not reinforced).	At 10 to 40 kPa, shattering of the wall.

Petroleum and Oil Storage Tanks

54. Floating-roof and conical-roof storage tanks.	Failure of storage tanks is regarded as the loss of contents by leakage. Such failure will usually be caused by lifting of the tank from its foundation sufficiently to result in plastic deformation and yielding of the joint between the side and base.

DESCRIPTION OF DAMAGE

SERIAL & STRUCTURAL TYPE	SEVERE	MODERATE	LIGHT
Moderately Deep Underground Structures			
(Note: Air blast will have negligible effect on deep underground structures. Damage will be the result of ground shock associated with cratering. Moderately deep is defned as the condition where the ratio of the depth of cover to the span of the structure is greater than unity).			
55. Relatively small, heavy well-designed underground structures.	Collapse	N/A	Slight cracking, severance of brittle external connections.
56. Relatively long, flexible structures, such as buried pipelines, storage tanks, etc.	Deformation and rupture.	Slight deformation and rupture.	Failure of connections.

ANNEX C

PHYSICAL VULNERABILITY TABLES

This annex presents nuclear detonation damage tables for a selection of weapon yields. Data are given for both air burst and surface burst conditions using the format, "AB/SB". A full explanation defining the content of these tables is given in Chapter IV.

Index of Yields - Data for each yield is introduced with a cover page giving useful nuclear burst parameters followed by several pages (seven) of damage-distance tables for various structural types.

Yield	Annex C Page	Yield	Annex C Page
150 kt	2	5 Mt	34
300 kt	10	10 Mt	42
500 kt	18	15 Mt	50
1 Mt	26	25 Mt	58

Using the Tables - A logical sequence of steps for estimating damage to a particular structure, equipment or resource of interest is as follows:

- Determine the distance (in kilometres) of the structure of interest from ground zero.
- Consider the yield and burst condition (air/surface) most likely used.
- From Annex B or C descriptions, determine which serial is the structural type that most closely resembles the structure of interest.
- Using the damage-distance tables for the likely yield, determine the damage classification (severe, moderate, light) that applies at the range of the structure of interest from ground zero.
- If desired, a detailed narrative description for the damage classification thus found can be extracted from Damage Criteria (Annex B).

Index of Tables - Nuclear weapon effects tables for eight selected yields are presented in this Annex as described in Chapter IV. Following is an index of contents:

PHYSICAL VULNERABILITY DATA

150 kt

Air Burst/Surface Burst

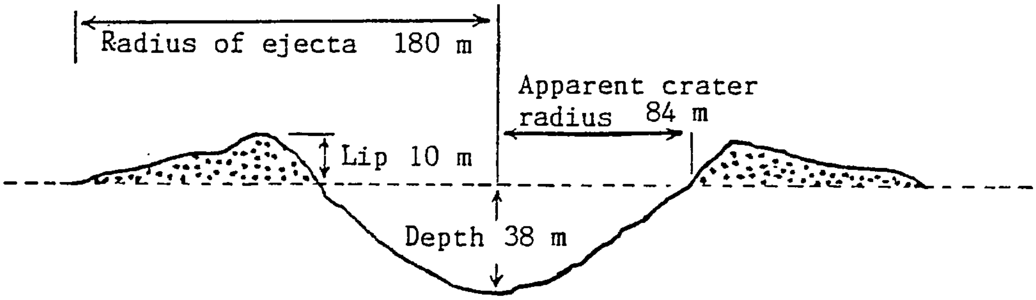
HEIGHT OF BURST FOR A TYPICAL AIR BURST - 410 m* to 800 m
(*Lower figure is minimum height of burst for negligible early fallout.)

NUCLEAR CLOUD DIMENSIONS - Cloud radius 7.8 km
- Cloud top height 15.3 km
- Cloud bottom height 9.8 km

DISTANCES AT WHICH FLASHBURNS COULD OCCUR TO BARE SKIN (km - AB/SB)
Third-degree 6/4 Second-degree 8/5 First-degree 15/9

DURATION OF THE THERMAL PULSE - 4 seconds

SURFACE BURST CRATER DIMENSIONS - Dry soil



SAMPLE PEAK OVERPRESSURE RADII AND ASSOCIATED BLAST WIND SPEEDS

Peak Overpressure (kPa)	Radii (km-AB/SB)	Wind Speed (km/h)
10*	8.4/5.0	85
25	4.6/2.9	190
50	2.9/1.9	355
100	2.0/1.3	625
250	0.9/0.8	1200
500	0.7/0.6	1900

(* 10 kPa = 1.45 psi)

DAMAGE - DISTANCE TABLES - 150 kt

SERIAL & STRUCTURAL TYPE	DAMAGE RADII (km) SEVERE	MODERATE	LIGHT
Buildings	AB/SB	AB/SB	AB/SB
1. Multistory reinforced concrete building, blast resistant, windowless.	1.0/0.8	1.2/0.9	2.4/1.7
2. Multistory reinforced concrete frame and wall building, small window area.	2.2/1.6	2.6/2.0	8.6/6.2
3. Multistory wall-bearing brick apartment house, up to three stories.	3.6/2.7	4.0/3.0	8.6/6.2
4. Multistory wall-bearing building, monumental type, up to four stories.	2.4/1.8	2.8/2.1	8.6/6.2
5. Wood frame, house type, one or two stories.	4.6/3.4	5.3/4.0	8.6/6.2
6. Light steel frame industrial building, one story, light walls, 5-tonne crane capacity.	2.4/1.8	2.9/2.1	8.6/6.2
7. Heavy steel frame industrial building, one story, 25.5 to 51-tonne crane capacity.	1.9/1.4	2.2/1.7	8.6/6.2
8. Heavy steel frame industrial building, one story, 61 to 102-tonne crane capacity.	1.6/1.2	1.9/1.4	8.6/6.2
9. Multistory steel frame office-type building, 3 to 10 stories, earthquake resistant.	1.2/0.9	1.4/1.0	8.6/6.2
10. Multistory steel frame office-type building, 3 to 10 stories, non-earthquake resistant.	1.5/1.1	1.8/1.3	8.6/6.2
11. Multistory reinforced concrete frame office-type building, 3 to 10 stories, earthquake resistant.	1.3/1.0	1.5/1.1	8.6/6.2
12. Multistory reinforced concrete frame office-type building, 3 to 10 stories, non-earthquake resistant.	1.6/1.2	1.8/1.4	8.6/6.2

DAMAGE - DISTANCE TABLES - 150 kt continued.

SERIAL & STRUCTURAL TYPE	DAMAGE RADII (km)		
	SEVERE	MODERATE	LIGHT
	AB/SB	AB/SB	AB/SB
Shallow Buried or Earth Covered Structures (Note: Due to allowance for differences in design, soil, shape and orientation, the moderate damage radius for Serial 13 is within the radius of severe damage. Serial 14 is a similar case for light damage.)			
13. Light, corrugated steel arch surface structure; 1.5 m earth cover.	0.8/0.7	←	1.0/0.9
14. Buried concrete arch, 20 cm thick with 5 m span; 1.2 m earth cover.	0.4/0.4	0.6/0.6	←
Bridges			
15.a) Highway truss bridges, 4-lane, spans 60 to 120 m; b) Railroad truss bridges, double track ballast floor, spans 60 to 120 m.	1.6/1.2	2.0/1.5	3.7/2.4
16.a) Highway truss bridges, 2-lane, spans 60 to 120 m; b) Railroad truss bridges, single track ballast or double track open floors, spans 60 to 120 m; c) Railroad truss bridges, single track open floor, span 120 m.	1.9/1.4	2.3/1.7	3.7/2.4
17. Railroad truss bridges, single track open floor, span 60 m.	2.1/1.6	2.5/1.9	3.7/2.4
18. Highway girder bridges, 4-lane through, span 25 m.	1.0/0.7	1.1/0.9	3.7/2.4
19.a) Highway girder bridges, 2-lane deck, 2-lane through, 4-lane deck, span 25 m; b) Railroad girder bridges, double track deck, open or ballast floor, span 25 m; c) Railroad girder bridges, single or double track through, ballast floors, span 25 m.	1.3/1.0	1.5/1.1	3.7/2.4
20.a) Railroad girder bridges, single track deck, open or ballast floors, span 25 m; b) Railroad girder bridges, single or double track through open floors, span 25 m.	1.9/1.4	2.3/1.7	3.7/2.4

DAMAGE - DISTANCE TABLES - 150 kt continued.

SERIAL & STRUCTURAL TYPE	DAMAGE RADII (km)		
	SEVERE	MODERATE	LIGHT
(Bridges continued)	AB/SB	AB/SB	AB/SB
21.a) Highway girder bridges, 2-lane through, 4-lane deck or through, span 60 m; b) Railroad girder bridges, double track deck or through, ballast floor, span 60 m.	1.6/1.2	1.9/1.4	3.7/2.4
22.a) Highway girder bridges, 2-lane deck, span 60 m; b) Railroad girder bridges, single track deck or through, ballast floors, span 60 m; c) Railroad girder bridges, double track deck or through, open floors, span 60 m.	2.2/1.6	2.6/2.0	3.7/2.4
23. Railroad girder bridges, single track deck or through open floors, span 60 m.	3.4/2.6	4.1/3.0	4.7/3.4
Land Transportation Equipment (Unprotected)			
24. Motor transport vehicles (cars, trucks, etc).	1.3/0.9	1.4/1.1	6.7/4.1
25. Truck mounted engineering equipment.	1.4/1.1	1.9/1.4	6.7/4.1
26. Bulldozers and graders.	1.3/0.9	1.4/1.1	6.7/4.1
27. Unloaded railroad cars.	3.9/2.9	4.5/3.4	8.6/6.2
28. Loaded railroad boxcars, flatcars, full tank cars and gondola cars (side-on orientation).	2.8/2.1	3.2/2.4	8.6/6.2
29. Loaded railroad boxcars, flatcars, full tank cars and gondola cars (end-on orientation).	1.0/1.0	1.2/1.2	8.6/6.2
30. Railroad locomotives (side-on orientation).	0.8/0.6	1.8/1.4	5.3/3.2
31. Railroad locomotives(end-on orientation)	0.5/0.5	0.9/0.9	5.3/3.2
Parked Aircraft (Unprotected, random orientation)			
32. Transport airplanes and helicopters.	5.3/3.2	6.7/4.1	8.6/6.2
33. Light aircraft.	6.7/4.1	8.6/6.2	9.8/7.4

DAMAGE - DISTANCE TABLES - 150 kt continued.

SERIAL & STRUCTURAL TYPE	DAMAGE RADII (km) SEVERE	MODERATE	LIGHT
Ships (Air blast effect)	AB/SB	AB/SB	AB/SB
34. Merchant shipping.	0.9/0.9	1.0/1.0	4.0/2.7
Communications and Power Lines			
35. Telephone and power lines (oriented radially from the burst).	2.7/2.0	N/A	N/A
36. Telephone and power lines (oriented transversly from the burst).	3.6/2.7	N/A	N/A
37. Transmitting towers.	3.8/3.5	4.7/4.1	5.7/5.4
Forests (Blast wave wind effect)			
38. Unimproved coniferous forest stand.	4.2/2.1	5.3/2.6	N/A
39. Average desiduous forest stand.	5.7/2.9	7.0/3.5	7.4/4.5
Selected Urban Elongated (Line) Features			
40. Highways, streets and airport runways.	N/A	N/A	5.0/3.8
41. Elevated roads and short span bridges.	5.0/3.8	6.8/5.6	8.6/6.2
42. Railroad yards and tracks.	N/A	N/A	8.6/6.2
43. Water mains.	N/A	N/A	5.0/3.8
44. Elevated water tanks.	5.0/3.8	N/A	8.6/6.2
45. Sewers and storm sewers.	N/A	N/A	2.7/2.0
46. Gas mains.	N/A	N/A	2.7/3.7
47. Underground electric power lines.	N/A	N/A	8.6/6.2

DAMAGE - DISTANCE TABLES - 150 kt continued.

SERIAL & STRUCTURAL TYPE		RADII OF BREAKAGE OR FAILURE (km)
Selected Structural Materials		AB/SB
48.	Glass windows, large and small.	13/10
49.	Corrugated asbestos siding.	8.6/6.2
50.	Corrugated steel or aluminum paneling.	8.6/6.2
51.	Brick wall panel, 20 or 30 cm thick (not reinforced).	5.3/3.2
52.	Wood siding panels, standard house construction.	8.6/6.2
53.	Concrete or cinder-block wall panels, 20 or 30 cm thick (not reinforced).	8.0/4.8

DAMAGE - DISTANCE TABLES - 150 kt continued.

SERIAL & STRUCTURAL TYPE	RADII OF FAILURE
Petroleum and Oil Storage Tanks	
54. Floating-roof and conical-roof storage tanks.	- Use airburst and surface burst Radii of Failure graphs below.

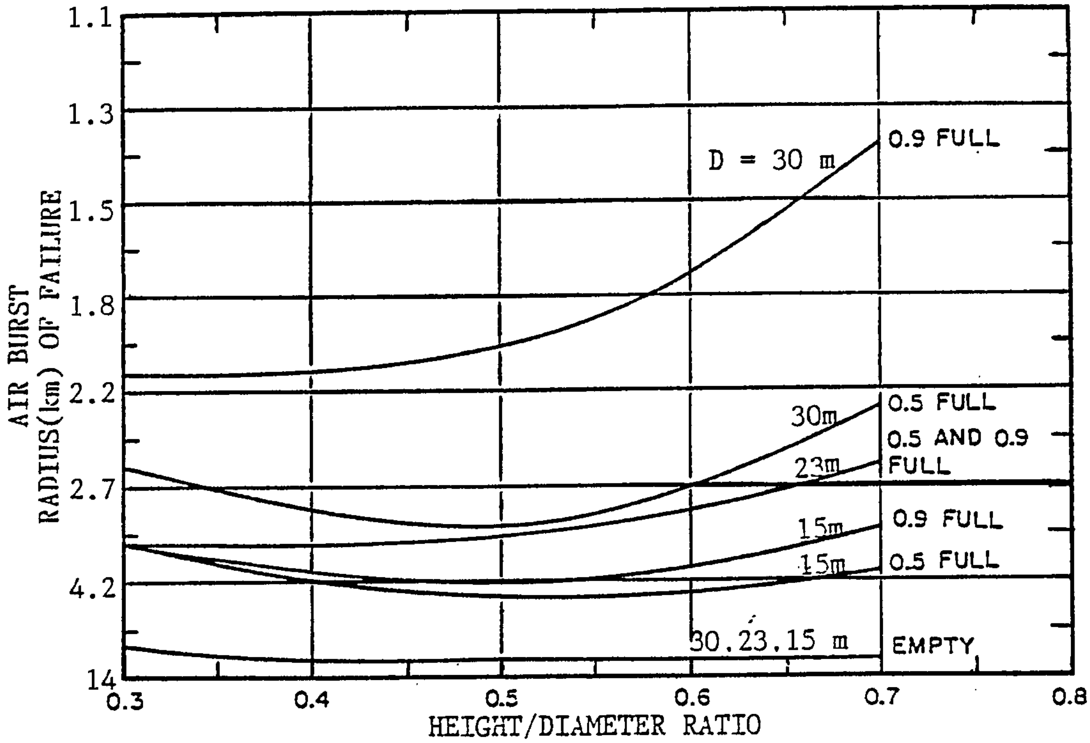


Figure 4B - 1 Radii (km) of Failure (loss of contents) for Storage Tanks of Diameter D from 150 kt Air Bursts.

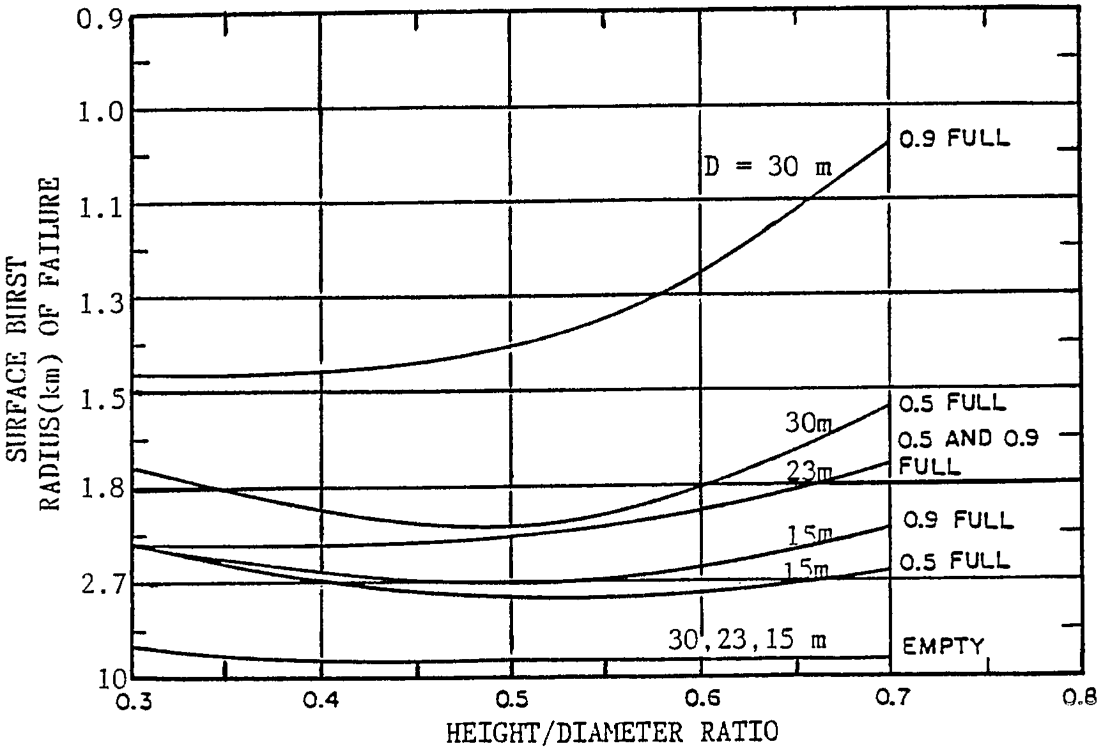


Figure 4B - 2 Radii (km) of Failure (loss of contents) for Storage Tanks of Diameter D from 150 kt Surface Bursts.

DAMAGE - DISTANCE TABLES - 150 kt continued.

SERIAL & STRUCTURAL TYPE	RADII OF DAMAGE (metres)		
	SEVERE	MODERATE	LIGHT
Moderately Deep Underground Structure (Ground shock damage) (Note: Figures are for ground shock damage from a contact burst. Moderately deep is defined as the condition where the ratio of depth of cover to the structure is greater than unity.)			
55. Small well designed underground structures.			
- Dry soil or dry soft rock	105 m	N/A	210 m
- Wet soil or wet soft rock	141	N/A	281
- Dry hard rock	84	N/A	168
- Wet hard rock	100	N/A	200
56. Long flexible structures such as buried pipelines, storage tanks, etc.			
- Dry soil or dry soft rock	126 m	168 m	252 m
- Wet soil or wet soft rock	169	225	338
- Dry hard rock	101	134	202
- Wet hard rock	120	160	239

FINAL NOTE:

"N/A" (not applicable) is used throughout the tables to indicate that a damage classification does not apply or is inappropriate for a particular structural type. A more detailed explanation will be found for the feature in Annex A - Damage Criteria.

PHYSICAL VULNERABILITY DATA

300 kt

Air Burst/Surface Burst

HEIGHT OF BURST FOR A TYPICAL AIR BURST - 540 m* to 1005 m
(*Lower figure is minimum height of burst for negligible early fallout.)

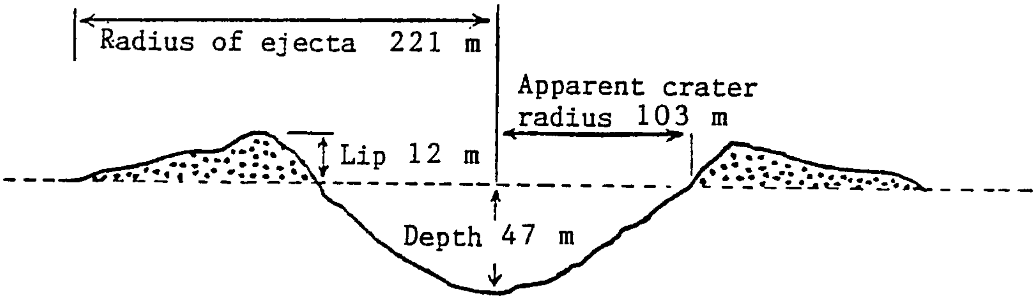
NUCLEAR CLOUD DIMENSIONS - Cloud radius 11.2 km
- Cloud top height 16.7 km
- Cloud bottom height 11.0 km

DISTANCES AT WHICH FLASHBURNS COULD OCCUR TO BARE SKIN (km - AB/SB)

Third-degree 8/5 Second-degree 10/6 First-degree 12/8

DURATION OF THE THERMAL PULSE - 5 seconds

SURFACE BURST CRATER DIMENSIONS - Dry soil



SAMPLE PEAK OVERPRESSURE RADII AND ASSOCIATED BLAST WIND SPEEDS

Peak Overpressure (kPa)	Radii (km-AB/SB)	Wind Speed (km/h)
10*	10.6/6.2	85
25	5.8/3.6	190
50	3.7/2.4	355
100	2.5/1.7	625
250	1.2/1.0	1200
500	0.8/0.8	1900

(*10 kPa = 1.45 psi)

DAMAGE - DISTANCE TABLES - 300 kt

SERIAL & STRUCTURAL TYPE	DAMAGE RADII (km)		
	SEVERE	MODERATE	LIGHT
Buildings	AB/SB	AB/SB	AB/SB
1. Multistory reinforced concrete building, blast resistant, windowless.	1.4/1.0	1.5/1.1	3.0/2.0
2. Multistory reinforced concrete frame and wall building, small window area.	3.0/2.2	3.4/2.5	11/7.8
3. Multistory wall-bearing brick apartment house, up to three stories.	4.5/3.4	5.1/3.8	11/7.8
4. Multistory wall-bearing building, monumental type, up to four stories.	3.2/2.4	3.6/2.7	11/7.8
5. Wood frame, house type, one or two stories.	5.9/4.4	6.7/5.0	11/7.8
6. Light steel frame industrial building, one story, light walls, 5-tonne crane capacity.	3.4/2.5	3.9/2.9	11/7.8
7. Heavy steel frame industrial building, one story, 25.5 to 51-tonne crane capacity.	2.6/1.9	3.0/2.2	11/7.8
8. Heavy steel frame industrial building, one story, 61 to 102-tonne crane capacity.	2.2/1.7	2.5/1.9	11/7.8
9. Multistory steel frame office-type building, 3 to 10 stories, earthquake resistant.	1.6/1.2	1.8/1.3	11/7.8
10. Multistory steel frame office-type building, 3 to 10 stories, non-earthquake resistant.	2.1/1.6	2.4/1.8	11/7.8
11. Multistory reinforced concrete frame office-type building, 3 to 10 stories, earthquake resistant.	1.7/1.3	2.0/1.5	11/7.8
12. Multistory reinforced concrete frame office-type building, 3 to 10 stories, non-earthquake resistant.	2.2/1.6	2.5/1.8	11/7.8

DAMAGE - DISTANCE TABLES - 300 kt continued.

SERIAL & STRUCTURAL TYPE	DAMAGE RADII (km) SEVERE		
	SEVERE	MODERATE	LIGHT
	AB/SB	AB/SB	AB/SB
Shallow Buried or Earth Covered Structures			
(Note: Due to allowance for differences in design, soil, shape and orientation, the moderate damage radius for Serial 13 is within the radius of severe damage. Serial 14 is a similar case for light damage.)			
13. Light, corrugated steel arch surface structure; 1.5 m earth cover.	1.1/1.0	←	1.3/1.2
14. Buried concrete arch, 20 cm thick with 5 m span; 1.2 m earth cover.	0.5/0.5	0.7/0.7	←
Bridges			
15.a) Highway truss bridges, 4-lane, spans 60 to 120 m; b) Railroad truss bridges, double track ballast floor, spans 60 to 120 m.	2.2/1.7	2.6/1.9	4.6/2.9
16.a) Highway truss bridges, 2-lane, spans 60 to 120 m; b) Railroad truss bridges, single track ballast or double track open floors, spans 60 to 120 m; c) Railroad truss bridges, single track open floor, span 120 m.	2.7/2.0	3.0/2.3	4.6/2.9
17. Railroad truss bridges, single track open floor, span 60 m.	2.9/2.2	3.4/2.5	4.6/2.9
18. Highway girder bridges, 4-lane through, span 25 m.	1.3/1.0	1.5/1.1	4.6/2.9
19.a) Highway girder bridges, 2-lane deck, 2-lane through, 4-lane deck, span 25 m; b) Railroad girder bridges, double track deck, open or ballast floor, span 25 m; c) Railroad girder bridges, single or double track through, ballast floors, span 25 m.	1.7/1.3	2.0/1.5	4.6/2.9
20.a) Railroad girder bridges, single track deck, open or ballast floors, span 25 m; b) Railroad girder bridges, single or double track through open floors, span 25 m.	2.6/1.9	3.0/2.2	4.6/2.9

DAMAGE - DISTANCE TABLES - 300 kt continued.

SERIAL & STRUCTURAL TYPE	DAMAGE RADII (km)		
	SEVERE	MODERATE	LIGHT
	AB/SB	AB/SB	AB/SB
(Bridges continued)			
21.a) Highway girder bridges, 2-lane through, 4-lane deck or through, span 60 m; b) Railroad girder bridges, double track deck or through, ballast floor, span 60 m.	2.2/1.6	2.5/1.9	6.8/4.4
22.a) Highway girder bridges, 2-lane deck, span 60 m; b) Railroad girder bridges, single track deck or through, ballast floors, span 60 m; c) Railroad girder bridges, double track deck or through, open floors, span 60 m.	3.0/2.2	3.4/2.6	6.8/4.4
23. Railroad girder bridges, single track deck or through open floors, span 60 m.	4.7/3.5	5.4/4.0	6.7/5.0
<u>Land Transportation Equipment</u> (Unprotected)			
24. Motor transport vehicles (cars, trucks, etc).	1.7/1.3	1.8/1.4	8.4/5.2
25. Truck mounted engineering equipment.	1.9/1.4	2.6/1.9	8.4/5.2
26. Bulldozers and graders.	1.7/1.3	1.9/1.4	8.4/5.2
27. Unloaded railroad cars.	5.2/3.9	6.1/4.5	11/7.8
28. Loaded railroad boxcars, flatcars, full tank cars and gondola cars (side-on orientation).	3.8/2.9	4.3/3.2	11/7.8
29. Loaded railroad boxcars, flatcars, full tank cars and gondola cars (end-on orientation).	1.3/1.3	1.5/1.5	11/7.8
30. Railroad locomotives (side-on orientation).	1.5/1.1	2.4/1.8	6.7/4.0
31. Railroad locomotives (end-on orientation)	0.7/0.7	1.1/1.1	6.7/4.0
Parked Aircraft (Unprotected, random orientation)			
32. Transport airplanes and helicopters.	6.7/4.0	8.4/5.2	11/7.8
33. Light aircraft.	8.4/5.2	11/7.8	12/9.3

DAMAGE - DISTANCE TABLES - 300 kt continued.

SERIAL & STRUCTURAL TYPE	DAMAGE RADII (km)		
	SEVERE	MODERATE	LIGHT
	AB/SB	AB/SB	AB/SB
Ships (Air blast effect)			
34. Merchant shipping.	1.2/1.2	1.3/1.3	5.0/3.4
Communications and Power Lines			
35. Telephone and power lines (oriented radially from the burst).	3.6/2.7	N/A	N/A
36. Telephone and power lines (oriented transversly from the burst).	4.9/3.6	N/A	N/A
37. Transmitting towers.	4.8/4.4	6.0/5.2	7.2/6.8
Forests (Blast wave wind effect)			
38. Unimproved coniferous forest stand.	5.5/2.7	7.0/3.5	N/A
39. Average desiduous forest stand.	7.6/3.8	9.1/4.6	9.3/5.6
Selected Urban Elongated (Line) Features.			
40. Highways, streets and airport runways.	N/A	N/A	6.4/4.8
41. Elevated roads and short span bridges.	6.4/4.8	8.6/7.0	11/7.8
42. Railroad yards and tracks.	N/A	N/A	11/7.8
43. Water mains.	N/A	N/A	6.4/4.8
44. Elevated water tanks.	6.4/4.8	N/A	11/7.8
45. Sewers and storm sewers.	N/A	N/A	3.4/2.5
46. Gas mains.	N/A	N/A	3.4/2.5
47. Underground electric power lines.	N/A	N/A	11/7.8

DAMAGE - DISTANCE TABLES - 300 kt continued.

SERIAL & STRUCTURAL TYPE	RADII OF BREAKAGE OR FAILURE (km)
Selected Structural Materials	AB/SB
48. Glass windows, large and small.	11/12
49. Corrugated asbestos siding.	11/7.8
50. Corrugated steel or aluminum paneling.	11/7.8
51. Brick wall panel, 20 or 30 cm thick (not reinforced).	6.7/4.1
52. Wood siding panels, standard house construction.	11/7.8
53. Concrete or cinder-block wall panels, 20 or 30 cm thick (not reinforced).	10/6

DAMAGE - DISTANCE TABLES - 300 kt continued.

SERIAL & STRUCTURAL TYPE		RADII OF FAILURE
Petroleum and Oil Storage Tanks		
54. Floating-roof and conical-roof storage tanks.	-	Use airburst and surface burst Radii of Failure graphs below.

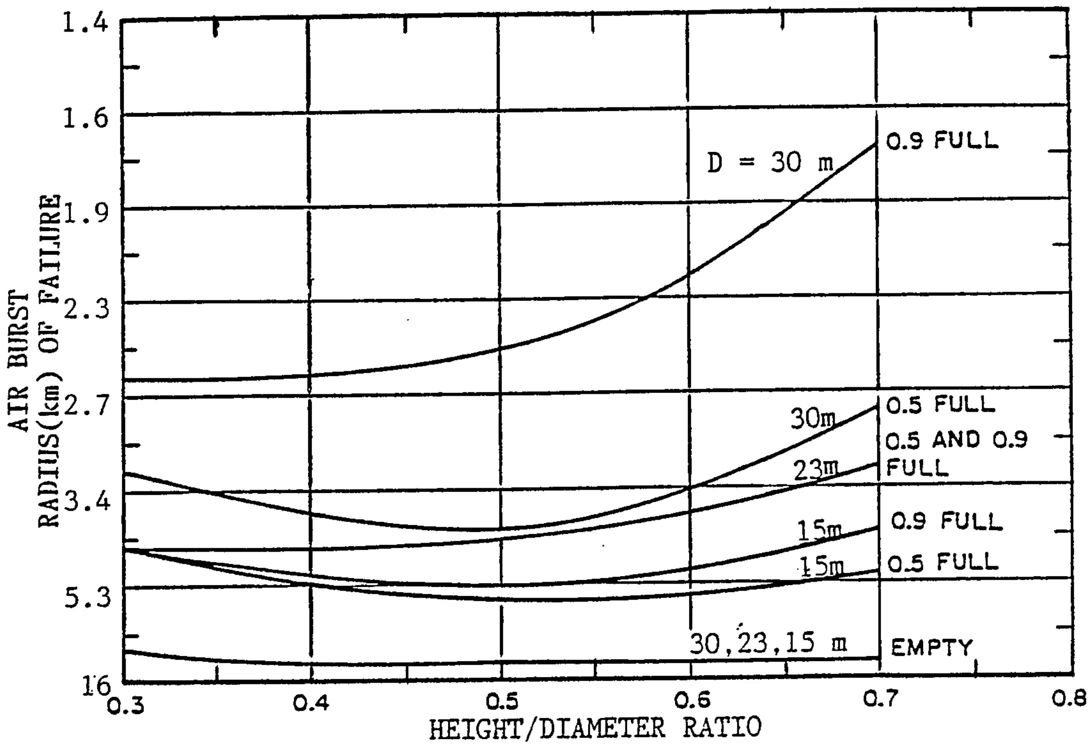


Figure 4B - 3 Radii (km) of Failure (loss of contents) for Storage Tanks of Diameter D from 300 kt Air Bursts.

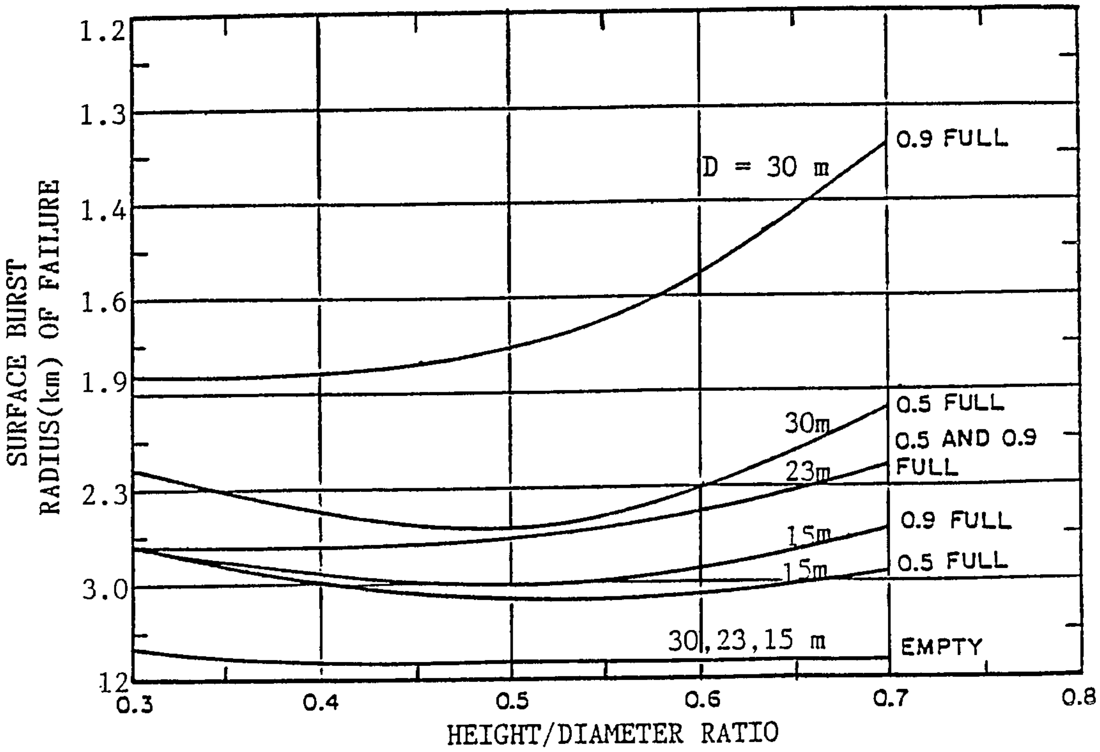


Figure 4B - 4 Radii (km) of Failure (loss of contents) for Storage Tanks of Diameter D from 300 kt Surface Bursts.

DAMAGE - DISTANCE TABLES - 300 kt continued.

SERIAL & STRUCTURAL TYPE	RADII OF DAMAGE (metres)		
	SEVERE	MODERATE	LIGHT
Moderately Deep Underground Structure (Ground shock damage)			
(Note: Figures are for ground shock damage from a contact burst. Moderately deep is defined as the condition where the ratio of depth of cover to the structure is greater than unity.)			
55. Small well designed underground structures.			
- Dry soil or dry soft rock	129 m	N/A	258 m
- Wet soil or wet soft rock	173	N/A	346
- Dry hard rock	103	N/A	206
- Wet hard rock	123	N/A	245
56. Long flexible structures such as buried pipelines, storage tanks, etc.			
- Dry soil or dry soft rock	155 m	206 m	309 m
- Wet soil or wet soft rock	208	276	414
- Dry hard rock	124	165	247
- Wet hard rock	147	196	294

FINAL NOTE:

"N/A" (not applicable) is used throughout the tables to indicate that a damage classification does not apply or is inappropriate for a particular structural type. A more detailed explanation will be found for the feature in Annex A - Damage Criteria.

PHYSICAL VULNERABILITY DATA

500 kt

Air Burst/Surface Burst

HEIGHT OF BURST FOR A TYPICAL AIR BURST - 660 m* to 1190 m
(*Lower figure is minimum height of burst for negligible early fallout.)

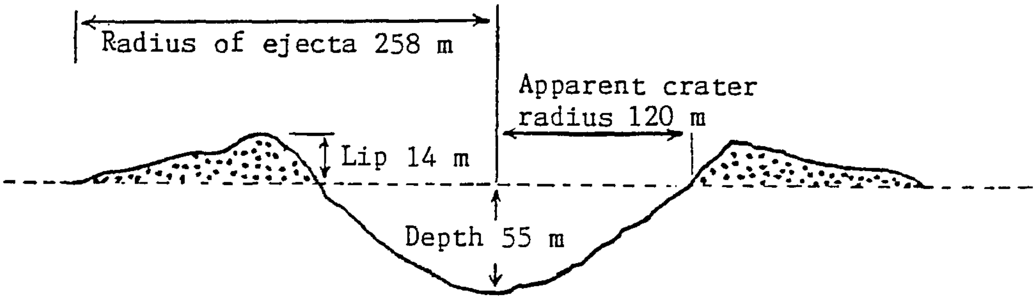
NUCLEAR CLOUD DIMENSIONS - Cloud radius 13.0 km
- Cloud top height 19.0 km
- Cloud bottom height 11.9 km

DISTANCES AT WHICH FLASHBURNS COULD OCCUR TO BARE SKIN (km - AB/SB)

Third-degree 10/6 Second-degree 12/8 First-degree 15/9

DURATION OF THE THERMAL PULSE - 6 seconds

SURFACE BURST CRATER DIMENSIONS - Dry soil



SAMPLE PEAK OVERPRESSURE RADII AND ASSOCIATED BLAST WIND SPEEDS

Peak Overpressure (kPa)	Radii (km-AB/SB)	Wind Speed (km/h)
10*	12.5/7.4	85
25	6.9/4.3	190
50	4.3/2.9	355
100	2.9/2.0	625
250	1.4/1.2	1200
500	1.0/0.9	1900

(*10 kPa = 1.45 psi)

DAMAGE - DISTANCE TABLES - 500 kt

SERIAL & STRUCTURAL TYPE	DAMAGE RADII (km)		
	SEVERE	MODERATE	LIGHT
Buildings	AB/SB	AB/SB	AB/SB
1. Multistory reinforced concrete building, blast resistant, windowless.	1.6/1.2	1.8/1.3	3.5/2.4
2. Multistory reinforced concrete frame and wall building, small window area.	3.7/2.7	4.1/3.1	13/9
3. Multistory wall-bearing brick apartment house, up to three stories.	5.3/4.0	5.9/4.5	13/9
4. Multistory wall-bearing building, monumental type, up to four stories.	3.7/2.8	4.2/3.2	13/9
5. Wood frame, house type, one or two stories.	7.0/5.3	8.0/6.0	13/9
6. Light steel frame industrial building, one story, light walls, 5-tonne crane capacity.	4.2/3.1	4.8/3.6	13/9
7. Heavy steel frame industrial building, one story, 25.5 to 51-tonne crane capacity.	3.3/2.4	3.7/2.8	13/9
8. Heavy steel frame industrial building, one story, 61 to 102-tonne crane capacity.	2.7/2.1	3.1/2.3	13/9
9. Multistory steel frame office-type building, 3 to 10 stories, earthquake resistant.	1.9/1.4	2.2/1.6	13/9
10. Multistory steel frame office-type building, 3 to 10 stories, non-earthquake resistant.	2.5/1.9	2.9/2.1	13/9
11. Multistory reinforced concrete frame office-type building, 3 to 10 stories, earthquake resistant.	2.1/1.6	2.4/1.8	13/9
12. Multistory reinforced concrete frame office-type building, 3 to 10 stories, non-earthquake resistant.	2.7/2.0	3.0/2.3	13/9

DAMAGE - DISTANCE TABLES - 500 kt continued.

	DAMAGE RADII (km)		
SERIAL & STRUCTURAL TYPE	SEVERE	MODERATE	LIGHT
Shallow Buried or Earth Covered Structures	AB/SB	AB/SB	AB/SB
(Note: Due to allowance for differences in design, soil, shape and orientation, the moderate damage radius for Serial 13 is within the radius of severe damage. Serial 14 is a similar case for light damage.)			
13. Light, corrugated steel arch surface structure; 1.5 m earth cover.	1.2/1.1	←	1.5/1.4
14. Buried concrete arch, 20 cm thick with 5 m span; 1.2 m earth cover.	0.6/0.6	0.9/0.8	←
Bridges			
15.a) Highway truss bridges, 4-lane, spans 60 to 120 m; b) Railroad truss bridges, double track ballast floor, spans 60 to 120 m.	2.7/2.1	3.2/2.4	5.4/3.5
16.a) Highway truss bridges, 2-lane, spans 60 to 120 m; b) Railroad truss bridges, single track ballast or double track open floors, spans 60 to 120 m; c) Railroad truss bridges, single track open floor, span 120 m.	3.3/2.5	3.7/2.7	5.4/3.5
17. Railroad truss bridges, single track open floor, span 60 m.	3.6/2.7	4.1/3.1	5.4/3.5
18. Highway girder bridges, 4-lane through, span 25 m.	1.6/1.2	1.8/1.4	5.4/3.5
19.a) Highway girder bridges, 2-lane deck, 2-lane through, 4-lane deck, span 25 m; b) Railroad girder bridges, double track deck, open or ballast floor, span 25 m; c) Railroad girder bridges, single or double track through, ballast floors, span 25 m.	2.1/1.6	2.4/1.8	5.4/3.5
20.a) Railroad girder bridges, single track deck, open or ballast floors, span 25 m; b) Railroad girder bridges, single or double track through open floors, span 25 m.	3.2/2.4	3.7/2.7	5.4/3.5

DAMAGE - DISTANCE TABLES - 500 kt continued.

SERIAL & STRUCTURAL TYPE	DAMAGE RADII (km) SEVERE	MODERATE	LIGHT
	AB/SB	AB/SB	AB/SB
(Bridges continued)			
21.a) Highway girder bridges, 2-lane through, 4-lane deck or through, span 60 m; b) Railroad girder bridges, double track deck or through, ballast floor, span 60 m.	2.7/2.0	3.1/3.2	5.4/3.5
22.a) Highway girder bridges, 2-lane deck, span 60 m; b) Railroad girder bridges, single track deck or through, ballast floors, span 60 m; c) Railroad girder bridges, double track deck or through, open floors, span 60 m.	3.7/2.7	4.2/3.2	5.4/3.5
23. Railroad girder bridges, single track deck or through open floors, span 60 m.	5.7/4.3	6.6/4.9	7/5
<u>Land Transportation Equipment</u> (Unprotected)			
24. Motor transport vehicles (cars, trucks, etc).	2.1/1.6	2.3/1.7	10/6
25. Truck mounted engineering equipment.	2.4/1.8	3.1/2.3	10/6
26. Bulldozers and graders.	2.1/1.6	2.4/1.8	10/6
27. Unloaded railroad cars.	6.4/4.8	7.4/5.6	13/9
28. Loaded railroad boxcars, flatcars, full tank cars and gondola cars (side-on orientation).	4.7/3.5	5.3/4.0	13/9
29. Loaded railroad boxcars, flatcars, full tank cars and gondola cars (end-on orientation).	1.6/1.6	1.8/1.8	13/9
30. Railroad locomotives (side-on orientation).	1.8/1.3	3.0/2.2	8/5
31. Railroad locomotives (end-on orientation)	0.8/0.8	1.3/1.3	8/5
<u>Parked Aircraft</u> (Unprotected, random orientation)			
32. Transport airplanes and helicopters.	8/5	10/6	13/9
33. Light aircraft.	10/6	13/9	15/11

DAMAGE - DISTANCE TABLES - 500 kt continued.

	DAMAGE RADII (km)		
SERIAL & STRUCTURAL TYPE	SEVERE	MODERATE	LIGHT
Ships (Air blast effect)	AB/SB	AB/SB	AB/SB
34. Merchant shipping.	1.4/1.4	1.6/1.6	6/4
Communications and Power Lines			
35. Telephone and power lines (oriented radially from the burst).	4.5/3.4	N/A	N/A
36. Telephone and power lines (oriented transversly from the burst).	5.9/4.2	N/A	N/A
37. Transmitting towers.	5.7/5.2	7.1/6.1	9/8
Forests (Blast wave wind effect)			
38. Unimproved coniferous forest stand.	6.8/3.4	8.6/4.3	N/A
39. Average desiduous forest stand.	9.3/4.6	11.0/5.5	12/7
Selected Urban Elongated (Line) Features			
40. Highways, streets and airport runways.	N/A	N/A	8/6
41. Elevated roads and short span bridges.	8/6	10/8	13/9
42. Railroad yards and tracks.	N/A	N/A	13/9
43. Water mains.	N/A	N/A	8/6
44. Elevated water tanks.	8/6	N/A	13/9
45. Sewers and storm sewers.	N/A	N/A	4.1/2.9
46. Gas mains.	N/A	N/A	4.1/2.9
47. Underground electric power lines.	N/A	N/A	13/9

DAMAGE - DISTANCE TABLES - 500 kt continued.

SERIAL & STRUCTURAL TYPE	RADII OF BREAKAGE OR FAILURE (km)
Selected Structural Materials	AB/SB
48. Glass windows, large and small.	19/14
49. Corrugated asbestos siding.	13/9
50. Corrugated steel or aluminum paneling.	13/9
51. Brick wall panel, 20 or 30 cm thick (not reinforced).	7.9/4.8
52. Wood siding panels, standard house construction.	13/9
53. Concrete or cinder-block wall panels, 20 or 30 cm thick (not reinforced).	12/7

DAMAGE - DISTANCE TABLES - 500 kt continued.

SERIAL & STRUCTURAL TYPE	RADII OF FAILURE
Petroleum and Oil Storage Tanks	
54. Floating-roof and conical-roof storage tanks.	Use airburst and surface burst Radii of Failure graphs below.

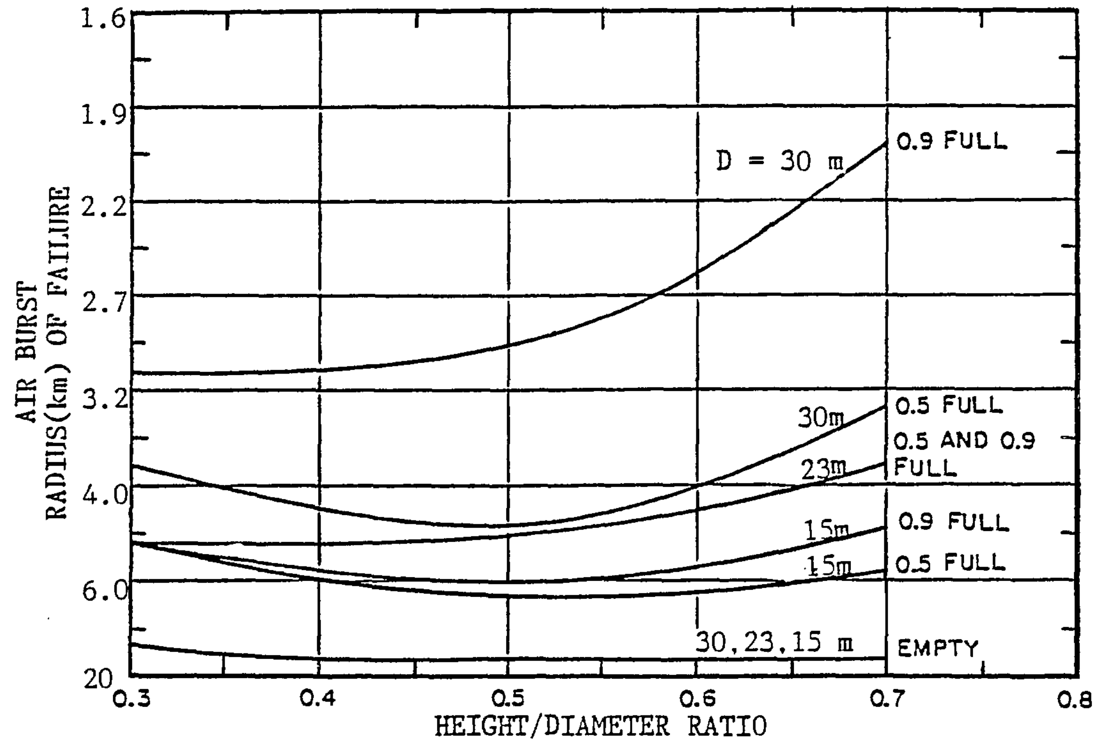


Figure 4B - 5 Radii (km) of Failure (loss of contents) for Storage Tanks of Diameter D from 500 kt Air Bursts.

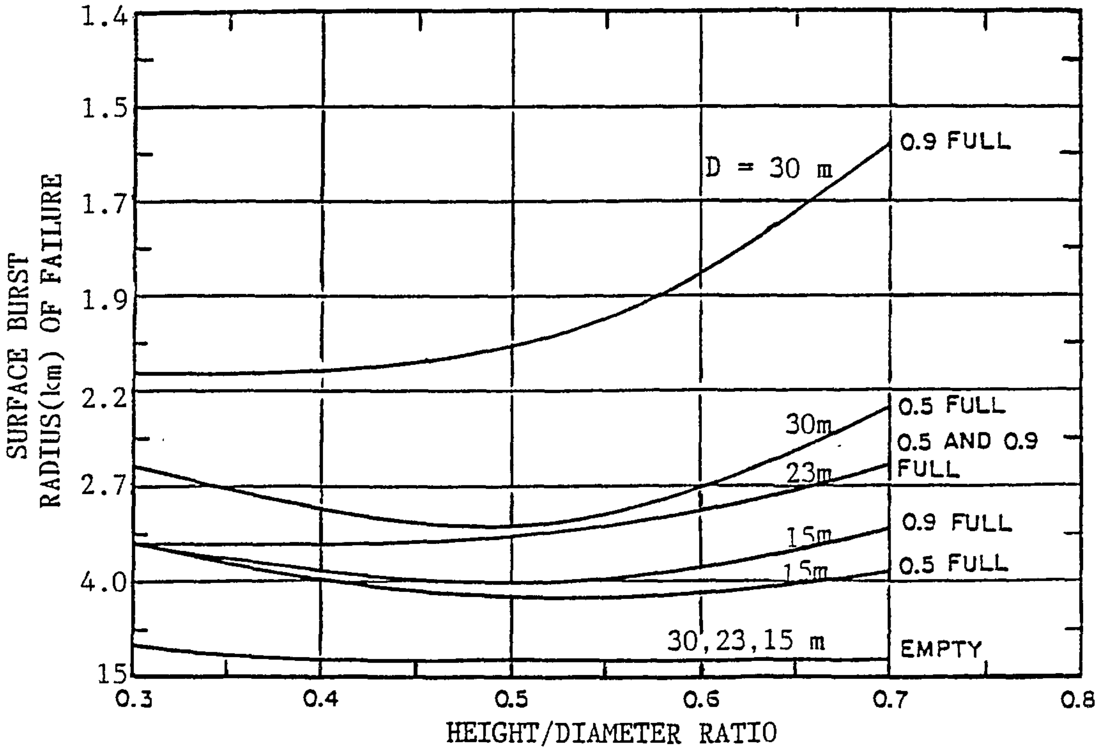


Figure 4B - 6 Radii (km) of Failure (loss of contents) for Storage Tanks of Diameter D from 500 kt Surface Bursts.

DAMAGE - DISTANCE TABLES - 500 kt continued.

SERIAL & STRUCTURAL TYPE	RADII OF DAMAGE (metres)		
	SEVERE	MODERATE	LIGHT
Moderately Deep Underground Structure (Ground shock damage) (Note: Figures are for ground shock damage from a contact burst. Moderately deep is defined as the condition where the ratio of depth of cover to the structure is greater than unity.)			
55. Small well designed underground structures.			
- Dry soil or dry soft rock	150 m	N/A	300 m
- Wet soil or wet soft rock	201	N/A	402
- Dry hard rock	120	N/A	240
- Wet hard rock	143	N/A	285
56. Long flexible structures such as buried pipelines, storage tanks, etc.			
- Dry soil or dry soft rock	180 m	240 m	360 m
- Wet soil or wet soft rock	241	322	482
- Dry hard rock	144	192	288
- Wet hard rock	171	228	342

FINAL NOTE:

"N/A" (not applicable) is used throughout the tables to indicate that a damage classification does not apply or is inappropriate for a particular structural type. A more detailed explanation will be found for the feature in Annex A - Damage Criteria.

PHYSICAL VULNERABILITY DATA

1 Mt

Air Burst/Surface Burst

HEIGHT OF BURST FOR A TYPICAL AIR BURST - 870 m* to 1500 m
(*Lower figure is minimum height of burst for negligible early fallout.)

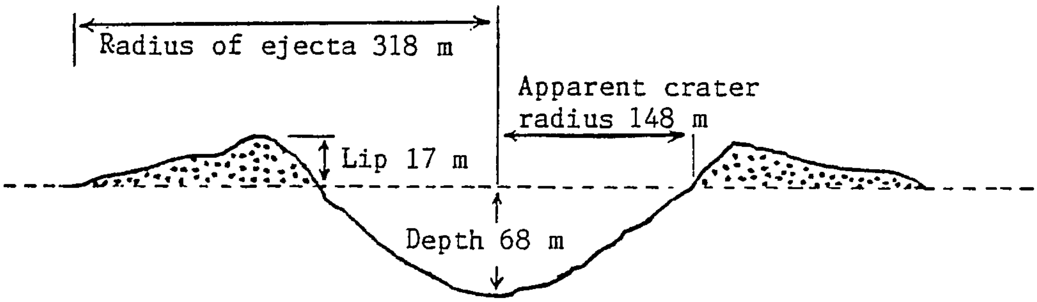
NUCLEAR CLOUD DIMENSIONS - Cloud radius 18.0 km
- Cloud top height 21.6 km
- Cloud bottom height 13.4 km

DISTANCES AT WHICH FLASHBURNS COULD OCCUR TO BARE SKIN (km - AB/SB)

Third-degree 13/8 Second-degree 15/9 First-degree 19/12

DURATION OF THE THERMAL PULSE - 9 seconds

SURFACE BURST CRATER DIMENSIONS - Dry soil



SAMPLE PEAK OVERPRESSURE RADII AND ASSOCIATED BLAST WIND SPEEDS

Peak Overpressure (kPa)	Radii (km-AB/SB)	Wind Speed (km/h)
10*	16/9	85
25	8.7/5.4	190
50	5.5/3.6	355
100	3.7/2.5	625
250	1.8/1.6	1200
500	1.3/1.2	1900

(*10 kPa = 1.45 psi)

DAMAGE - DISTANCE TABLES - 1 Mt

SERIAL & STRUCTURAL TYPE	DAMAGE RADII (km)		
	SEVERE	MODERATE	LIGHT
	AB/SB	AB/SB	AB/SB
Buildings			
1. Multistory reinforced concrete building, blast resistant, windowless.	2.0/1.5	2.2/1.7	4.4/3
2. Multistory reinforced concrete frame and wall building, small window area.	4.7/3.5	5.2/3.9	16/12
3. Multistory wall-bearing brick apartment house, up to three stories.	6.5/4.8	7.3/5.5	16/12
4. Multistory wall-bearing building, monumental type, up to four stories.	4.5/3.4	5.2/3.9	16/12
5. Wood frame, house type, one or two stories.	8.8/6.6	10.1/7.5	16/12
6. Light steel frame industrial building, one story, light walls, 5-tonne crane capacity.	5.6/4.2	6.3/4.7	16/12
7. Heavy steel frame industrial building, one story, 25.5 to 51-tonne crane capacity.	4.3/3.2	4.8/3.6	16/12
8. Heavy steel frame industrial building, one story, 61 to 102-tonne crane capacity.	3.7/2.7	4.0/3.0	16/12
9. Multistory steel frame office-type building, 3 to 10 stories, earthquake resistant.	2.5/1.9	2.8/2.1	16/12
10. Multistory steel frame office-type building, 3 to 10 stories, non-earthquake resistant.	3.4/2.6	3.9/2.9	16/12
11. Multistory reinforced concrete frame office-type building, 3 to 10 stories, earthquake resistant.	2.7/2.1	3.1/2.3	16/12
12. Multistory reinforced concrete frame office-type building, 3 to 10 stories, non-earthquake resistant.	3.6/2.7	3.9/2.9	16/12

DAMAGE - DISTANCE TABLES - 1 Mt continued.

SERIAL & STRUCTURAL TYPE	DAMAGE RADII (km)		
	SEVERE	MODERATE	LIGHT
	AB/SB	AB/SB	AB/SB
Shallow Buried or Earth Covered Structures			
(Note: Due to allowance for differences in design, soil, shape and orientation, the moderate damage radius for Serial 13 is within the radius of severe damage. Serial 14 is a similar case for light damage.)			
13. Light, corrugated steel arch surface structure; 1.5 m earth cover.	1.6/1.5	←	2.0/1.7
14. Buried concrete arch, 20 cm thick with 5 m span; 1.2 m earth cover.	0.8/0.8	1.1/1.1	←
Bridges			
15.a) Highway truss bridges, 4-lane, spans 60 to 120 m;	3.7/2.8	4.2/3.1	7/5
b) Railroad truss bridges, double track ballast floor, spans 60 to 120 m.			
16.a) Highway truss bridges, 2-lane, spans 60 to 120 m;	4.3/3.2	4.9/3.7	7/5
b) Railroad truss bridges, single track ballast or double track open floors, spans 60 to 120 m;			
c) Railroad truss bridges, single track open floor, span 120 m.			
17. Railroad truss bridges, single track open floor, span 60 m.	4.9/3.6	5.3/4.0	7/5
18. Highway girder bridges, 4-lane through, span 25 m.	2.1/1.5	2.4/1.8	7/5
19.a) Highway girder bridges, 2-lane deck, 2-lane through, 4-lane deck, span 25 m;	2.8/2.1	3.2/2.4	7/5
b) Railroad girder bridges, double track deck, open or ballast floor, span 25 m;			
c) Railroad girder bridges, single or double track through, ballast floors, span 25 m.			
20.a) Railroad girder bridges, single track deck, open or ballast floors, span 25 m;	4.2/3.2	4.8/3.6	7/5
b) Railroad girder bridges, single or double track through open floors, span 25 m.			

DAMAGE - DISTANCE TABLES - 1 Mt continued.

SERIAL & STRUCTURAL TYPE	DAMAGE RADII (km)		
	SEVERE	MODERATE	LIGHT
	AB/SB	AB/SB	AB/SB
(Bridges continued)			
21.a) Highway girder bridges, 2-lane through, 4-lane deck or through, span 60 m; b) Railroad girder bridges, double track deck or through, ballast floor, span 60 m.	3.7/2.7	4.2/3.2	7/5
22.a) Highway girder bridges, 2-lane deck, span 60 m; b) Railroad girder bridges, single track deck or through, ballast floors, span 60 m; c) Railroad girder bridges, double track deck or through, open floors, span 60 m.	4.9/3.7	5.5/4.1	7/5
23. Railroad girder bridges, single track deck or through open floors, span 60 m.	7.6/5.7	8.5/6.4	9/7
Land Transportation Equipment (Unprotected)			
24. Motor transport vehicles (cars, trucks, etc).	2.7/2.1	3.1/2.3	13/8
25. Truck mounted engineering equipment.	3.1/2.4	4.2/3.2	13/8
26. Bulldozers and graders.	2.7/2.1	3.1/2.4	13/8
27. Unloaded railroad cars.	8.3/6.2	9.8/7.3	16/12
28. Loaded railroad boxcars, flatcars, full tank cars and gondola cars (side-on orientation).	6.2/4.6	7.0/5.2	16/12
29. Loaded railroad boxcars, flatcars, full tank cars and gondola cars (end-on orientation).	2.0/2.0	2.3/2.3	16/12
30. Railroad locomotives (side-on orientation).	2.4/1.8	4.0/3.0	10/6
31. Railroad locomotives (end-on orientation)	1.0/1.0	1.7/1.7	10/6
Parked Aircraft (Unprotected, random orientation)			
32. Transport airplanes and helicopters.	10/6	13/8	16/12
33. Light aircraft.	13/8	16/12	19/14

DAMAGE - DISTANCE TABLES - 1 Mt continued.

SERIAL & STRUCTURAL TYPE		DAMAGE RADII (km) SEVERE	MODERATE	LIGHT
Ships (Air blast effect)		AB/SB	AB/SB	AB/SB
34.	Merchant shipping.	1.7/1.7	2.0/2.0	8/5
Communications and Power Lines				
35.	Telephone and power lines (oriented radially from the burst).	5.9/4.4	N/A	N/A
36.	Telephone and power lines (oriented transversly from the burst).	7.8/5.8	N/A	N/A
37.	Transmitting towers.	7.2/6.6	8.9/7.7	11/10
Forests (Blast wave wind effect)				
38.	Unimproved coniferous forest stand.	8.8/4.4	11.0/5.6	N/A
39.	Average desiduous forest stand.	10.0/6.1	14/7	15/8
Selected Urban Elongated (Line) Features				
40.	Highways, streets and airport runways.	N/A	N/A	9.5/7.2
41.	Elevated roads and short span bridges.	9.5/7.2	12.9/10.5	16/13
42.	Railroad yards and tracks.	N/A	N/A	16/13
43.	Water mains.	N/A	N/A	9.5/7.2
44.	Elevated water tanks.	9.5/7.2	N/A	16/13
45.	Sewers and storm sewers.	N/A	N/A	5.2/3.7
46.	Gas mains.	N/A	N/A	5.2/3.7
47.	Underground electric power lines.	N/A	N/A	16/13

DAMAGE - DISTANCE TABLES - 1 Mt continued.

SERIAL & STRUCTURAL TYPE		RADII OF BREAKAGE OR FAILURE (km)
Selected Structural Materials		AB/SB
48.	Glass windows, large and small.	24/18
49.	Corrugated asbestos siding.	16/12
50.	Corrugated steel or aluminum paneling.	16/12
51.	Brick wall panel, 20 or 30 cm thick (not reinforced).	10/6
52.	Wood siding panels, standard house construction.	16/12
53.	Concrete or cinder-block wall panels, 20 or 30 cm thick (not reinforced).	15/9

SERIAL & STRUCTURAL TYPE		RADII OF FAILURE
Petroleum and Oil Storage Tanks		
54. Floating-roof and conical-roof storage tanks.	-	Use airburst and surface burst Radii of Failure graphs below.

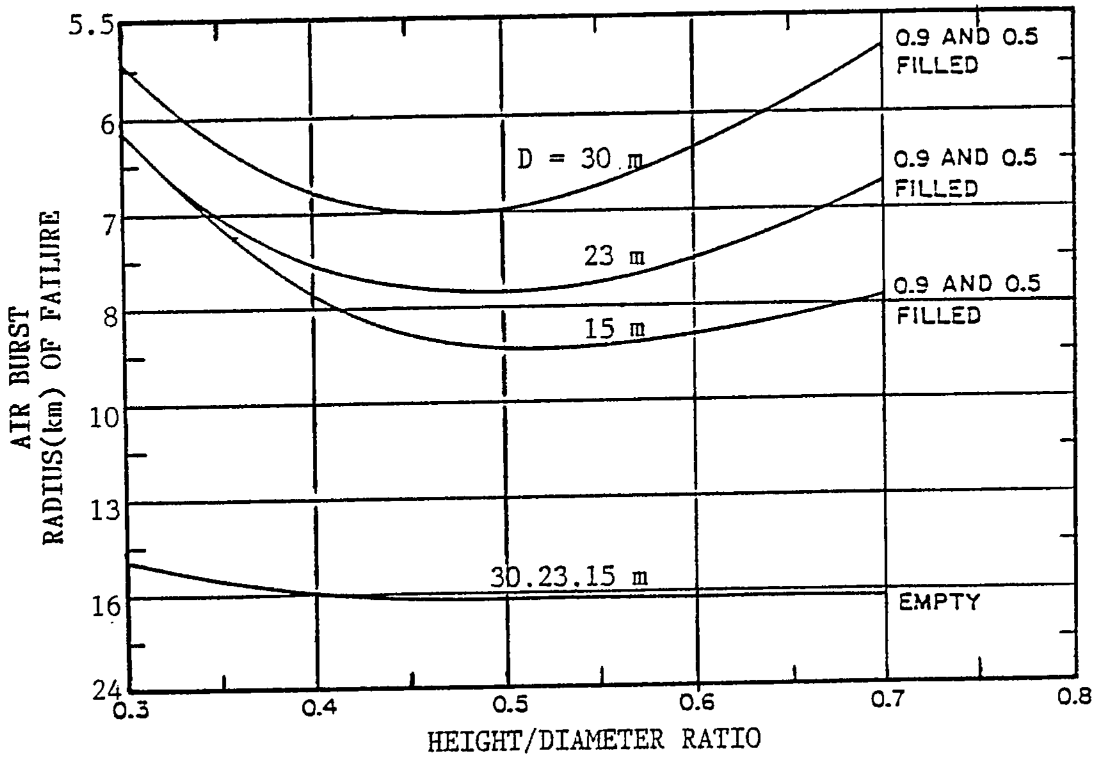


Figure 4B - 7 Radii (km) of Failure (loss of contents) for Storage Tanks of Diameter D from 1 Mt Air Bursts.

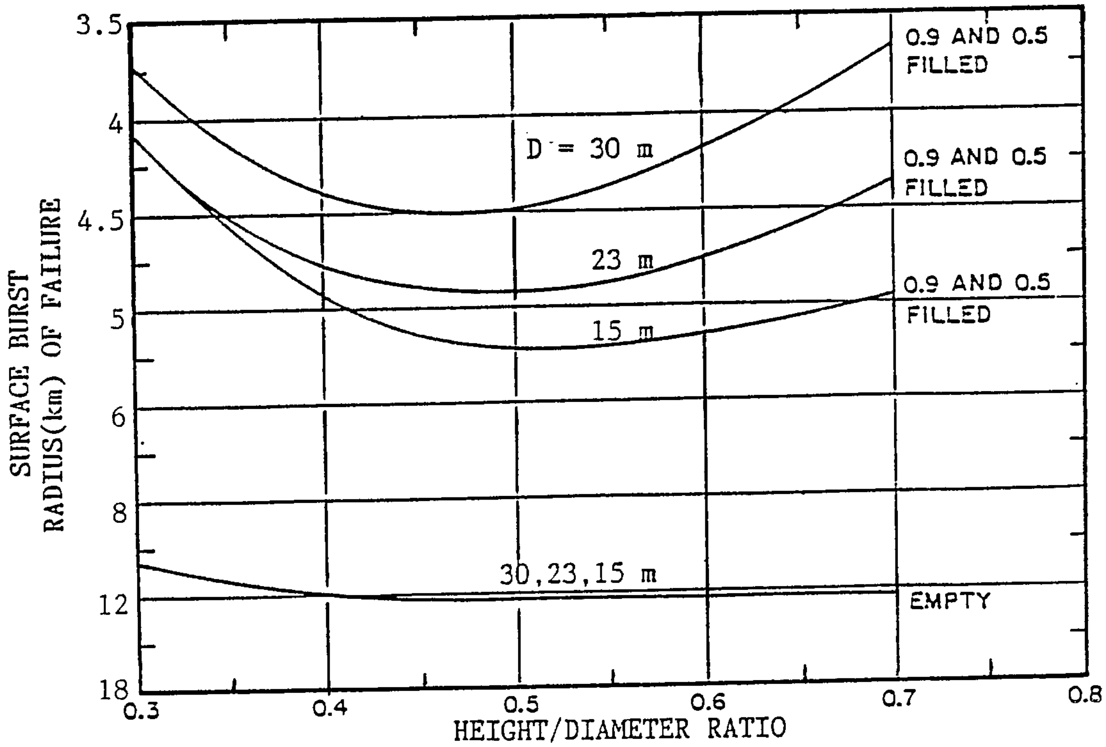


Figure 4B - 8 Radii (km) of Failure (loss of contents) for Storage Tanks of Diameter D from 1 Mt Surface Bursts.

DAMAGE - DISTANCE TABLES - 1 Mt continued.

SERIAL & STRUCTURAL TYPE	RADII OF DAMAGE (metres)		
	SEVERE	MODERATE	LIGHT
<u>Moderately Deep Underground Structure</u> (Ground shock damage)			
(Note: Figures are for ground shock damage from a contact burst. Moderately deep is defined as the condition where the ratio of depth of cover to the structure is greater than unity.)			
55. Small well designed underground structures.			
- Dry soil or dry soft rock	185 m	N/A	370 m
- Wet soil or wet soft rock	248	N/A	496
- Dry hard rock	148	N/A	296
- Wet hard rock	176	N/A	352
56. Long flexible structures such as buried pipelines, storage tanks, etc.			
- Dry soil or dry soft rock	222 m	296 m	444 m
- Wet soil or wet soft rock	297	397	595
- Dry hard rock	178	237	355
- Wet hard rock	211	281	422

FINAL NOTE:

"N/A" (not applicable) is used throughout the tables to indicate that a damage classification does not apply or is inappropriate for a particular structural type. A more detailed explanation will be found for the feature in Annex A - Damage Criteria.

PHYSICAL VULNERABILITY DATA

5 Mt

Air Burst/Surface Burst

HEIGHT OF BURST FOR A TYPICAL AIR BURST - 1660 m* to 2565 m
(*Lower figure is minimum height of burst for negligible early fallout.)

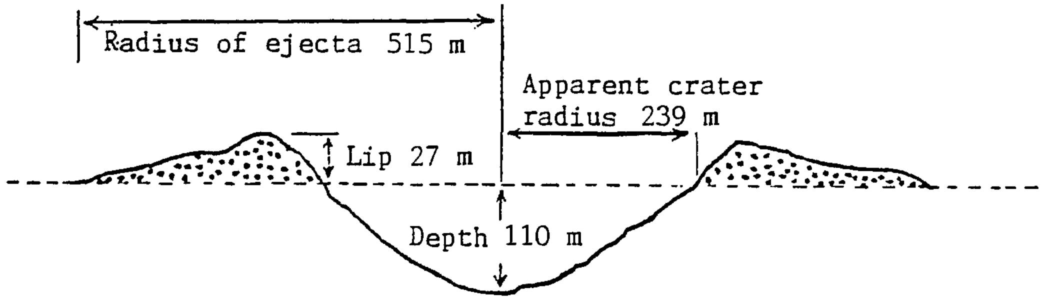
NUCLEAR CLOUD DIMENSIONS - Cloud radius 35.0 km
- Cloud top height 28.8 km
- Cloud bottom height 17.3 km

DISTANCES AT WHICH FLASHBURNS COULD OCCUR TO BARE SKIN (km - AB/SB)

Third-degree 24/15 Second-degree 28/17 First-degree 34/21

DURATION OF THE THERMAL PULSE - 18 seconds

SURFACE BURST CRATER DIMENSIONS - Dry soil



SAMPLE PEAK OVERPRESSURE RADII AND ASSOCIATED BLAST WIND SPEEDS

Peak Overpressure (kPa)	Radii (km-AB/SB)	Wind Speed (km/h)
10*	27/16	85
25	15/19	190
50	9/6	355
100	6/4	625
250	3.0/2.7	1200
500	2.2/2.0	1900

(*10 kPa = 1.45 psi)

DAMAGE - DISTANCE TABLES - 5 Mt

SERIAL & STRUCTURAL TYPE	DAMAGE RADII (km) SEVERE	MODERATE	LIGHT
Buildings	AB/SB	AB/SB	AB/SB
1. Multistory reinforced concrete building, blast resistant, windowless.	3.7/2.7	3.9/2.9	8/5
2. Multistory reinforced concrete frame and wall building, small window area.	8.7/6.5	9.4/7.1	28/20
3. Multistory wall-bearing brick apartment house, up to three stories.	11.9/8.9	12.5/9.4	28/20
4. Multistory wall-bearing building, monumental type, up to four stories.	8.3/6.2	8.9/6.7	28/20
5. Wood frame, house type, one or two stories.	16/12	17/13	28/20
6. Light steel frame industrial building, one story, light walls, 5-tonne crane capacity.	11/8	12/9	28/20
7. Heavy steel frame industrial building, one story, 25.5 to 51-tonne crane capacity.	8.1/6.1	8.5/6.4	28/20
8. Heavy steel frame industrial building, one story, 61 to 102-tonne crane capacity.	6.8/5.1	7.3/5.5	28/20
9. Multistory steel frame office-type building, 3 to 10 stories, earthquake resistant.	4.9/3.7	5.2/3.9	28/20
10. Multistory steel frame office-type building, 3 to 10 stories, non-earthquake resistant.	6.7/5.0	7.2/5.4	28/20
11. Multistory reinforced concrete frame office-type building, 3 to 10 stories, earthquake resistant.	5.2/3.9	5.5/4.2	28/20
12. Multistory reinforced concrete frame office-type building, 3 to 10 stories, non-earthquake resistant.	6.7/5.0	7.1/5.3	28/20

DAMAGE - DISTANCE TABLES - 5 Mt continued.

SERIAL & STRUCTURAL TYPE	DAMAGE RADII (km)		
	SEVERE	MODERATE	LIGHT
	AB/SB	AB/SB	AB/SB
Shallow Buried or Earth Covered Structures			
(Note: Due to allowance for differences in design, soil, shape and orientation, the moderate damage radius for Serial 13 is within the radius of severe damage. Serial 14 is a similar case for light damage.)			
13. Light, corrugated steel arch surface structure; 1.5 m earth cover.	2.7/2.5	←	3.3/3.0
14. Buried concrete arch, 20 cm thick with 5 m span; 1.2 m earth cover.	1.3/1.3	1.8/1.8	←
Bridges			
15.a) Highway truss bridges, 4-lane, spans 60 to 120 m; b) Railroad truss bridges, double track ballast floor, spans 60 to 120 m.	7.3/5.5	7.7/5.8	12/8
16.a) Highway truss bridges, 2-lane, spans 60 to 120 m; b) Railroad truss bridges, single track ballast or double track open floors, spans 60 to 120 m; c) Railroad truss bridges, single track open floor, span 120 m.	8.5/6.4	9.1/6.8	12/8
17. Railroad truss bridges, single track open floor, span 60 m.	9.1/6.9	9.9/7.4	12/8
18. Highway girder bridges, 4-lane through, span 25 m.	4.0/3.0	4.3/3.2	12/8
19.a) Highway girder bridges, 2-lane deck, 2-lane through, 4-lane deck, span 25 m; b) Railroad girder bridges, double track deck, open or ballast floor, span 25 m; c) Railroad girder bridges, single or double track through, ballast floors, span 25 m.	5.5/4.1	5.8/4.3	12/8
20.a) Railroad girder bridges, single track deck, open or ballast floors, span 25 m; b) Railroad girder bridges, single or double track through open floors, span 25 m.	8.2/6.1	8.5/6.4	12/8

DAMAGE - DISTANCE TABLES - 5 Mt continued.

SERIAL & STRUCTURAL TYPE	DAMAGE RADII (km)		
	SEVERE	MODERATE	LIGHT
(Bridges continued)	AB/SB	AB/SB	AB/SB
21.a) Highway girder bridges, 2-lane through, 4-lane deck or through, span 60 m; b) Railroad girder bridges, double track deck or through, ballast floor, span 60 m.	7.3/5.5	7.8/5.9	12/8
22.a) Highway girder bridges, 2-lane deck, span 60 m; b) Railroad girder bridges, single track deck or through, ballast floors, span 60 m; c) Railroad girder bridges, double track deck or through, open floors, span 60 m.	9.7/7.3	10.1/7.6	12/8
23. Railroad girder bridges, single track deck or through open floors, span 60 m.	15/11	16/12	17/13
Land Transportation Equipment (Unprotected)			
24. Motor transport vehicles (cars, trucks, etc).	5.3/4.0	5.8/4.3	21/13
25. Truck mounted engineering equipment.	6.0/4.5	7.9/5.9	21/13
26. Bulldozers and graders.	5.3/4.0	6.0/4.5	21/13
27. Unloaded railroad cars.	16/12	19/14	28/20
28. Loaded railroad boxcars, flatcars, full tank cars and gondola cars (side-on orientation).	12/9	13/10	28/20
29. Loaded railroad boxcars, flatcars, full tank cars and gondola cars (end-on orientation).	3.4/3.4	3.9/3.9	28/20
30. Railroad locomotives (side-on orientation).	4.5/3.4	7.6/5.7	17/10
31. Railroad locomotives (end-on orientation)	1.8/1.8	2.5/2.5	17/10
Parked Aircraft (Unprotected, random orientation)			
32. Transport airplanes and helicopters.	17/10	21/13	28/20
33. Light aircraft.	21/13	28/20	32/24

DAMAGE - DISTANCE TABLES - 5 Mt continued.

SERIAL & STRUCTURAL TYPE	DAMAGE RADII (km) SEVERE	 MODERATE	 LIGHT
Ships (Air blast effect)	AB/SB	AB/SB	AB/SB
34. Merchant shipping.	2.9/2.9	3.4/3.4	13/9
Communications and Power Lines			
35. Telephone and power lines (oriented radially from the burst).	11.2/8.4	N/A	N/A
36. Telephone and power lines (oriented transversly from the burst).	15/11	N/A	N/A
37. Transmitting towers.	12/11	15/13	18/17
Forests (Blast wave wind effect)			
38. Unimproved coniferous forest stand.	17/8	21/11	N/A
39. Average desiduous forest stand.	22/11	25/13	26/14
Selected Urban Elongated (Line) Features			
40. Highways, streets and airport runways.	N/A	N/A	16/12
41. Elevated roads and short span bridges.	16/12	22/18	28/20
42. Railroad yards and tracks.	N/A	N/A	28/20
43. Water mains.	N/A	N/A	16/12
44. Elevated water tanks.	16/12	N/A	28/20
45. Sewers and storm sewers.	N/A	N/A	9/6
46. Gas mains.	N/A	N/A	9/6
47. Underground electric power lines.	N/A	N/A	28/20

DAMAGE - DISTANCE TABLES - 5 Mt continued.

SERIAL & STRUCTURAL TYPE		RADII OF BREAKAGE OR FAILURE (km)
Selected Structural Materials		AB/SB
48.	Glass windows, large and small.	41/31
49.	Corrugated asbestos siding.	28/20
50.	Corrugated steel or aluminum paneling.	28/20
51.	Brick wall panel, 20 or 30 cm thick (not reinforced).	17/10
52.	Wood siding panels, standard house construction.	28/20
53.	Concrete or cinder-block wall panels, 20 or 30 cm thick (not reinforced).	26/15

DAMAGE - DISTANCE TABLES - 5 Mt continued.

SERIAL & STRUCTURAL TYPE		RADII OF FAILURE
Petroleum and Oil Storage Tanks		
54. Floating-roof and conical-roof storage tanks.	-	Use airburst and surface burst Radii of Failure graphs below.

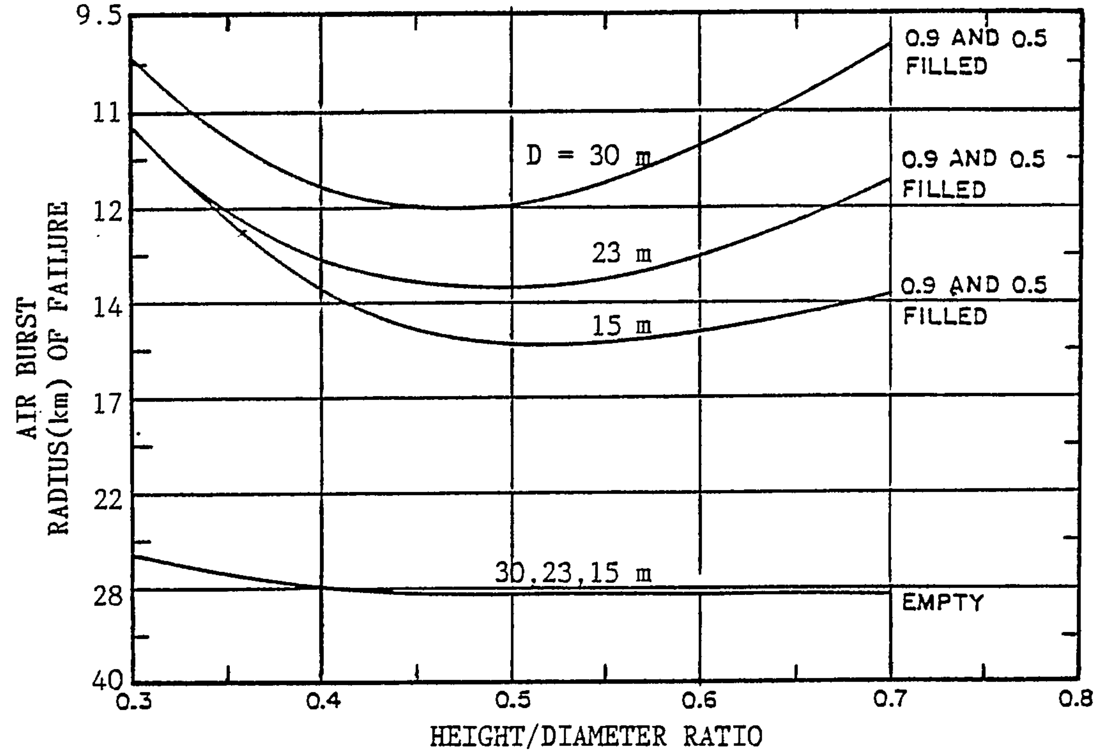


Figure 4B - 9 Radii (km) of Failure (loss of contents) for Storage Tanks of Diameter D from 5 Mt Air Bursts.

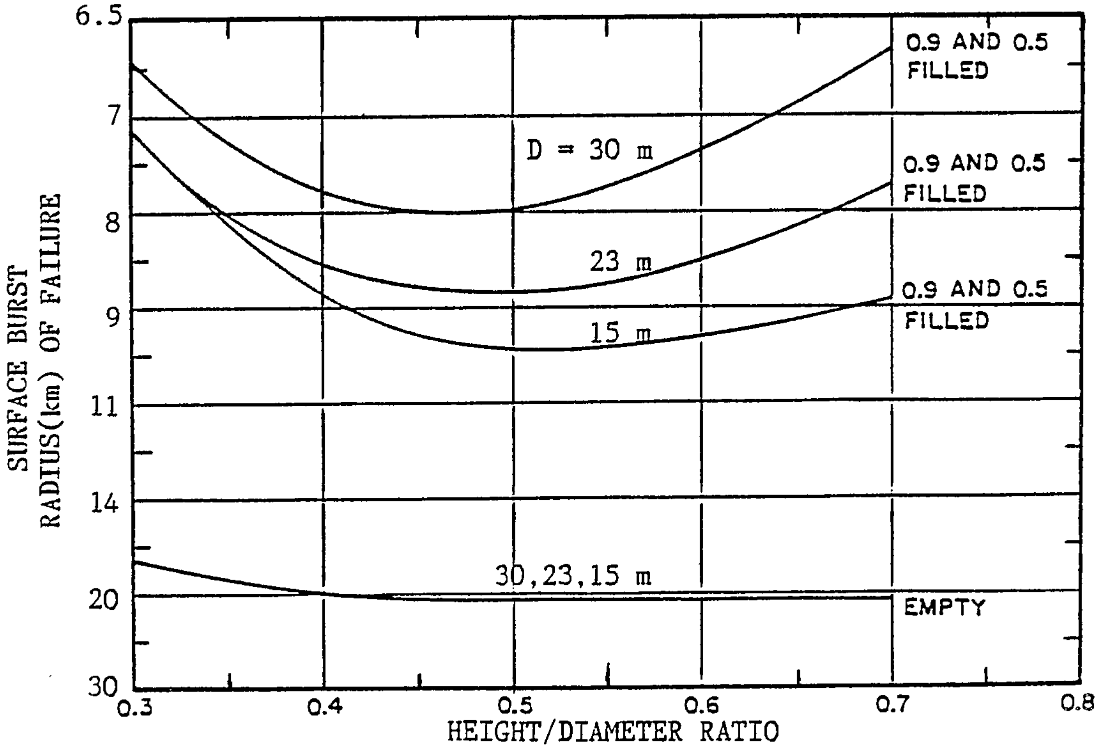


Figure 4B - 10 Radii (km) of Failure (loss of contents) for Storage Tanks of Diameter D from 5 Mt Surface Bursts.

DAMAGE - DISTANCE TABLES - 5 Mt continued.

SERIAL & STRUCTURAL TYPE	RADII OF DAMAGE (metres) SEVERE	MODERATE	LIGHT
Moderately Deep Underground Structure (Ground shock damage) (Note: Figures are for ground shock damage from a contact burst. Moderately deep is defined as the condition where the ratio of depth of cover to the structure is greater than unity.)			
55. Small well designed underground structures.			
- Dry soil or dry soft rock	299 m	N/A	598 m
- Wet soil or wet soft rock	401	N/A	801
- Dry hard rock	239	N/A	478
- Wet hard rock	284	N/A	568
56. Long flexible structures such as buried pipelines, storage tanks, etc.			
- Dry soil or dry soft rock	359 m	478 m	717 m
- Wet soil or wet soft rock	481	641	961
- Dry hard rock	287	382	574
- Wet hard rock	341	454	681

FINAL NOTE:

"N/A" (not applicable) is used throughout the tables to indicate that a damage classification does not apply or is inappropriate for a particular structural type. A more detailed explanation will be found for the feature in Annex A - Damage Criteria.

PHYSICAL VULNERABILITY DATA

10 Mt

Air Burst/Surface Burst

HEIGHT OF BURST FOR A TYPICAL AIR BURST - 2190 m* to 3230 m
(*Lower figure is minimum height of burst for negligible early fallout.)

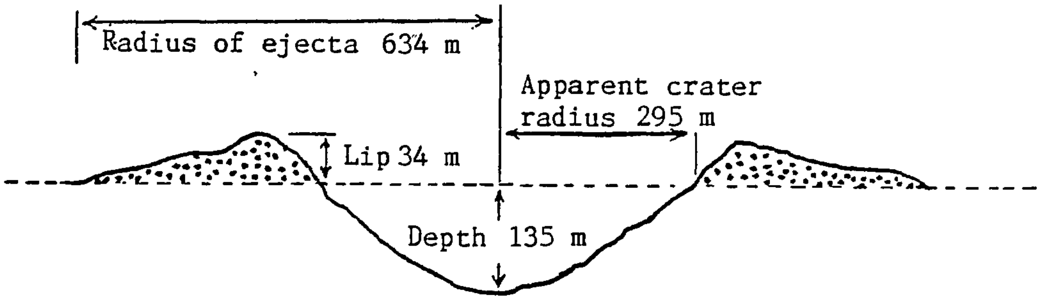
NUCLEAR CLOUD DIMENSIONS - Cloud radius 48 km
- Cloud top height 33 km
- Cloud bottom height 19 km

DISTANCES AT WHICH FLASHBURNS COULD OCCUR TO BARE SKIN (km - AB/SB)

Third-degree 31/19 Second-degree 35/22 First-degree 42/26

DURATION OF THE THERMAL PULSE - 24 seconds

SURFACE BURST CRATER DIMENSIONS - Dry soil



SAMPLE PEAK OVERPRESSURE RADII AND ASSOCIATED BLAST WIND SPEEDS

Peak Overpressure (kPa)	Radii (km-AB/SB)	Wind Speed (km/h)
10*	34/20	85
25	19/12	190
50	12/8	355
100	8/5	625
250	3.8/3.4	1200
500	2.7/2.6	1900

(*10 kPa = 1.45 psi)

DAMAGE - DISTANCE TABLES - 10 Mt

SERIAL & STRUCTURAL TYPE	DAMAGE RADII (km) SEVERE	MODERATE	LIGHT
Buildings	AB/SB	AB/SB	AB/SB
1. Multistory reinforced concrete building, blast resistant, windowless.	4.6/3.4	4.9/3.7	10/7
2. Multistory reinforced concrete frame and wall building, small window area.	11.5/8.6	11.9/8.9	35/25
3. Multistory wall-bearing brick apartment house, up to three stories.	15.2/11.4	15.8/11.9	35/25
4. Multistory wall-bearing building, monumental type, up to four stories.	10.7/8.0	11.1/8.3	35/25
5. Wood frame, house type, one or two stories.	21/16	22/16.5	35/25
6. Light steel frame industrial building, one story, light walls, 5-tonne crane capacity.	15/11	16/12	35/25
7. Heavy steel frame industrial building, one story, 25.5 to 51-tonne crane capacity.	10.7/8.0	11.3/8.5	35/25
8. Heavy steel frame industrial building, one story, 61 to 102-tonne crane capacity.	9.1/6.8	9.6/7.2	35/25
9. Multistory steel frame office-type building, 3 to 10 stories, earthquake resistant.	6.5/4.9	6.7/5.1	35/25
10. Multistory steel frame office-type building, 3 to 10 stories, non-earthquake resistant.	9.1/6.8	9.6/7.2	35/25
11. Multistory reinforced concrete frame office-type building, 3 to 10 stories, earthquake resistant.	6.8/5.1	7.3/5.6	35/25
12. Multistory reinforced concrete frame office-type building, 3 to 10 stories, non-earthquake resistant.	8.9/6.7	9.4/7.1	35/25

DAMAGE - DISTANCE TABLES - 10 Mt continued.

SERIAL & STRUCTURAL TYPE	DAMAGE RADII (km)		
	SEVERE	MODERATE	LIGHT
	AB/SB	AB/SB	AB/SB
Shallow Buried or Earth Covered Structures (Note: Due to allowance for differences in design, soil, shape and orientation, the moderate damage radius for Serial 13 is within the radius of severe damage. Serial 14 is a similar case for light damage.)			
13. Light, corrugated steel arch surface structure; 1.5 m earth cover.	3.4/3.1	←	4.2/3.7
14. Buried concrete arch, 20 cm thick with 5 m span; 1.2 m earth cover.	1.6/1.6	2.3/2.3	←
Bridges			
15.a) Highway truss bridges, 4-lane, spans 60 to 120 m; b) Railroad truss bridges, double track ballast floor, spans 60 to 120 m.	9.9/7.5	10.3/7.7	15/10
16.a) Highway truss bridges, 2-lane, spans 60 to 120 m; b) Railroad truss bridges, single track ballast or double track open floors, spans 60 to 120 m; c) Railroad truss bridges, single track open floor, span 120 m.	11.4/8.6	11.9/8.9	15/10
17. Railroad truss bridges, single track open floor, span 60 m.	12.2/9.1	12.8/9.6	15/10
18. Highway girder bridges, 4-lane through, span 25 m.	5.2/3.9	5.5/4.1	15/10
19.a) Highway girder bridges, 2-lane deck, 2-lane through, 4-lane deck, span 25 m; b) Railroad girder bridges, double track deck, open or ballast floor, span 25 m; c) Railroad girder bridges, single or double track through, ballast floors, span 25 m.	7.3/5.5	7.7/5.8	15/10
20.a) Railroad girder bridges, single track deck, open or ballast floors, span 25 m; b) Railroad girder bridges, single or double track through open floors, span 25 m.	10.8/8.1	11.4/8.6	15/10

DAMAGE - DISTANCE TABLES - 10 Mt continued.

SERIAL & STRUCTURAL TYPE	DAMAGE RADII (km)		
	SEVERE	MODERATE	LIGHT
(Bridges continued)	AB/SB	AB/SB	AB/SB
21.a) Highway girder bridges, 2-lane through, 4-lane deck or through, span 60 m; b) Railroad girder bridges, double track deck or through, ballast floor, span 60 m.	10.0/7.5	10.4/7.8	15/10
22.a) Highway girder bridges, 2-lane deck, span 60 m; b) Railroad girder bridges, single track deck or through, ballast floors, span 60 m; c) Railroad girder bridges, double track deck or through, open floors, span 60 m.	12.7/9.5	13.4/10.1	15/11
23. Railroad girder bridges, single track deck or through open floors, span 60 m.	20.7/15.5	21.4/16.0	22/17
<u>Land Transportation Equipment</u> (Unprotected)			
24. Motor transport vehicles (cars, trucks, etc).	6.8/5.1	7.6/5.7	27/17
25. Truck mounted engineering equipment.	7.9/5.9	9.8/7.4	27/17
26. Bulldozers and graders.	6.8/5.1	7.9/5.9	27/17
27. Unloaded railroad cars.	21/16	24/18	35/25
28. Loaded railroad boxcars, flatcars, full tank cars and gondola cars (side-on orientation).	15.5/11.6	17.3/13.0	35/25
29. Loaded railroad boxcars, flatcars, full tank cars and gondola cars (end-on orientation).	4.4/4.4	5.0/5.0	35/25
30. Railroad locomotives (side-on orientation).	5.9/4.4	9.9/7.4	22/13
31. Railroad locomotives (end-on orientation)	2.3/2.3	3.6/3.6	22/13
<u>Parked Aircraft</u> (Unprotected, random orientation)			
32. Transport airplanes and helicopters.	22/13	27/17	35/25
33. Light aircraft.	27/17	35/25	40/30

DAMAGE - DISTANCE TABLES - 10 Mt continued.

SERIAL & STRUCTURAL TYPE	DAMAGE RADII (km)		
	SEVERE	MODERATE	LIGHT
Ships (Air blast effect)	AB/SB	AB/SB	AB/SB
34. Merchant shipping.	3.7/3.7	4.3/4.3	16/11
Communications and Power Lines			
35. Telephone and power lines (oriented radially from the burst).	15/11	N/A	N/A
36. Telephone and power lines (oriented transversly from the burst).	20/15	N/A	N/A
37. Transmitting towers.	16/14	19/17	23/22
Forests (Blast wave wind effect)			
38. Unimproved coniferous forest stand.	22/11	28/14	N/A
39. Average desiduous forest stand.	29/14	34/17	35/18
Selected Urban Elongated (Line) Features			
40. Highways, streets and airport runways.	N/A	N/A	20/16
41. Elevated roads and short span bridges.	20/16	28/23	35/25
42. Railroad yards and tracks.	N/A	N/A	35/25
43. Water mains.	N/A	N/A	20/16
44. Elevated water tanks.	20/16	N/A	35/25
45. Sewers and storm sewers.	N/A	N/A	11/8
46. Gas mains.	N/A	N/A	11/8
47. Underground electric power lines.	N/A	N/A	35/25

DAMAGE - DISTANCE TABLES - 10 Mt continued.

SERIAL & STRUCTURAL TYPE	RADII OF BREAKAGE OR FAILURE (km)
Selected Structural Materials	AB/SB
48. Glass windows, large and small.	52/39
49. Corrugated asbestos siding.	35/25
50. Corrugated steel or aluminum paneling.	35/25
51. Brick wall panel, 20 or 30 cm thick (not reinforced).	22/13
52. Wood siding panels, standard house construction.	35/25
53. Concrete or cinder-block wall panels, 20 or 30 cm thick (not reinforced).	33/19

DAMAGE - DISTANCE TABLES - 10 Mt continued.

SERIAL & STRUCTURAL TYPE		RADII OF FAILURE
Petroleum and Oil Storage Tanks		
54. Floating-roof and conical-roof storage tanks.	-	Use airburst and surface burst Radii of Failure graphs below.

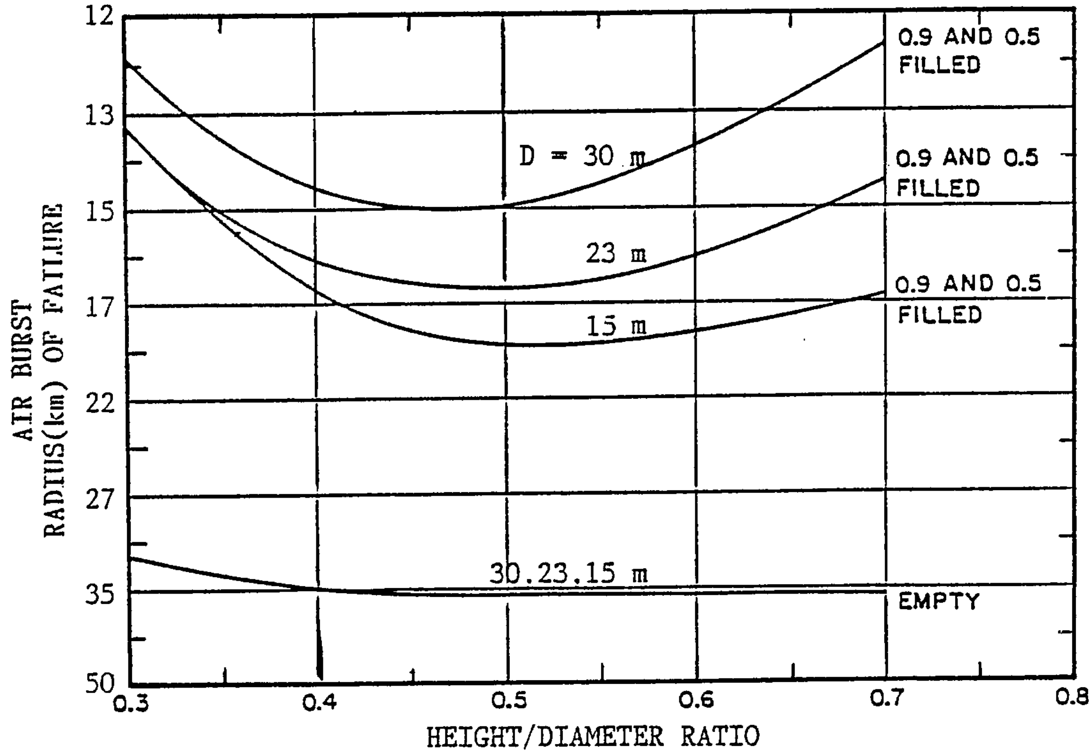


Figure 4B - 11 Radii (km) of Failure (loss of contents) for Storage Tanks of Diameter D from 10 Mt Air Bursts.

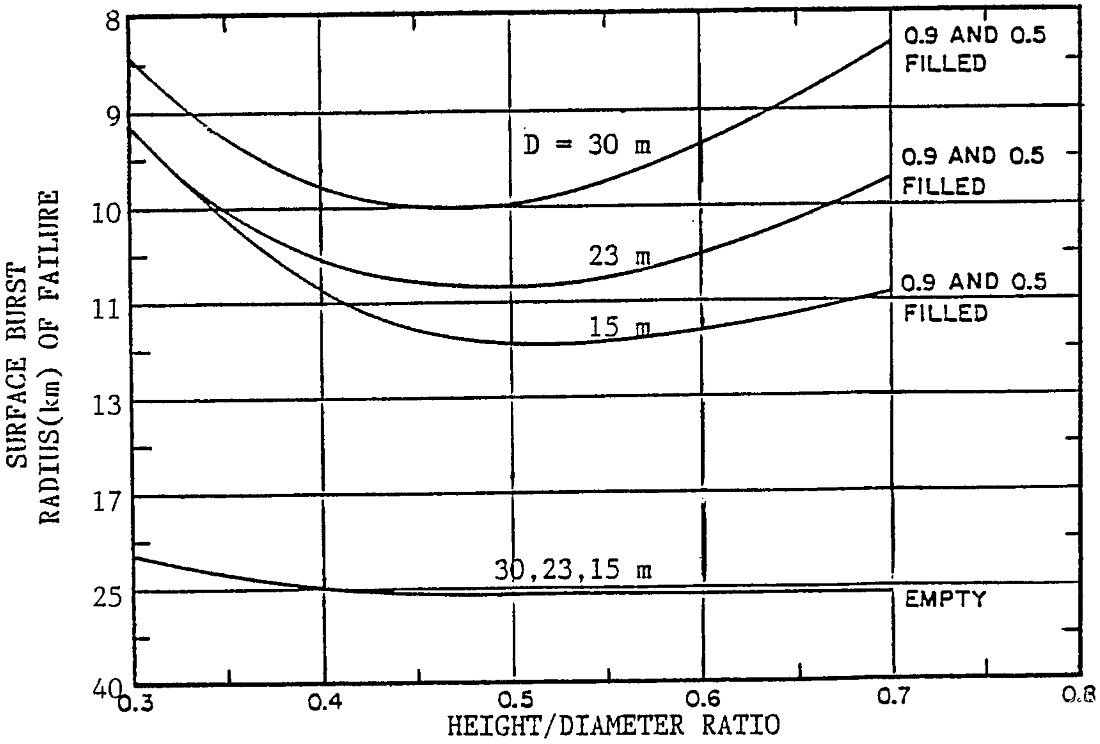


Figure 4B - 12 Radii (km) of Failure (loss of contents) for Storage Tanks of Diameter D from 10 Mt Surface Bursts.

DAMAGE - DISTANCE TABLES - 10 Mt continued.

SERIAL & STRUCTURAL TYPE	RADII OF DAMAGE (metres)		
	SEVERE	MODERATE	LIGHT
Moderately Deep Underground Structure (Ground shock damage) (Note: Figures are for ground shock damage from a contact burst. Moderately deep is defined as the condition where the ratio of depth of cover to the structure is greater than unity.)			
55. Small well designed underground structures.			
- Dry soil or dry soft rock	369 m	N/A	738 m
- Wet soil or wet soft rock	494	N/A	989
- Dry hard rock	295	N/A	590
- Wet hard rock	351	N/A	701
56. Long flexible structures such as buried pipelines, storage tanks, etc.			
- Dry soil or dry soft rock	443 m	590 m	885 m
- Wet soil or wet soft rock	594	791	1186
- Dry hard rock	354	472	708
- Wet hard rock	421	561	841

FINAL NOTE:

"N/A" (not applicable) is used throughout the tables to indicate that a damage classification does not apply or is inappropriate for a particular structural type. A more detailed explanation will be found for the feature in Annex A - Damage Criteria.

PHYSICAL VULNERABILITY DATA

15 Mt

Air Burst/Surface Burst

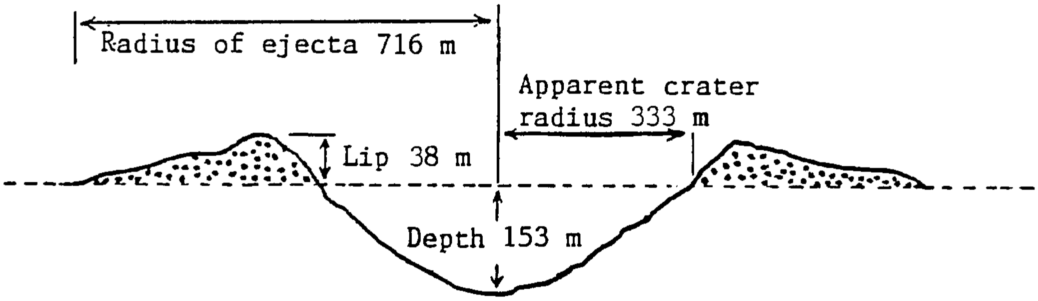
HEIGHT OF BURST FOR A TYPICAL AIR BURST - 2575 m* to 3700 m
(*Lower figure is minimum height of burst for negligible early fallout.)

NUCLEAR CLOUD DIMENSIONS - Cloud radius 55 km
- Cloud top height 35 km
- Cloud bottom height 20.5 km

DISTANCES AT WHICH FLASHBURNS COULD OCCUR TO BARE SKIN (km - AB/SB)
Third-degree 36/23 Second-degree 41/25 First-degree 48/30

DURATION OF THE THERMAL PULSE - 29 seconds

SURFACE BURST CRATER DIMENSIONS - Dry soil



SAMPLE PEAK OVERPRESSURE RADII AND ASSOCIATED BLAST WIND SPEEDS

Peak Overpressure (kPa)	Radii (km-AB/SB)	Wind Speed (km/h)
10*	39/23	85
25	22/13	190
50	13/9	355
100	9/6	625
250	4.3/3.9	1200
500	3.1/2.9	1900

(*10 kPa = 1.45 psi)

DAMAGE - DISTANCE TABLES - 15 Mt

SERIAL & STRUCTURAL TYPE	DAMAGE RADII (km)		
	SEVERE	MODERATE	LIGHT
	AB/SB	AB/SB	AB/SB
Buildings			
1. Multistory reinforced concrete building, blast resistant, windowless.	5.2/3.9	5.5/4.1	11/7.5
2. Multistory reinforced concrete frame and wall building, small window area.	13/10.1	14/10.3	40/29
3. Multistory wall-bearing brick apartment house, up to three stories.	17/13.0	18/13.5	40/29
4. Multistory wall-bearing building, monumental type, up to four stories.	12.1/9.1	12.6/9.4	40/29
5. Wood frame, house type, one or two stories.	24.1/18.0	24.7/18.6	40/29
6. Light steel frame industrial building, one story, light walls, 5-tonne crane capacity.	18.0/13.5	18.9/14.2	40/29
7. Heavy steel frame industrial building, one story, 25.5 to 51-tonne crane capacity.	12.6/9.5	13.2/9.9	40/29
8. Heavy steel frame industrial building, one story, 61 to 102-tonne crane capacity.	10.4/7.8	11.0/8.2	40/29
9. Multistory steel frame office-type building, 3 to 10 stories, earthquake resistant.	7.6/5.7	7.9/5.9	40/29
10. Multistory steel frame office-type building, 3 to 10 stories, non-earthquake resistant.	10.7/8.0	11.1/8.3	40/29
11. Multistory reinforced concrete frame office-type building, 3 to 10 stories, earthquake resistant.	8.5/6.4	8.9/6.7	40/29
12. Multistory reinforced concrete frame office-type building, 3 to 10 stories, non-earthquake resistant.	10.4/7.8	10.7/8.0	40/29

DAMAGE - DISTANCE TABLES - 15 Mt continued.

SERIAL & STRUCTURAL TYPE	DAMAGE RADII (km)		
	SEVERE	MODERATE	LIGHT
	AB/SB	AB/SB	AB/SB
Shallow Buried or Earth Covered Structures (Note: Due to allowance for differences in design, soil, shape and orientation, the moderate damage radius for Serial 13 is within the radius of severe damage. Serial 14 is a similar case for light damage.)			
13. Light, corrugated steel arch surface structure; 1.5 m earth cover.	3.9/3.6	←	4.8/4.3
14. Buried concrete arch, 20 cm thick with 5 m span; 1.2 m earth cover.	1.9/1.9	2.7/2.6	←
Bridges			
15.a) Highway truss bridges, 4-lane, spans 60 to 120 m; b) Railroad truss bridges, double track ballast floor, spans 60 to 120 m.	11.3/8.4	11.6/8.7	17/11
16.a) Highway truss bridges, 2-lane, spans 60 to 120 m; b) Railroad truss bridges, single track ballast or double track open floors, spans 60 to 120 m; c) Railroad truss bridges, single track open floor, span 120 m.	13.4/10.0	13.9/10.4	17/11
17. Railroad truss bridges, single track open floor, span 60 m.	14.1/10.6	14.7/11.0	17/11
18. Highway girder bridges, 4-lane through, span 25 m.	6.0/4.5	6.2/4.7	17/11
19.a) Highway girder bridges, 2-lane deck, 2-lane through, 4-lane deck, span 25 m; b) Railroad girder bridges, double track deck, open or ballast floor, span 25 m; c) Railroad girder bridges, single or double track through, ballast floors, span 25 m.	8.5/6.4	9.0/6.7	17/11
20.a) Railroad girder bridges, single track deck, open or ballast floors, span 25 m; b) Railroad girder bridges, single or double track through open floors, span 25 m.	12.6/9.5	13.1/9.8	17/11

DAMAGE - DISTANCE TABLES - 15 Mt continued.

	DAMAGE RADII (km)		
SERIAL & STRUCTURAL TYPE	SEVERE	MODERATE	LIGHT
(Bridges continued)	AB/SB	AB/SB	AB/SB
21.a) Highway girder bridges, 2-lane through, 4-lane deck or through, span 60 m; b) Railroad girder bridges, double track deck or through, ballast floor, span 60 m.	11.6/8.7	12.2/9.1	17/11
22.a) Highway girder bridges, 2-lane deck, span 60 m; b) Railroad girder bridges, single track deck or through, ballast floors, span 60 m; c) Railroad girder bridges, double track deck or through, open floors, span 60 m.	14.6/11.0	15.2/11.4	17/12
23. Railroad girder bridges, single track deck or through open floors, span 60 m.	24/18	25/19	26/20
<u>Land Transportation Equipment</u> (Unprotected)			
24. Motor transport vehicles (cars, trucks, etc).	8.0/6.0	8.9/6.6	31/19
25. Truck mounted engineering equipment.	9/7	12/9	31/19
26. Bulldozers and graders.	8/6	9/7	31/19
27. Unloaded railroad cars.	24/18	29/22	40/29
28. Loaded railroad boxcars, flatcars, full tank cars and gondola cars (side-on orientation).	18/14	20/15	40/29
29. Loaded railroad boxcars, flatcars, full tank cars and gondola cars (end-on orientation).	5.0/5.0	5.6/5.6	40/29
30. Railroad locomotives (side-on orientation).	7/5	12/9	25/15
31. Railroad locomotives (end-on orientation)	2.6/2.6	4.0/4.0	25/15
<u>Parked Aircraft</u> (Unprotected, random orientation)			
32. Transport airplanes and helicopters.	25/15	31/19	40/29
33. Light aircraft.	31/19	40/29	46/34

DAMAGE - DISTANCE TABLES - 15 Mt continued.

SERIAL & STRUCTURAL TYPE	DAMAGE RADII (km)		
	SEVERE	MODERATE	LIGHT
Ships (Air blast effect)	AB/SB	AB/SB	AB/SB
34. Merchant shipping.	4.3/4.3	4.9/4.9	18/13
Communications and Power Lines			
35. Telephone and power lines (oriented radially from the burst).	17/13	N/A	N/A
36. Telephone and power lines (oriented transversly from the burst).	23/17	N/A	N/A
37. Transmitting towers.	18/16	22/19	27/25
Forests (Blast wave wind effect)			
38. Unimproved coniferous forest stand.	26/13	32/16	N/A
39. Average desiduous forest stand.	34/17	39/19	40/21
Selected Urban Elongated (Line) Features			
40. Highways, streets and airport runways.	N/A	N/A	23/18
41. Elevated roads and short span bridges.	23/18	32/26	40/29
42. Railroad yards and tracks.	N/A	N/A	40/29
43. Water mains.	N/A	N/A	23/18
44. Elevated water tanks.	23/18	N/A	40/29
45. Sewers and storm sewers.	N/A	N/A	13/9
46. Gas mains.	N/A	N/A	13/9
47. Underground electric power lines.	N/A	N/A	40/29

DAMAGE - DISTANCE TABLES - 15 Mt continued.

SERIAL & STRUCTURAL TYPE	RADII OF BREAKAGE OR FAILURE (km).
Selected Structural Materials	AB/SB
48. Glass windows, large and small.	60/45
49. Corrugated asbestos siding.	40/29
50. Corrugated steel or aluminum paneling.	40/50
51. Brick wall panel, 20 or 30 cm thick (not reinforced).	25/15
52. Wood siding panels, standard house construction.	40/29
53. Concrete or cinder-block wall panels, 20 or 30 cm thick (not reinforced).	37/22

DAMAGE - DISTANCE TABLES - 15 Mt continued.

SERIAL & STRUCTURAL TYPE		RADII OF FAILURE
Petroleum and Oil Storage Tanks		
54. Floating-roof and conical-roof storage tanks.	-	Use airburst and surface burst Radii of Failure graphs below.

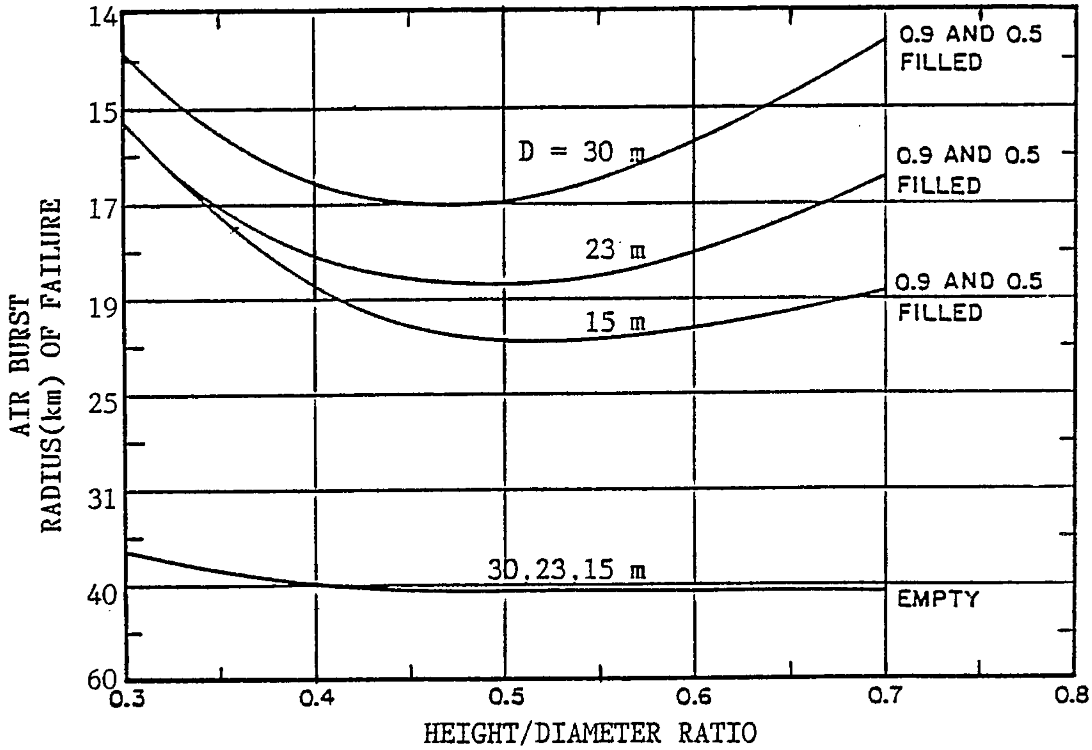


Figure 4B - 13 Radii (km) of Failure (loss of contents) for Storage Tanks of Diameter D from 15 Mt Air Bursts.

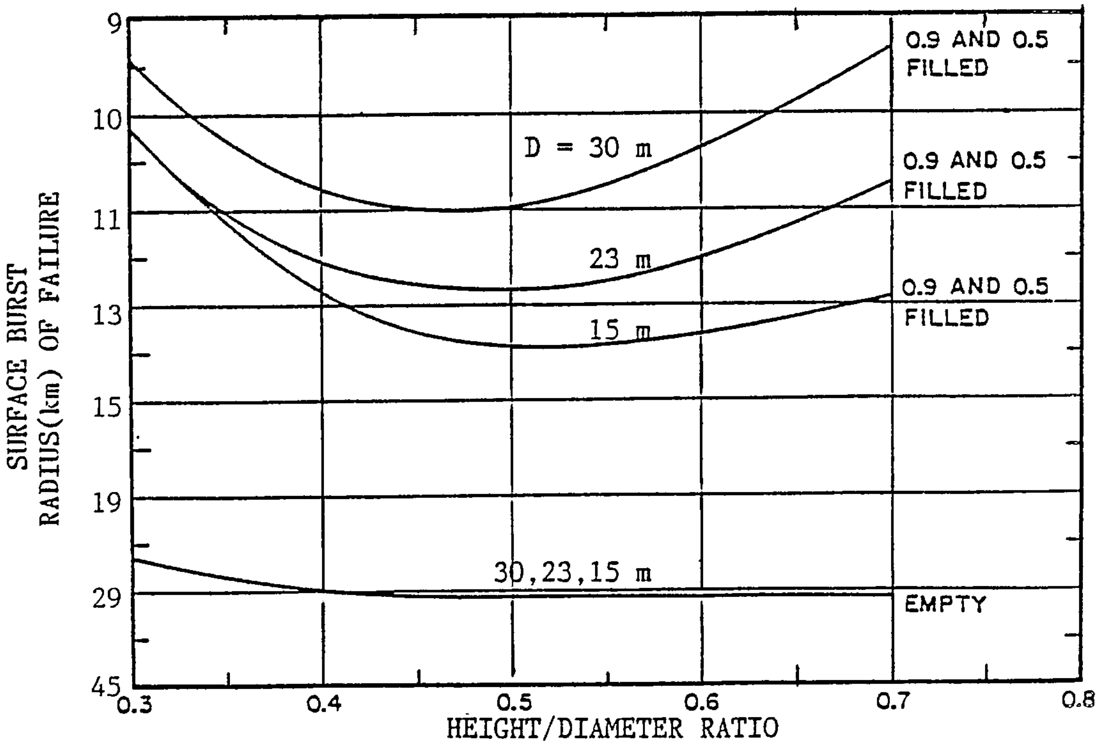


Figure 4B - 14 Radii (km) of Failure (loss of contents) for Storage Tanks of Diameter D from 15 Mt Surface Bursts.

DAMAGE - DISTANCE TABLES - 15 Mt continued.

SERIAL & STRUCTURAL TYPE	RADII OF DAMAGE (metres) SEVERE	MODERATE	LIGHT
Moderately Deep Underground Structure (Ground shock damage) (Note: Figures are for ground shock damage from a contact burst. Moderately deep is defined as the condition where the ratio of depth of cover to the structure is greater than unity.)			
55. Small well designed underground structures.			
- Dry soil or dry soft rock	416 m	N/A	833 m
- Wet soil or wet soft rock	557	N/A	1116
- Dry hard rock	333	N/A	666
- Wet hard rock	395	N/A	791
56. Long flexible structures such as buried pipelines, storage tanks, etc.			
- Dry soil or dry soft rock	500 m	666 m	999 m
- Wet soil or wet soft rock	670	892	1339
- Dry hard rock	400	533	799
- Wet hard rock	475	633	949

FINAL NOTE:

"N/A" (not applicable) is used throughout the tables to indicate that a damage classification does not apply or is inappropriate for a particular structural type. A more detailed explanation will be found for the feature in Annex A - Damage Criteria.

PHYSICAL VULNERABILITY DATA

25 Mt

Air Burst/Surface Burst

HEIGHT OF BURST FOR A TYPICAL AIR BURST - 3160 m* to 4385 m
(*Lower figure is minimum height of burst for negligible early fallout.)

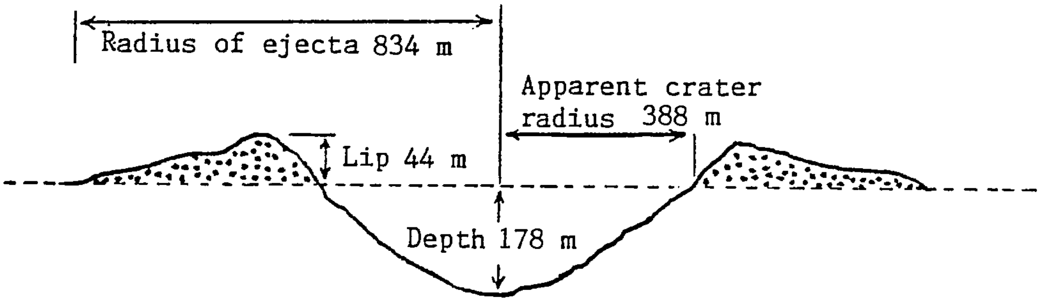
NUCLEAR CLOUD DIMENSIONS - Cloud radius 68 km
- Cloud top height 39 km
- Cloud bottom height 25 km

DISTANCES AT WHICH FLASHBURNS COULD OCCUR TO BARE SKIN (km - AB/SB)

Third-degree 43/27 Second-degree 51/32 First-degree 56/35

DURATION OF THE THERMAL PULSE - 36 seconds

SURFACE BURST CRATER DIMENSIONS - Dry soil



SAMPLE PEAK OVERPRESSURE RADII AND ASSOCIATED BLAST WIND SPEEDS

Peak Overpressure (kPa)	Radii (km-AB/SB)	Wind Speed (km/h)
10*	46/27	85
25	26/16	190
50	16/11	355
100	11/7	625
250	5.1/4.6	1200
500	3.7/3.5	1900

(*10 kPa = 1.45 psi)

DAMAGE - DISTANCE TABLES - 25 Mt

SERIAL & STRUCTURAL TYPE	DAMAGE RADII (km)		
	SEVERE	MODERATE	LIGHT
Buildings	AB/SB	AB/SB	AB/SB
1. Multistory reinforced concrete building, blast resistant, windowless.	6.1/4.6	6.5/4.9	13/9
2. Multistory reinforced concrete frame and wall building, small window area.	14/10	16/12	47/34
3. Multistory wall-bearing brick apartment house, up to three stories.	21.0/15.8	21.6/16.2	47/34
4. Multistory wall-bearing building, monumental type, up to four stories.	14.3/10.7	15.2/11.4	47/34
5. Wood frame, house type, one or two stories.	28/21	30/22	47/34
6. Light steel frame industrial building, one story, light walls, 5-tonne crane capacity.	23/17	24/18	47/34
7. Heavy steel frame industrial building, one story, 25.5 to 51-tonne crane capacity.	15.5/11.6	16.2/12.1	47/34
8. Heavy steel frame industrial building, one story, 61 to 102-tonne crane capacity.	12.9/9.7	13.4/10.1	47/34
9. Multistory steel frame office-type building, 3 to 10 stories, earthquake resistant.	9.6/7.2	10.0/7.5	47/34
10. Multistory steel frame office-type building, 3 to 10 stories, non-earthquake resistant.	13.3/10.0	13.7/10.3	47/34
11. Multistory reinforced concrete frame office-type building, 3 to 10 stories, earthquake resistant.	10.0/7.5	10.4/7.8	47/34
12. Multistory reinforced concrete frame office-type building, 3 to 10 stories, non-earthquake resistant.	12.8/9.6	13.4/10.1	47/34

DAMAGE - DISTANCE TABLES - 25 Mt continued.

SERIAL & STRUCTURAL TYPE	DAMAGE RADII (km)		
	SEVERE	MODERATE	LIGHT
	AB/SB	AB/SB	AB/SB
Shallow Buried or Earth Covered Structures (Note: Due to allowance for differences in design, soil, shape and orientation, the moderate damage radius for Serial 13 is within the radius of severe damage. Serial 14 is a similar case for light damage.)			
13. Light, corrugated steel arch surface structure; 1.5 m earth cover.	4.6/4.2	←	5.7/5.1
14. Buried concrete arch, 20 cm thick with 5 m span; 1.2 m earth cover.	2.2/2.2	3.2/3.1	←
Bridges			
15.a) Highway truss bridges, 4-lane, spans 60 to 120 m; b) Railroad truss bridges, double track ballast floor, spans 60 to 120 m.	14.0/10.5	14.8/11.1	20/13
16.a) Highway truss bridges, 2-lane, spans 60 to 120 m; b) Railroad truss bridges, single track ballast or double track open floors, spans 60 to 120 m; c) Railroad truss bridges, single track open floor, span 120 m.	16.7/12.5	17.1/12.8	20/13
17. Railroad truss bridges, single track open floor, span 60 m.	18.0/13.5	18.3/13.7	20/15
18. Highway girder bridges, 4-lane through, span 25 m.	7.3/5.5	7.6/5.7	20/13
19.a) Highway girder bridges, 2-lane deck, 2-lane through, 4-lane deck, span 25 m; b) Railroad girder bridges, double track deck, open or ballast floor, span 25 m; c) Railroad girder bridges, single or double track through, ballast floors, span 25 m.	10.4/7.8	10.8/8.1	20/13
20.a) Railroad girder bridges, single track deck, open or ballast floors, span 25 m; b) Railroad girder bridges, single or double track through open floors, span 25 m.	15.8/11.8	16.2/12.1	20/13

DAMAGE - DISTANCE TABLES - 25 Mt continued.

SERIAL & STRUCTURAL TYPE	DAMAGE RADII (km) SEVERE	MODERATE	LIGHT
	AB/SB	AB/SB	AB/SB
(Bridges continued)			
21.a) Highway girder bridges, 2-lane through, 4-lane deck or through, span 60 m; b) Railroad girder bridges, double track deck or through, ballast floor, span 60 m.	14.3/10.7	15.1/11.3	20/13
22.a) Highway girder bridges, 2-lane deck, span 60 m; b) Railroad girder bridges, single track deck or through, ballast floors, span 60 m; c) Railroad girder bridges, double track deck or through, open floors, span 60 m.	18.3/13.7	19.0/14.3	20/15
23. Railroad girder bridges, single track deck or through open floors, span 60 m.	30.2/22.6	30.8/23.1	32/24
<u>Land Transportation Equipment</u> (Unprotected)			
24. Motor transport vehicles (cars, trucks, etc).	10.1/7.5	11.1/8.3	37/23
25. Truck mounted engineering equipment.	11.5/8.6	14.4/10.8	37/23
26. Bulldozers and graders.	10.1/7.5	11.1/8.3	37/23
27. Unloaded railroad cars.	30.4/22.8	31.0/23.3	47/34
28. Loaded railroad boxcars, flatcars, full tank cars and gondola cars (side-on orientation).	23/17	25/19	47/24
29. Loaded railroad boxcars, flatcars, full tank cars and gondola cars (end-on orientation).	5.5/5.5	6.7/6.7	47/24
30. Railroad locomotives (side-on orientation).	8.5/6.4	14/11	29/18
31. Railroad locomotives (end-on orientation)	3.0/3.0	4.9/4.9	29/18
<u>Parked Aircraft</u> (Unprotected, random orientation)			
32. Transport airplanes and helicopters.	29/18	37/23	47/34
33. Light aircraft.	37/23	47/34	54/40

DAMAGE - DISTANCE TABLES - 25 Mt continued.

SERIAL & STRUCTURAL TYPE	DAMAGE RADII (km)		
	SEVERE	MODERATE	LIGHT
	AB/SB	AB/SB	AB/SB
Ships (Air blast effect)			
34. Merchant shipping.	5.1/5.1	5.8/5.8	22/15
Communications and Power Lines			
35. Telephone and power lines (oriented radially from the burst).	21/16	N/A	N/A
36. Telephone and power lines (oriented transversly from the burst).	28/21	N/A	N/A
37. Transmitting towers.	21/19	26/23	32/30
Forests (Blast wave wind effect)			
38. Unimproved coniferous forest stand.	32/16	40/20	N/A
39. Average desiduous forest stand.	42/21	46/23	47/25
Selected Urban Elongated (Line) Features			
40. Highways, streets and airport runways.	N/A	N/A	28/21
41. Elevated roads and short span bridges.	28/21	38/31	47/34
42. Railroad yards and tracks.	N/A	N/A	47/34
43. Water mains.	N/A	N/A	28/21
44. Elevated water tanks.	28/21	N/A	47/34
45. Sewers and storm sewers.	N/A	N/A	15/11
46. Gas mains.	N/A	N/A	15/11
47. Underground electric power lines.	N/A	N/A	47/34

DAMAGE - DISTANCE TABLES - 25 Mt continued.

SERIAL & STRUCTURAL TYPE		RADII OF BREAKAGE OR FAILURE (km)
Selected Structural Materials		AB/SB
48.	Glass windows, large and small.	71/53
49.	Corrugated asbestos siding.	47/34
50.	Corrugated steel or aluminum paneling.	47/34
51.	Brick wall panel, 20 or 30 cm thick (not reinforced).	29/18
52.	Wood siding panels, standard house construction.	47/34
53.	Concrete or cinder-block wall panels, 20 or 30 cm thick (not reinforced).	44/26

SERIAL & STRUCTURAL TYPE		RADII OF FAILURE
Petroleum and Oil Storage Tanks		
54. Floating-roof and conical-roof storage tanks.	-	Use airburst and surface burst Radii of Failure graphs below.

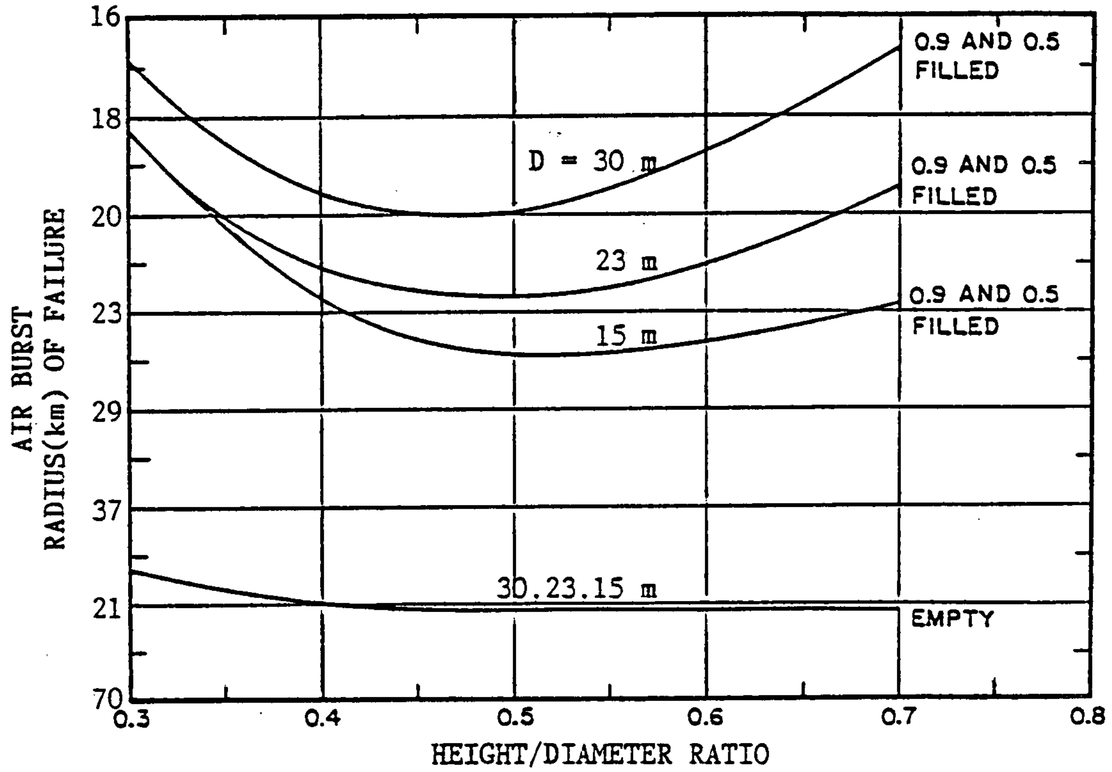


Figure 4B - 15 Radii (km) of Failure (loss of contents) for Storage Tanks of Diameter D from 25 Mt Air Bursts.

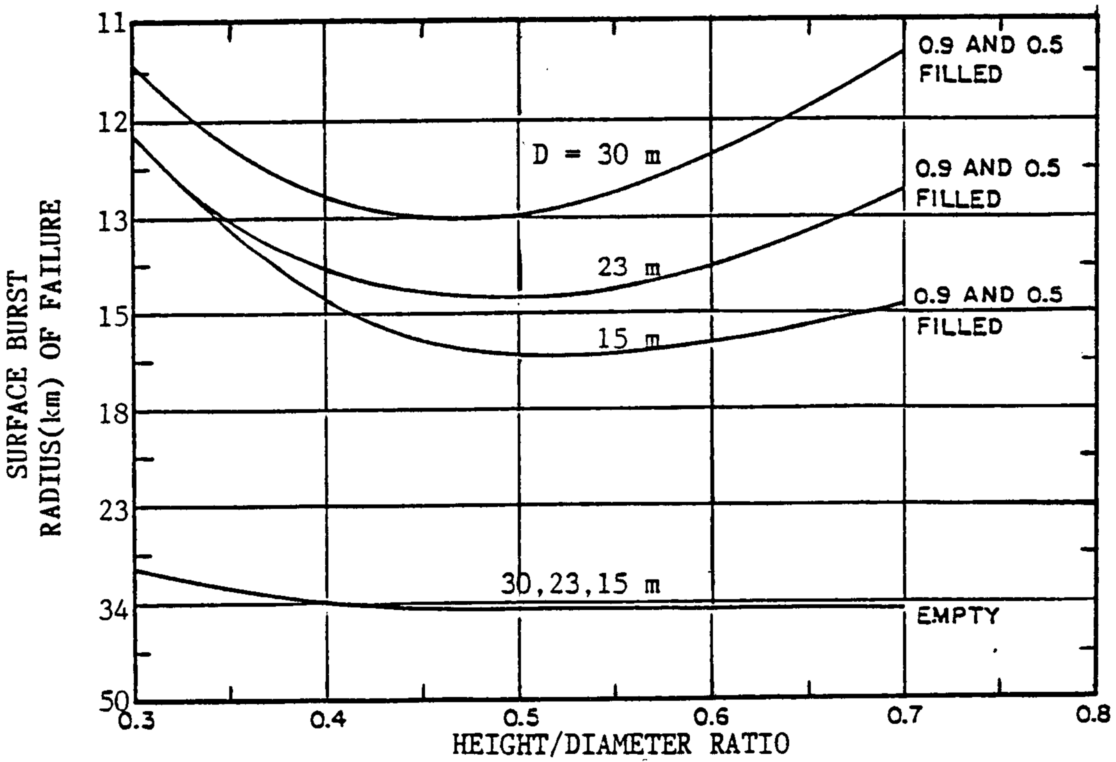


Figure 4B - 16 Radii (km) of Failure (loss of contents) for Storage Tanks of Diameter D from 25 Mt Surface Bursts.

DAMAGE - DISTANCE TABLES - 25 Mt continued.

SERIAL & STRUCTURAL TYPE	RADII OF DAMAGE (metres)		
	SEVERE	MODERATE	LIGHT
Moderately Deep Underground Structure (Ground shock damage) (Note: Figures are for ground shock damage from a contact burst. Moderately deep is defined as the condition where the ratio of depth of cover to the structure is greater than unity.)			
55. Small well designed underground structures.			
- Dry soil or dry soft rock	485 m	N/A	970 m
- Wet soil or wet soft rock	650	N/A	1300
- Dry hard rock	388	N/A	776
- Wet hard rock	461	N/A	922
56. Long flexible structures such as buried pipelines, storage tanks, etc.			
- Dry soil or dry soft rock	582 m	776 m	1164 m
- Wet soil or wet soft rock	780	1040	1560
- Dry hard rock	466	621	931
- Wet hard rock	553	737	1106

FINAL NOTE:

"N/A" (not applicable) is used throughout the tables to indicate that a damage classification does not apply or is inappropriate for a particular structural type. A more detailed explanation will be found for the feature in Annex A - Damage Criteria.