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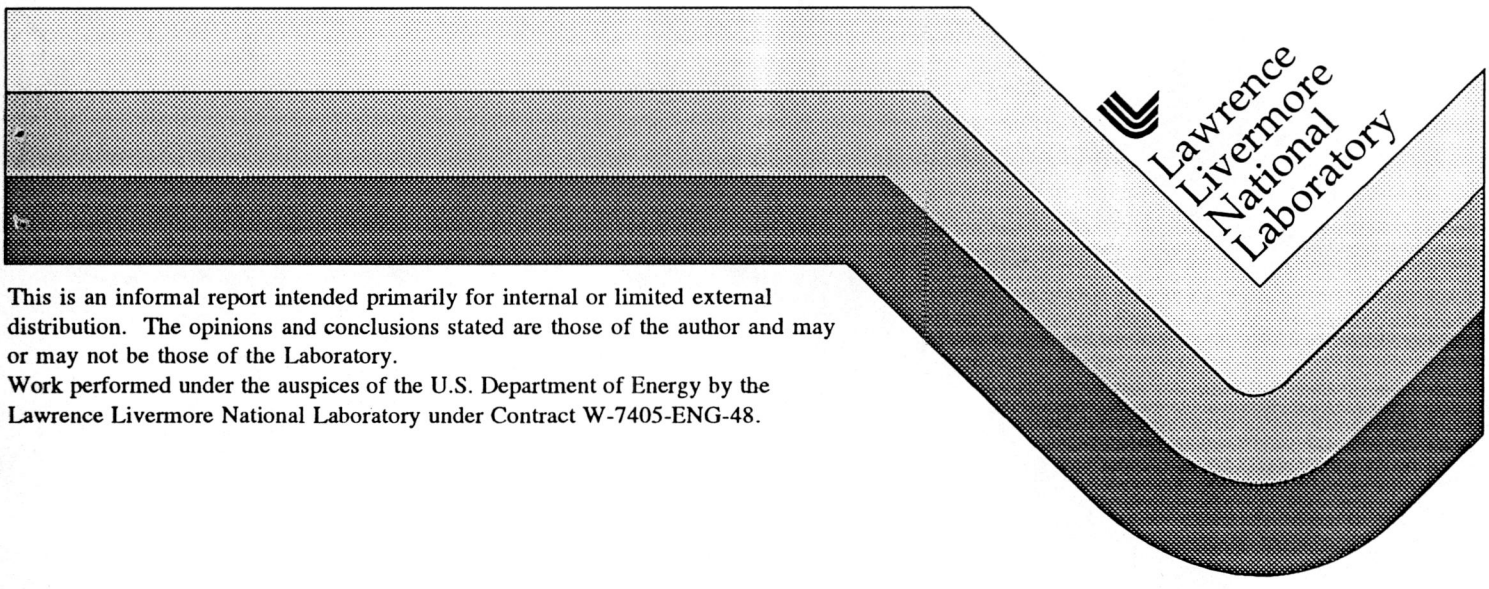
Panama Canal II, Estimates of Activity Levels for Tritium in the Air, Surface Water, and Canal Water

J. B. Knox

January 15, 1964



H. Heller

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MEMORANDUM

TO: E. H. Fleming

FROM: J. B. Knox

SUBJECT: Panama Canal (II): Estimates of Activity Levels for Tritium in the Air, Surface Water, and Canal Water.

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1. Tritium in the air

In order to estimate the tritium concentration in the cloud at cloud-stabilization, we assume that

(a) 100% of the tritium produced by the device is vented to the atmosphere,

(b) $7.5 \times 6.7 \times 10^6$ curies of tritium is produced per megaton of fusion yield,

(c) turbulent motion in the base surge and main cloud is of sufficient intensity and duration to mix the tritium uniformly.

With the aid of these assumptions, we find that for Detonation #6, in dry, hard rock of Route #17, that this 35 MT shot results in a base surge cloud of 160×10^{16} cc with an average T-concentration of 1100 μμc/cc or 220 times tolerance (T).

For Detonation #11 on Route #17 (wet rock), we assume 80% of T vented enters into main cloud and 20% into the base surge. Thus, the average T concentration in the main cloud (Vol = 160×10^{16} cc) is 480 TOL (T) and the average T-concentration in the base surge (Vol = 160×10^{16} cc) is ~ 12 TOL (T).

It is pertinent, in regard to Detonation #6 on Route #17, to estimate the time required for the tritium (assumed to be in the base surge cloud initially)

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to diffuse to tolerance for T of 5 μμc/cc (or 5 x 10^{-6} c/m^3). Detonation #6 (Route #17) constitutes a source for ~ 1750 x 10^6 curies of tritium; with this source of T, an estimate of the time required to diffuse to tolerance, t_T, is

$$t_T = \frac{Q}{4\pi DH \times 5 \times 10^{-6}} = \frac{1750 \times 10^6}{4\pi \times 10^4 \times 10^4 \times 5 \times 10^{-6}} \sim 3.5 \text{ days.}$$

If the diffusion coefficient were ~ 5 x 10^4 m^2/s and precipitation scavenging were to occur, then $t_T \leq .7$ days. In preparing this estimate, it was assumed that all the vented T is injected into the base surge cloud. If, in fact, some of the tritium were injected above the base surge cloud, t_T would be < .7 days.

If the tritium, due to the mechanics of venting to the atmosphere, were injected into the atmosphere above the base surge in Det. #6 (rather than in the middle of the surge cloud), then the maximum tritium concentration at ground level would be lower.

2. Scavenging of tritium by precipitation

a. Case of "immediate" scavenging

Consider a typical, young, cumulus cell that is embedded, or else develops, within a tritium bearing cloud with an average concentration of 1100 μμc/cc of air. We assume that the cross sectional area of the updraft is $\pi(1000)^3$, and that an average updraft velocity of 10 m/s* is maintained for an hour. The volume of air entering this cumulus cell is

$$V_{cu} = \pi(1000)^3 \times 10 \times 3600 \text{ m}^3$$

* The diameter of a developing cumulus cell and updraft velocity is taken from Byers and Braham, "The Thunderstorm", p-22, USGPO, 1949.

and the amount of tritium entrained into the cloud is

$$V_{cu} \times 1100\ \mu\mu c/cc = 120 \times 10^6 \text{ curies}$$

Thus, if all the tritium entrained into this idealized cumulus were to fallout on precipitation, then ~ 7% of the tritium would be scavenged from the tritium cloud per hour per cumulus cell. The complete scavenging of entrained tritium is probably an unrealistic model; thus, a more reasonable estimate is that 2% of the tritium in the tritium cloud is scavenging/hour/cumulus cell. If N_c = the average number of precipitating cumulus cells within the tritium cloud, then the rate of change of tritium concentration c_T (in the absence of diffusion) is

$$\frac{dc_T}{dt} = - .02\ c_T N_c$$

or

$$c_T = c_T(0)\ e^{-.02\ N_c t}$$

where t is in hours. Hence, on the average the tritium air concentration c_T, will become $\lesssim$ tolerance for tritium, when

$$\frac{c_T}{c_T(0)} = \frac{1}{220} = e^{-.02\ N_c t} = .0045$$

or

$$.02\ N_c t = 5.4 \qquad N_c t = 270$$

This above result ($N_c t = 270$) constitutes an estimate of the number of precipitation-cell hours needed to scavenge the tritium from the atmosphere for Detonation #6 such that the residual (T) is on the average ~ 5 μμc/cc.

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This estimate is based on updraft characteristics of an idealized cumulus cell and assumes zero diffusion during the scavenging. Because of this latter assumption, the "actual" atmospheric tritium concentration may drop below tolerance for times < $270/N_c$. Climatological studies of the detonation areas would be needed in order to estimate N_c adequately. However, if N_c were ~ 13, then approximately one day would be required for the idealized precipitating-cumulus cells to scavenge the airborne tritium such that c_T approaches tolerance on the average.

3. Concentration of tritium in surface waters

a. Surface waters originating from immediate scavenging

If the hourly accumulated depth of precipitation is 3 cm, under the cumulus updraft, then the volume of rain water is $\sim \pi(1000)^3\ m^2\ (10^4\ \frac{cm^2}{m^2}) \times 3\ cm = 10^{11}$ cc. The tritium concentration is this accumulated surface rain water in absence of dilution upon deposition, is 14,000 tolerance for T in water. Since (a) the base surge clouds from a typical excavation detonation may cover a whole water shed along the route and (b) precipitating cumulus cells may be sufficiently prevalent that tritiated rain falls in most of the watershed, then a pulse of tritiated water (>> tolerance) could move downstream conceivably without encountering sufficient dilution to be diluted to tolerance. I would suggest that the surface hydrology of tritiated rain waters for a typical Panama route be submitted to the USGS (maybe, Art Piper) for study, comments, and recommendation.

(b) Surface water originating from "delayed" scavenging

In the case of scavenging of tritium by precipitating cumuli 7-8 hours after detonation in an unstable atmosphere, the average atmospheric

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concentration of tritium from this T-cloud by cumuli and deposited on the earth's surface by rain would be ~ 400 tolerance (for T in water).

4. Tritium in canal water

The hydrological information currently available is insufficient to estimate, even roughly, the tritium concentration in the various segments of the canal as a function of time. However, if a "freshly" nuclear excavated canal segment were flooded with "clean" water shortly after detonation, it is estimated that T, Sr^{90}, and Cs^{157} concentrations in the equilibrated rubble zone would be at or below tolerance for these isotopes. Since the canal segments are constructed with the channel bottom below sea level, it is probable that water level in the canal is below the ground water table in most of the region. Under these conditions, water bearing radio nuclides if once in the canal (or sea) should remain there. The principal source of contaminated canal (or river) water will be tritium scavenging from the atmosphere.

JBK:eg

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