Sandia National Laboratories
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Mr. Larry Bell
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Dear Larry:

This letter is in response to your request for a description of the proper way to combine CCDFs of accident consequences for different fractions of the population or for different fractions of the time. I think the easiest way for me to explain this is with an example.

Imagine there is a reactor site with a population distribution consisting of a town of 1000 people located 10 km from the site, and no other people within 1000 km. Let's look at two possible emergency response scenarios for this town. Scenario one is a very effective evacuation and scenario two is no emergency response. Let's also assume two weather sequences (denoted sequence a and b) and that the wind always blows toward this town. For weather sequence a, the individual risk of early death at 10 km is 0.0 for emergency response scenario one and 0.85 for scenario two. For weather sequence b, the individual risk of early death at 10 km is 0.5 for scenario one and 1.0 for scenario two. Further we will assume that weather sequence a occurs with a probability of 70% and that sequence b occurs with a probability of 30%.

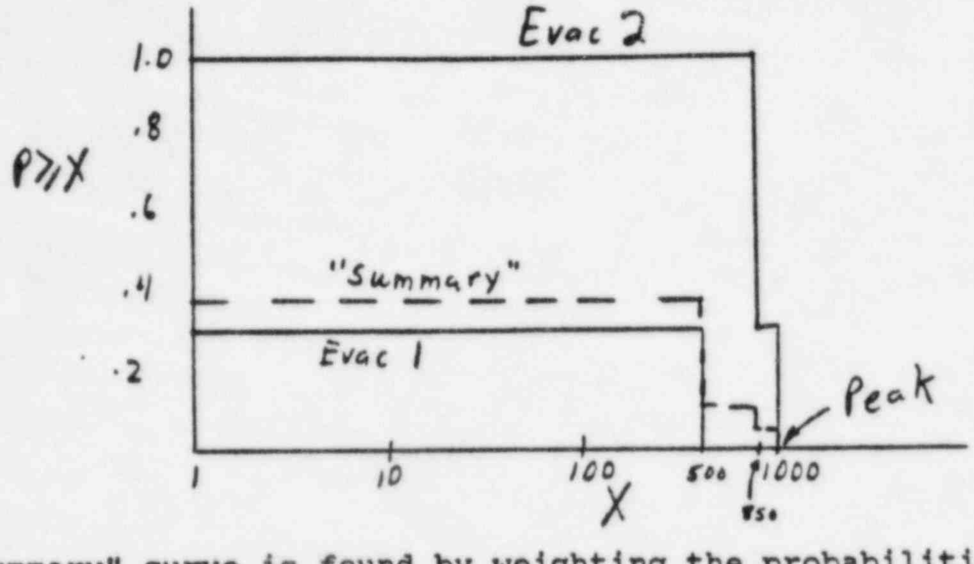
The individual risk at 10 km for the four possible cases are summarized as follows:

	weather sequence a (70%)	weather sequence b (30%)
evacuation 1	0.00	0.50
evacuation 2	0.85	1.00

Case 1.

Let's say 90% of the TIME everybody in the town follows scenario one and 10% of the time everybody follows scenario two. For weather sequence a, scenario one results in (0.0 x 1000 =) 0 deaths and scenario two results in (0.85 x 1000 =) 850 deaths. For weather sequence b, scenario one results in 500 deaths and scenario two results in 1000 deaths.

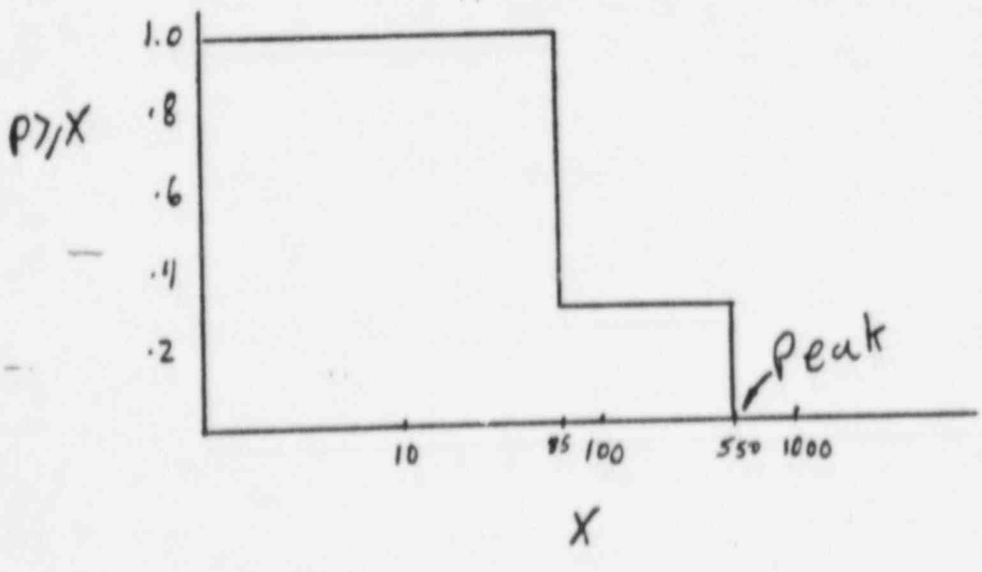
These results give rise to the following CCDFS:



The "summary" curve is found by weighting the probabilities of the two curves by their assumed conditional probabilities (90% and 10%). (Note, that the peak number of deaths is 1000.) The mean number of deaths (e.g., the average over both weather sequences) for evacuation scenario one is .7(0)+.3(500)=150 and the mean for scenario two is .7(850)+.3(1000)=895. Since evacuation scenario one is assumed to occur 90% of the TIME while scenario two occurs 10% of the TIME, the "summary" mean number of deaths is .9(150)+.1(895)=224.5 deaths. (This case is analogous to David Aldrich's "summary evacuation" and in Sandia's version of CRAC2 is called the ("evacuation summary.")

Case 2.

Let's say 90% of the PEOPLE (e.g., 900 people) follow emergency response scenario one <u>all</u> of the time while 10% of PEOPLE (e.g., 100 people) follow scenario two all of the time. In this case, weather sequence a results in 0.0(900)+0.85(100)=85 deaths and weather sequence b results in 0.5(900)+1.0(100)=550 deaths. These results give rise to only one CCDF as follows:



Note that the peak of this distribution is only 550 and that the mean (.7(85)+.3(550)=230.8) is the same as for case 1. I suspect the fact that the means are the same in the two cases is giving rise to the confusion about the error in the "staff" version.

My understanding of the current "staff" version of CRAC2 is that it is forming a CCDF for each population group and then trying to combine them. This is a major deficiency in the "staff" version because the two curves (one for each of the population groups) are not mutually exclusive (as they are in case 1, above) and thus, can not be combined. However, the mean early death and injury calculations provided by the "staff" version are likely to be correct. We are currently investigating a fairly simple fix to CRAC2 that will permit multiple population groups to be examined; we'll keep you posted. (Simple "horizontal" addition of the two curves as I have recommended in the past is not technically correct either.) There are two codes that I know of that properly handle multiple population groups as in case 2: Sandia's new consequence model, MACCS and the NUS version of CRAC2 prepared by Dr. Kaiser, et al.

I hope this is an adequate response to your request. If I can be of any further assistance please do not hesitate to call.

Sincerely,

Dan

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