Nuclear Survival Modelling using a Menu-Driven Computer Program

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ABSTRACT A 1 Megaton, 100% yield nuclear ground burst bomb, shell or missile blast would cause controllable fire, some damage and glass breakage to a home 9 to 14 km away. Major injury to sheltered people would be unlikely. Given adequate preparation, such a 'local' holocaust plus resultant fallout is survivable. From atmospheric and particle fall-rate information, together with weapon radiation data (much not normally available), no-frills software was developed to tie important variables together for estimating: detailed shelter protection dactors; 'backyard' remote bomb size, mushroom shape and ground-zero range; health threats with various degrees of and times in shelter, as well as shelter: start (out) time, entry time, re-entry time, stay (out) time and release time based on safe dose requirements. My Reverse-time algorithm also yields the dose one could already have received by calculating dose and dose rates before present time T, even though current dose rate would only be measured much later than when fallout (FO) initially occurred.

GLOSSARY FOM=Max. FO DR EMP=electro magnetic pulse Mt=bomb megatons H+1=blast time+1 hour
Rads=DR in roentgens/hour=r/H MPD=Max. Permitted Dose DR-1=DR at H+1 r=roentgens dose
RADIAC=DR measure/meter PF= rad' protection factor TOB=time of burst TAB=time after burst
Wind direction=from which it blows Time hours after blast, or after average of several.
HOT LINE=the line (usually downwind) along which DR >than on points either side.
H+1 Timeline arc=distance (usual downwind) that FO is expected in H+1, or related coverage segment.
Unit-Time Reference DR=that which would be received from a given constant amount of FO at unit time (say 1 hour) after blast, even though this quantity may still be in transit. Used in Radiac program to estimate subsequent dose and DR.
NBC=nuclear, biologic, chemical, ie. in warfare or pollutants.

1. GLOBAL STRATEGIC SCENARIOS

Naturally civilized people detest war. Yet over 200 international armed global conflicts have flared since 1945. There may be no warning for either nuclear attack or fallout, nor any indication of targets, whether civilian or military. Missiles, seldom accurate, may be used as a demonstration in a non-strategic-target area. Fallout can also result from serious **nuclear powerhouse faults or from industrial sabotage and carelessness**. Authorities have been covertly and deeply concerned for decades over the spectre of a volatile anarchist devastating an entire nuclear facility or stockpile with nothing more than a cheap single-shot bazooka rocket! **Bulk plutonium** is transported world wide, lately by ship via the barrier reef - or drops from orbit, as recently. Natural blizzards, fire, chemical blasts, earthquakes, floods and epidemics exacerbate the situation.

1.1 DELIVERY OF NUCLEAR, BIOLOGICAL AND CHEMICAL WEAPONS IS CHEAP

20 years ago I learned both the futility and complacency in believing Americas' total defence concept. Nuclear wars need not be conducted via missiles so easily detectable by satellite, from special radars or by offshore spying devices. When I landed in Hawaii in my tiny schooner en route from Los Angeles to Sydney **during the Vietnam War**, not one of various authorities could be persuaded to board the yacht, much less inspect the capacious bilges. Surprisingly, the mountains surrounding Honolulu were visibly dotted with defence radar and missile sites in great profusion! Presumably delivering a missile there would be child's play on July 4th with so much radar-confusing fireworks up at that time. Private ultra-light planes represent other 'innocent' weapons carriers. Weapons, often no bigger than a backpack loaded in a diplomatic pouch, may already be installed in-situ awaiting security-coded electronic signals. Undoubtedly such bomb will be 'fallout-dirty' because it is implanted at ground level and yet of fairly low destructive radius.

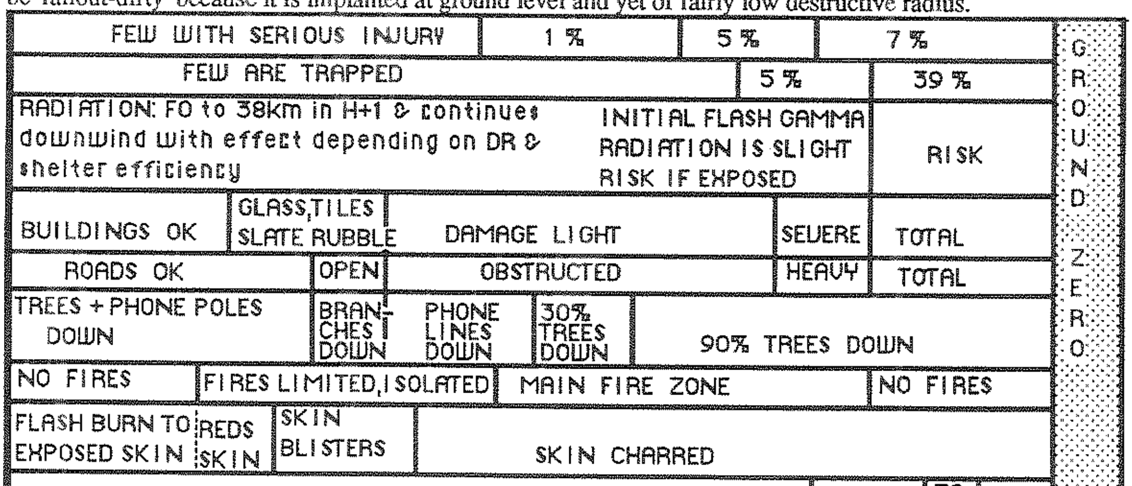

Figure 1 Possible effects from a 1 Mt, 100% (or 2 Mt, 50%) yield ground-burst nuclear weapon on rough terrain with approximate distances to GZ. These distances can be scaled up (or down) by the multiplying factor $(Mt)^{1/3}$.

1.2 ELECTRO MAGNETIC PULSES

In the detonation of just one nuclear device 560 Km above the ground there may be no further service from unprotected or unshielded radio, TV, phones, computers, mains power, electronic-ignition cars and electrical equipment due to awesome sub-microsecond EMP. Extensive fires may be started by huge sparks conducted into the home by crippled phone lines, power wires and antennas. Thus the ideal computer would be an economical battery operated or pocket unit to run programs detailed in this paper. With battery spares, the entire system including small low-power printer, should be **permanently** EMP-protected. Naturally the Radiac meter and radio (+ spare, with short wave option for foreign news if your local station is blasted) can share such protection.

1.3 HOLOCAUST SURVIVAL IS FACT

Many people believe there is little hope in trying to survive disasters in general and a nuclear attack in particular. To survive, we must **know** that we will. But consider:

* On a hot day people emerged unprotected from shelters after previous 'all clear'. Two thirds of the total Hiroshima and Nagasaki population and 60% of the city actually **survived** the effects of a small nuclear explosion equivalent to 20 kilotons of TNT. An example of how Shelter can save is the 43% of people in a building who survived only 353 meters from the explosion centre. Large sections of the Exhibition dome at GZ still survives. Many suffered from malnutrition and infections. 31,000 lived within 1km of Hiroshima ground zero, yet despite flying debris, fire, radiation, burns and lack of medical help, over 14% survived; 5% uninjured. These percentages climb to 72% and 36% in a ring 1 to 2.5 km from GZ. Blast-effect radius goes up only as the cube root of bomb tonnage.
* Fire, undoubtedly the greatest killer in Japan's tinder-dry houses, destroyed only one square mile of hilly Nagasaki and 4.5 square miles of flat Hiroshima, or about a quarter of the area destroyed earlier in a conventional fire bombing of Tokyo where dead and injured amounted to about 80,000 in just one raid, 40,000 more than from all causes in the Hiroshima attack. Raids on some German cities also caused greater damage than in Hiroshima. 85% of German people caught in the fierce Hamburg firestorm survived.
* Since 1945, of the 109,000 known to have been exposed to initial bomb radiation, only about 210 have died from induced cancers. So far, the incidence of genetic abnormalities has not exceeded that found elsewhere in Japan. Next generation children appear normal.
* On day 1, after the Hiroshima bomb, several bridges were re-opened and electricity restored in some areas. On day 2, trains were running on undamaged or hastily-repaired tracks. By day 3, some local transport began operating. In 9 days the telephone system was working. In outlying areas of the city, water and gas supplies were uninterrupted. During the 8 weeks before Americans arrived, survivors were co-operating to rebuild or repair houses.
* Admittedly the nuclear weapons now available have vastly greater power, though still survivable on the outskirts of our less flammable cities - but only in carefully planned home shelter areas. Today Hiroshima and Nagasaki are the great garden and seed-producing areas! Thus there IS hope. Even such a 'local' holocaust or multi-weapon blast is survivable.

1.4 FALLOUT WARNING

Do not count on it. About 35 seconds after the 15 second duration flash starts, the violent shockwave wind would be felt. Blast blindness, if affected, may last half an hour. With no other knowledge of GZ distance except that there may be light damage to housing (see figure 1), assume only about 10 to 45 minutes (possibly to 24 hours) available before FO settles visibly on exposed surfaces up to 160 km downwind from flashpoint. Fine dust fallout could occur weeks later. FO can even emerge upwind from the epicenter during calm weather. The mushroom drift direction should be noted. If that is moving away for several hours and the mushroom cloud isn't overhead, local FO is unlikely. If it does arrive, each dust particle gives off most deadly gamma rays for about 14 days, the greatest intensity over the first 2 days.

Then what? After several days in a shelter (protected with thicknesses of very dense material to give sufficient Protection Factor), only older adults should go outside for a few minutes for essential duties, without depending on neighbors or authorities for help over the 2-4 weeks after blast; or until All-Clear (2-4 weeks) is notified. However, longer shelter stays (eg. 6 weeks, complete with provisions) mean better survival chances - especially if there is a further surprise attack, or should one's location be a radioactive dust hot pocket. The All-Clear wasteland encountered may appear totally alien.

Although many countries have NBC warfare contingency plans, shelters, equipment and exercises - certainly UK was prepared before WW2, albeit not now - most, Australia included, have nothing by comparison. It's amazing how dead are the phones and how locked up and deserted are our Emergency Services between disasters. It therefore behoves individuals and groups to fend for themselves.

1.5 GAMMA RADIATION CONTAMINATION

Radiation can't be destroyed by boiling, washing (unless that removes it) or by burning. Symptoms that may appear in a victim days or weeks later are not contagious. They include: temporary nausea shortly after exposure, loss of hair, headache, loss of appetite, increasing paleness, weakness, diarrhoea, sore throat, tired, listless, bleeding gums, easy bruising, subsequent convulsions, vomiting, sometimes apparent recovery, then possibly death. There are no drugs or palliatives to cure radiation sickness. Any one symptom should not cause panic as even small doses can cause temporary symptoms.

* If one survives 7 weeks after a single radiation dose and infection is avoided, recovery is likely.
* No person should have a total dose >75 r over a 14 day period.
* A dose rate< 0.5 is "considered" safe.

2. GROUND RULES, INSTRUMENTATION, COMPUTER, HINTS AND PRECAUTIONS:

* Use the latest GZ, wind, DR and other data in all calculations. Clouds suggest upper windspeeds.
* Safety dose and DR standards used by the computer may need revision, based on future research.
* Triple check all data and computer inputs because the operator will be under great strain and prone to errors. Also check for reasonableness, such as an earlier DR > later DR.

* Obtain many readings of initial and later data such as DR, dose, time, wind etc. Do many computer runs.
* For practice, worked examples are given with disk routine.
* **Screen capture** is available either to disk file for subsequent retrieval or direct to a printer.
* **Computer:** All 5 MENU-driven programs are in simple appropriate BASIC - not locked, easily altered or adapted - for use preferably on a laptop.
* **RADIAC DR Measurement:** These low-power items or kits are readily available and must be calibrated. Preferably the unit should measure outside FO DR, but how does one take readings from a shelter? Possibly have the sensing head outside with the remainder inside. Or have the whole unit (except batteries) outside where radioactive dust can't accumulate, yet viewable from within by binoculars.

2.1 WEAPON, TARGET and WEATHER ASSUMPTIONS

Most relevant assumptions are computer screen-printed as necessary - except where stated. Here's a brief Summary:
* Unspecified bomb tonnage=3 Megatons.
* Constant windspeed and angle at all altitudes with minimal wind shear=15 deg. Windspeeds are rarely outside range 13-73 Km. No rain.
* FOM arrives about 3 times as many hours after ignition than does Initial FO.
* 3 MTon Bomb Particles which reach Ground furthest Downwind in 1 hour are 700uM Diameter and originate at cloud base 1/2 way along downwind cloud radius. See Figure 2. FO particles have density=2.5gm/cc, most smooth and spherical like dry sand.
* DR-1 > 5000 r/H very seldom and then only near GZ.
* Usually DR-7 << 400 r/H, even on single bomb plume Hotline.
* After 30 hours, large DRs shouldn't appear.
* 3 months after blast, DR=1/10,000 part of DR-1.
* Calculations presume a single 100% yield groundburst weapon (ignition at altitude wont pick up FO dirt), but in real situations, without better data, presume only 50% Fission Yield - multiply expected DR by 0.5
* Surface roughness Terrain Shielding Factor - multiply expected DR by 0.7 or less.
* Rough hilly country, city buildings, trees, rain can further reduce yield - multiply expected DR by .5 to .6
* Radiation reduces proportional to square of distance - divide expected DR by 4 if your distance from it doubles.
* A Shelter surrounded by masses of thick heavy slabs (see 1st item, next Section) - divide expected DR by the shelter Protection Factor (PF) which could usefully range from >1 to 100.
* Localized hot spots can lead to much bigger expected DRs.
* To confirm that FO has ceased falling (see Exercise 3, Item 5, Section 4), try the following, using a Radiac radiation DR measuring instrument: Say DR-2=40. Measure the DR-4 2 hours later. If the latter figure is predictable from the former, using the RADIAC program (MENU 1), then the conclusion is that no further FO has landed. Of course measured DR-4 could be smaller than expected - in which case check for accuracy, or if rain has fallen.

3. INTRODUCING THE 5 MENU-DRIVEN COMPUTER PROGRAMS.

These are in sequence of their typical priority application - as reflected by the disk titles.
1. **"SHELTER PROTECTION FACTORS"** computes the PF (>1) safety against FO radiation of: material slabs, typical dwellings, trenches, basements, shelters, cars, boats, trains, buildings in detail.
* ACTIVATE a long time before imminent attack.
* INPUT data consists of: shelter type available, detailed building dimensions, configurations, depths of basements and configuration of adjacent structures.

2. **"NUCLEAR BOMB SENSING"** Simple 'Backyard' measurements of angles and times computes bomb MTons and/or GZ and cloud dimensions (but more reliable if digitally automated) in order to estimate FO Earliest Time of Arrival (ETA) on the subsequent programs.
* ACTIVATE immediately on attack after much earlier preparation. Fig 2 is definitive.
* INPUT data options are requested by selecting only 2 items (though others will provide backup accuracy), data for which is known, of the following 8-Item MENU, namely: GZ or bomb Mt (one or other may be known), seconds measured after flash before blast sound, fireball duration, angle in degrees across fireball diameter from your location, angle measured across mushroom cloud, angle measured across the stem, stem height angle. Fireball height angle is yet another input capable of warning against possible FO (No FO from high altitude explosions). Several more "Backyard" measurement phenomena are suggested. The computer may take a few seconds to solve non-linear equations via the author's MICROOTS, an extract from his Maths Algorithm Library (MAL). On screen will appear: Bomb MTons, GZ Km, cloud radius Km, stem radius Km, stem height Km and FO expectations.

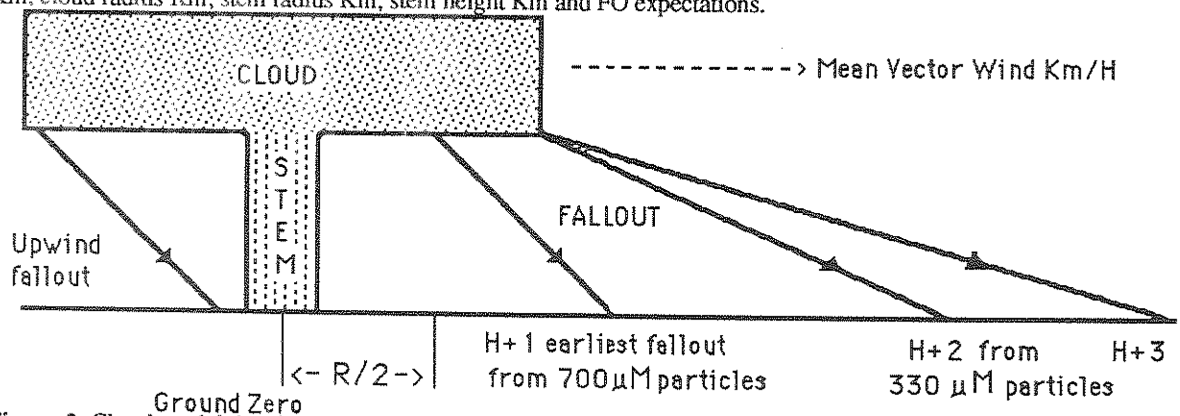

Figure 2 Cloud model developed from nuclear weapon test data and used to predict time lines. Particles reaching farthest downwind in 1 hour - including a 10 minute stabilization - are shown emanating from half way along the cloud radius.

3. "**H+1 FALLOUT PLUME**" yields not the imminent DRs, but the mushroom cloud radius, together with H+1, H+2, H+3 upwind and downwind FO Plume Arc Templates from GZ - see Fig 3.
* ACTIVATE immediately after attack.
* INPUT data consists only of bomb MTons (if available, or as calculated in previous item 2, but MT=3 if unspecified), average wind speed and direction with an assumed wind shear=15 degrees. To allow for wind direction changes much later, add about 20 degrees to the FO angle either side of Hotline.

4. "**DOSERATE CONTOURS, ETA**" computes: the Earliest FO ETA = GOTO shelter time estimates - Hotline FOM - Unit-Time Reference DR Contour Plot (as in Figure 4) - damage rings around GZ - cloud radius Km - stem radius Km - stem height Km. Though such early surface-burst FO need not yet have arrived, these DR contour results printed as TABLE 2 (ITEM 4, SECTION 4) by this program are vital for initiating RADIAC DR estimates in the next disk program item 5. DR figures may be used as an upper limit FOM DR estimate at a Downwind Hotline Distance.
* ACTIVATE immediately after attack.
* INPUT data consists only of bomb MTons and GZ Km figures (if available, or as calculated earlier in item 2, but MTons=3 if unspecified), average wind speed and direction.

5. "**RADIAC DOSE/RATE**", including Health-threat effects with or without shelter protection, computes: DR and dose received at any later time, dose over an interval, dose contributed whilst FO is still falling, start time, entry time, re-entry time, stay time and release time based on requests and safe dose requirements. Some calculations are summarized in Fig 1. This program is especially useful for nuclear "accidents" re power houses etc.
* ACTIVATE shortly after attack.
* INPUT data consists primarily of a FO DR value (very often the FOM) measured, derived or interpolated from contour results in TABLE 2 as applied to Figure 4 above, together with the Hours T after blast at which that DR was measured or calculated. Our Reverse-time algorithm is fascinating in that most DR and dose estimates are also available BEFORE this time T, so that even though you only received or measured primary DR figures very much later than when it fell, nevertheless this program yields the dose you could **already** have received.

	Days before DR falls to:		
DR-7	4 r/H, which allows shelter exit for 1 hour in 24.	1 r/H, which allows shelter exit for 9 hours in 24.	.5 r/H, allows permanent release
400 r/H	13	42	75
300	10	33	60
100	4	14	24
30	1.5	5	9
10	1	2	3.5

TABLE 1 Summary chart of Shelter Release Days. Usually DR-7 << 400 r/H, even on a single bomb Plume Hotline. For every 7-fold time increase after ignition, DR decreases by a factor of 10. Thus after 1 week, the dose rate is 1/10 of that after day 1. Three months after ignition, the doserate is 1/10,000 of that after day 1.

4. COMMENTS AND EXAMPLES FOR THE 5 COMPUTER PROGRAMS

1. "**BUILDING PROTECTION FACTORS**" in Imperial units for building industry. (All INPUT values in all routines are prompted at each input request and every RESULT printed as a total software test). INPUTS:
10*10ft Building=100 sqft. Perimeter=40 ft. 4 walls 10*10 sqft.
All walls, slab and floor etc. thickness=10 inch Brick having Slab Density=10 lb/sqft/inch, and Weight=100 lb/sqft.
Room floor 1 ft above ground. Basement ceiling at ground level. A similar unrelated 1/2 Basement is buried 5 ft.
Adjacent surrounding 4 buildings also have 10*10 sqft walls placed 10 ft from shelter house.

RESULTS: PF for 10 inch Brick Slab=14. PF for Center of: Ground Floor Room=16: 1/2 Basement=55: Basement=117.

2. "**NUCLEAR BOMB SENSING**" - See Fig 2. TEST FIGURES: Select any 2 MENU items in any order and then input requested data:

Items:	bomb size	ground zero	blast arrival	fireball duration	fireball diam.	cloud diam.	stem diam.	stem height
MENU:	0	1	2	3	4	5	6	7
INPUT:	.01	20	53	1.102	1.1	14	7.6	17.5
Units:	MTons	Km	secs	secs	degrees	deg	deg	deg

RESULTS (approximate):

bomb MTons	GZ Km.	cloud radius Km.	stem radius Km.	stem height Km.
.01	20	2.6	1.3	6.1

"You are Not under the mushroom cloud and no FO if bomb downwind . . .". Now when asked: "Fireball Height Angla degrees?", Input a value of 5 for instance. Note next statement: "Fallout expected somewhere. . ." (because blast was low enough to pick up FO). The software contains several other phenomena capable of yielding similar results algorithms.

3. " **H+1 FALLOUT PLUME**" - two examples shown. See Fig 3.

<----------TEST---------->				<----------RESULTS---------->			
Input wind speed	input wind direction (N=0)	bomb MTons known?	input bomb MTons	cloud radius Km	H+1 downwind FO arc Km.	FO angle within	H+1 upwind FO arc Km
20	0	Y	1	18	33	0±52	3
10	180	N	assume 3	28	39	180±52	9

4. "**DOSERATE CONTOURS, ETA**" - See Fig 4.
TEST AND RESULTS FIGURES: INPUT Bomb MTons=.01 to print RESULTS:

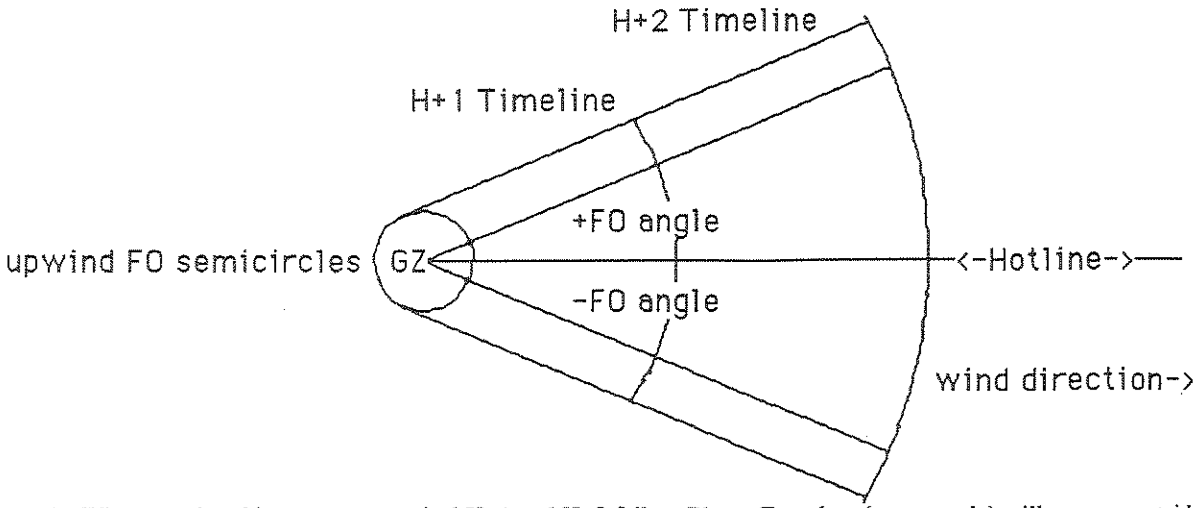

Figure 3. When running this program a typical H+1 and H+2 fallout Plume Template (not to scale) will appear, outside of which no FO is expected at those times. With variable windsheer, edges may be unequal. Results will be screen-printed on this schematic. Only professional meteorological data can produce better.

House damage Ring 2.1 to 3.2 Km; Mushroom Cloud Radius =3 Km; Stem Radius =1 Km; Cloud Height =6 Km.
Now INPUT Wind Speed, Km/H=20 and Distance to Ground Zero, Km=10 for RESULTS:
CHOOSE MENU=1: ETA=GOTO Down Wind Shelter before .77 Hours. No Up-Wind FO Expected.
CHOOSE MENU=2: Hot-Line FOM=118 r/H.
CHOOSE MENU =3: From IDEAL DR-1 EARLY FO CONTOUR MENU, the following will be printed:

TABLE 2 is screen-printed with Fig 4: Note that such FO with the relevant DR may not yet have arrived:

DoseRate r/H	DownWind Km.	Max. Width Km.	Upwind Radius Km.
1	165.9	16.0	3.1
3	124.4	11.2	1.8
10	99.51	7.6	1.4
30	66.34	4.4	1.1
100	36.9	2.43	.82
300	18.7	1.0	.49
1000	7.5	.33	.18
3000	3.9	.1	.08

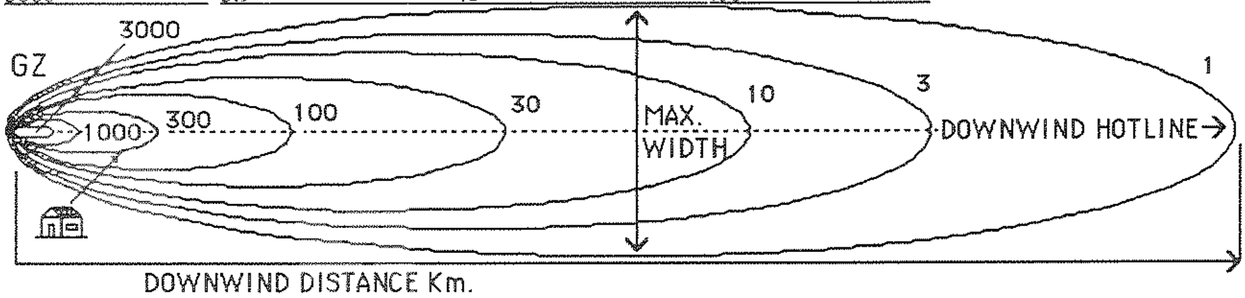

Figure 4. Idealized Unit-Time Reference DR Contour Pattern for early fallout from a nuclear 100% fission yield surface-burst, even though such FO may not yet have arrived. The house shown would expect to be on a 300 contour. To save space, Vertical and horizontal scales are not identical - see Table 2. If necessary, computer drawing software can easily interpolate between ellipses after a scan-in.

5. "RADIAC DOSE/RATE" EXERCISES: After nuclear detonation has occurred and the family is safely ensconced in the shelter awaiting DR decay, this program will be the only software lifeline. Because of above-mentioned Reverse-time (backwards/forwards) flexibility of these problem-solving routines, most all forward-time answers may be used as a backward-time problem.

DoseRate decay estimates after time T are based on the $T^{-1.2}$ law for most expected nuclei mix. However, the exponent could range from -0.9 to -2. Thus $DR_2=DR_1\,(T_1/T_2)^{1.2}$, accurate to approximately ± 25%. After about 6 months, DR is much less than that given by the $T^{-1.2}$ law. If DR_1=DR at Unit-Time T_1 (usually as here, 1 hour) after ignition, providing NO ± change in the quantity of FO occurs, then $DR_2=DR_1\,(T_2)^{-1.2}$.

EXAMPLES: **1.** Suppose, as in Table 2, that the Figure 4 house distance to GZ=15 Km. approx. Note the dwelling is estimated to virtually sit on the DR-1=300 contour, which is sufficient data to enter the Radiac program. However, shortly after attack, outside radiation DR intensity was measured frequently, starting from H+1/2 hour when the first FO dust started to arrive, until 1.5 hours after blast when DR-1.5 peaked at 330 r/H - differing a little from that contour just calculated, possibly because of a local Hotspot. Applying the Radiac program MENU=1 reveals that in 2 weeks outside, this DR=330 will drop to a safe level of .5 r/H. Thus without a shelter the total received outside dose (type "Yes" to the FOM computer question) would be a Lethal 1801 r; see Figure 5 for typical radiation decay curve shape!
Radiac with MENU=4 discloses that after 2 weeks in a Shelter having PF=24, the equivalent of a 25.5 cms (10 inches) concrete roof, will result in your receiving no more than the Maximum Permissible safe Dose=75 r, and a peak DR =13.7

r/H (=330/24) at the quoted FOM, 1.5 hours after blast.

2a. See FIGURE 5 for a backwards-time problem. If the FOM time isn't given or needed and DR-48=100 r/H, what was the DR-24 (backwards-time, but enter "N" to option FOM)? Answer=229.74 (MENU=1).
What dose accumulated from H+24 to H+36 (backwards-time)? A=2147.4 (MENU=2).

2b. However, it was suspected, again as in Fig.5, that what had arrived at H+24 was indeed the Max. DR (ie. FOM). This time type "Y" to the FOM computer question. What is required DR-24 value and what would have been the dose accumulated (under the triangular section) from To (approx.=8 hrs) to T_1? A=DR-24 again=229.74 (MENU=1).
Dose A+B=5406.68 r is available from MENU=1 with original part 2a. input data DR-48=100 r/H and the Desired Earlier/Later time input=1 Day. Dose B=3568.8 can be found similar to the second part of 2a. with limits H+24 to H+48 and MENU=2. A=Dose 5406.68 - 3568.8=1837.9

3. Typical practical problem: A nuclear strike in Brisbane began at 0600 hrs this morning after a warning at 0550 hrs. No weapons ignition reported since 1100 hrs. At 1200 hrs the DR=65 r/H outside Control HQ. Blast damage included the roof-mounted radio mast. Controller has agreed to allow 2 older Signals Staff a staytime out of shelter of 2 hours for urgent repair work providing their total accumulated MPD < 75r. Because they have been in shelters below Council Chambers since before attack warning, we can assume they have received no appreciable dose. The time is now 1300 hrs and the DR=47 r/H outside has just been reported. Evidently FO is complete. When can the maintenance team start work?

Set down the essential data in clear logical order - preferably using a sketch like Figure 5. 1st bomb at 0600 hrs: last bomb at 1100 hrs: thus attack duration=5 hrs: mid-time H-hour=0830. DR at 1200 (H+3.5) hrs=65 r/H: DR at 1300 (H+4.5) hrs=47 r/H and FO is complete, as MENU=1 can verify, owing to the 47 r/H being near-predictable (actually 48.1) from DR-3.5=65. The start (exposure) time as computed=4.56 hours (MENU=3, SUB-MENU 1), almost immediately, as can be confirmed by back-checking. We suggest another half hour shelter to account for inaccuracy. To get a latest DR reading, the team would take instruments out with them - and duck back inside shelter if DR is larger than anticipated. Thus risk to personnel receiving a large dose from starting work too early is eliminated thanks to maths computing. We have been perhaps over-generous with numerical results to give the reader a feeling for magnitude.

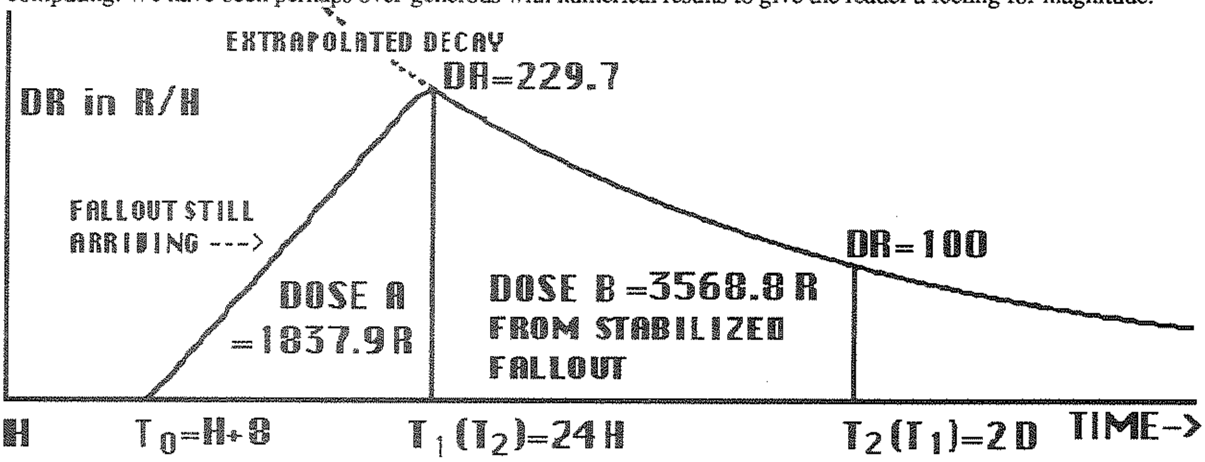

FIGURE 5. Fallout decay curve from blast time H. The increase in doserate during continuing FO arrival (from T_0 to T_1) is approximately assumed linear to the Max. DR (FOM) at T_1 when all FO is presumed to have fallen and stabilized. Decay typically then follows a $T^{-1.2}$ law initially. Dose is simply the area under the curve between any two time limits. This example is Exercise 3 above.

5. BRIEF NON-SECRET REFERENCES - others referred to within these, or available from author on request:

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6th Report, Royal Commission on Environmental Pollution - for reactor danger.