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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

Before the Atomic Safety and Licensing Board

In the Matter of)

Philadelphia Electric Company) Docket Nos. 50-352
(Limerick Generating Station,) 50-353
Units 1 and 2)

TESTIMONY OF B.W. BARTRAM, G.F. DAEBELER, C.F. GUARINO, G.D. KAISER S. LEVINE, E.R. SCHMIDT, A.L. TOBLIN, R. WALLER RELATING TO CONTENTION CITY-15

Contention City 15, as admitted by the Atomic Safety and Licensing Board, reads as follows:

> The DES does not adequately analyze the Contamination that could occur to nearby liquid pathways, and the City's water supplies sourced therefrom, as a result of precipitation after a release. A reasoned decision as to environmental impacts cannot be made without a site specific analysis of such a scenario.
>
> The DES addresses at great length releases to groundwater (DES at 5-34 et seq.), but gives only a cursory and conclusory discussion of contamination of open water (DES at 5-33). This issue is of crucial concern here as the two major water bodies at and near the facility are the City's only water supplies. The City also has open reservoirs within its boundaries which could be contaminated through precipitation. For an issue of such great importance, insufficient consideration has been given here. The mandate of NEPA to take a hard look at environmental consequences has been ignored.

INTRODUCTION AND SUMMARY

B.W. Bartram 1. The purpose of this testimony is to estimate the public

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Philadelphia's ("City") drinking water after a severe accident at the Limerick Generating Station. A probabilistic treatment of the levels of contamination of the drinking water is also provided.

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2. This testimony considers the deposition of airborne radionuclides onto the Schuylkill and Delaware watersheds and predicts Complementary Cumulative Distribution Functions (CCDFs) of the concentration of those radionuclides that are the most important contributors to the longer term contamination of water supplies, strontium and cesium. This is accomplished using a computer model that was originally developed for use at Indian Point (Ref. 1, Appl. Exh.   ; Ref 2, Appl. Exh.   ). This testimony considers dry deposition as well as the "rainout" scenario postulated by the contention. CCDFs of the concentration of strontium and cesium are calculated for drinking water supplies taken from the Delaware and Schuylkill Rivers. The probability that these rivers will be contaminated above the Pennsylvania Emergency Management Agency's (PEMA) Protective Action Guides (PAGs) is shown to be very small. The probability of contamination of the drinking water supplies as a result of direct deposition onto the raw water basins or other open reservoir at the City's water treatment facilities is also discussed. It is shown that the contamination of drinking water after reactor accidents as a result of

atmospherically deposited radionuclides or as a result of direct deposition onto the raw water basins or other open reservoirs is a small contributor to risk compared with the risk arising from the airborne pathways and therefore may be properly neglected in terms of overall risk considerations.

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3. This testimony also contains in the context of an environmental impact evaluation some general discussion of countermeasures that could be considered in both the short and long term in the extremely unlikely event that in the rivers or raw, in-process, or finished water were to be contaminated above PEMA's PAGs. It should be clear, however, that the Applicant believes that its evaluation demonstrates that the probability and risk associated with this pathway is so small that specific planning considerations are not required; in any event this testimony does not purport to consider the emergency planning requirements of 10 CFR part 50 Appendix E, or NUREG-0654.

DESCRIPTION OF MODEL

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4. The model used in the preparation of this testimony has the following parts; (1) calculation of the amount of radioactive material deposited in each watershed (i.e.,

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Schuylkill and Delaware) for each combination of fission product source term, weather sequence and wind direction, using CRAC2; (2) calculation of the consequent time dependent concentrations of radioactive strontium and cesium in the City drinking water supplies; (3) relating the drinking water concentrations to population dose; (4) repetition of the calculations for different wind directions, weather sequences and fission product source terms in order to compile CCDFs of radionuclide concentrations in water and CCDFs of population dose. The analysis focuses on strontium and cesium because, by virtue of their potentially large release quantities, relatively long radiological half lives, and recognized radiotoxicity, they dominate the long term contamination of ingestion pathways (Ref. 2, Appl. Exh. ; Ref. 3, Appl. Exh.). WASH-1400 also considered strontium and cesium as the principal contributors to long-term doses received via the ingestion pathways (see WASH-1400 Appendix VI, p. 8-22, Ref. 4, Appl. Exh.). However, when considering population doses arising from the drinking of contaminated water in the short term (e.g., one month), consideration is given to other radionuclides, such as ^{133}I and ^{131}I as discussed in paragraph 18 below.

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5. The amount of radioactive material initially deposited on the two watersheds is calculated by the CRAC2 code, using the methods and assumptions described in Chapter 10 and

Assessment (SARA) to calculate the point estimate CCDFs. For each weather sequence and source term, CRAC2 calculates the activity of each radionuclide deposited on the ground in Curies per square meter, as a function of distance from the reactor. This information, together with information on the plume width as a function of distance downwind, is used by the LIQPATH code.

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6. The LIQPATH code is a modification by NUS of the code IPRES that was used at the Indian Point Hearings (Ref. 1, Appl. Exh. ; Ref. 2, Appl. Exh.). LIQPATH takes the deposited levels of radioactivity provided by CRAC2 and calculates the total amount of strontium and cesium that is deposited in the Schuylkill or Delaware watershed. This is done in the code by essentially overlaying the plume footprint on a map of the watershed and integrating the deposited activity over that part of the plume that lies within the watershed. It should be noted that the deposition in the watershed also includes that directly deposited in the river.

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7. Once the total amount of each radionuclide that has been deposited within each watershed has been calculated, the LIQPATH code predicts the subsequent temporal variation of the concentration of each radionuclide in the City of Philadelphia drinking water. Physical phenomena which

influence these concentrations include radioactive decay, run-off, erosion, ground water transport, sediment scavenging enroute and possible removal of radionuclides by the water treatment system itself and are empirically treated as discussed below.

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8. The LIQPATH code contains an empirical correlation that relates the quantity of a radionuclide deposited in the watershed to the subsequent concentration in City drinking water. This correlation, which is described in detail in Appendix 1, is based on the analysis by Codell (Ref. 2, Appl. Exh.   ), which correlated the measured rate of fallout of ^{90}Sr from atomic bomb tests with measured concentrations of ^{90}Sr in New York City tapwater over a period of about twenty years. This correlation is shown in Figure 1, which is reproduced from Codell's work. Within LIQPATH, this correlation is described by an empirical expression that contains a number of parameters (see pp 12 and 19 of Ref. 2, Appl. Exh.   ) that are determined by fitting the data as described in Appendix 1.

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9. A correlation similar to that given for New York City drinking water is applicable to any watershed and any radionuclide, although the numerical values of the parameters may change. The appropriate parameters for a

given watershed can be calculated given a data base consisting of the salient variables (in this case deposition rate and drinking water concentrations). The parameters in the correlation can then be adjusted so that a best fit of the data base is obtained. This parametric adjustment has been made in the calculations described herein.

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10. With regard to data on which to base the correlation parameters, a long term, continuous monthly record of fallout rate is available as a function of latitude (Refs. 5, 6 and 7, Appl. Exh.   and   ) and has been used in the calculations described in this testimony. By far the best available data on tapwater concentrations is that for New York City, for which there is a nearly continuous, monthly data base of ^{90}Sr from 1954 through late 1981, and a seventeen-year data base of ^{137}Cs (Ref. 8, Appl. Exh.   ). This New York City tapwater concentration data base is unique. For the Schuylkill and Delaware Rivers, limited data are available from a number of sources. The Department of Health, Education, and Welfare (HEW: Ref. 9, Appl. Exh.   ) measured quarterly ^{90}Sr concentrations in the Delaware and Schuylkill Rivers at Philadelphia (and other rivers such as the Susquehanna) sporadically from the third quarter of 1959 through the third quarter of 1967. The Philadelphia

Electric Company (PECo; Ref. 10, Appl. Exh.) took ^{90}Sr measurements in the Schuylkill River in the vicinity of Limerick between June 1971 and October 1977. The Environmental Protection Agency (EPA; Ref. 11, Appl. Exh.) has taken infrequent ^{90}Sr measurements in the Delaware River at Trenton, New Jersey (as well as other rivers such as the Susquehanna) since 1976. A single ^{90}Sr measurement on May 8, 1979 was taken for the City of Philadelphia Water Department from finished water at each of its three major plants as well as from one distribution point. The results of this single measurement appear to be high when compared with the concurrent EPA readings and internally inconsistent (the concentration at the distribution point is greater than at any of the plants).

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11. Figure 2 shows the comparability of the concentrations in the Schuylkill, Delaware, and New York City tapwater. The Susquehanna River data indicate similar comparability. This is expected for the following reasons;

- The deposition (fallout) rate is latitude dependent (Ref. 7, Appl. Exh.); these watersheds are at similar latitudes (i.e., the quantities of ^{90}Sr and ^{137}Cs falling on each watershed per unit area are approximately equal).

- The watershed dynamics (e.g., removal rates) in response to deposition is expected to be similar for these northeast United States sites, which have similar values for rainfall, run-off and sediment yield (i.e., the fractions of the total ^{90}Sr removed over a given time are equal, Ref. 12, Appl. Exh.   ).

- The flow rates per unit watershed area are approximately equal for these systems, (Ref. 13, Appl. Exh.   ).

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12. In order to extend the limited Schuylkill and Delaware River radionuclide water concentration data bases (to obtain a long continuous record which can be used to find the appropriate coefficients of the equations in Appendix 1), the 1959 through 1967 HEW data for each river were correlated with the New York City tapwater concentrations. Since the range of HEW concentrations is much larger that that of the other measurement programs, the HEW correlations were applied to the 28 years of New York City data to simulate a 28-year monthly data base for each of the Delaware and Schuylkill Rivers at Philadelphia. This data base was then used to find the appropriate parameters in the expression relating initial deposition to concentrations in each of the Philadelphia rivers. Details are given in Appendix 1.

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13. It is important to note that the New York City *tapwater* data have been correlated with the Schuylkill and Delaware *river* water data. This approach can be used because the New York City water has minimal treatment. There may be a further reduction in the predicted Delaware and Schuylkill drinking water concentrations to allow for some removal of strontium and cesium by the Philadelphia water treatment system (Ref. *14*, Appl. Exh.). However, it is not expected that the system as presently operated will significantly reduce strontium and cesium concentrations between the river and the drinking water and no credit has been taken for such removal.

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14. As noted in paragraph 7, the expression relating the amount of each radionuclide deposited in the watershed to the subsequent tapwater concentrations encapsulates the important physical processes that occur as the radionuclide is transported from the watershed to the tapwater. Other calculations carried out by the LIQPATH code are straightforward. These include taking the input data file from CRAC2 and calculating the total amount of each radionuclide deposited in the watershed for each combination of source term and weather sequence, as described in paragraph 6. The calculation of drinking water concentrations is repeated for each combinaition of

weather sequence, wind direction and source term. The output of these calculations is the CCDF of concentrations in tapwater, as described below.

PUBLIC RISK - WHOLE BODY DOSE

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15. The consumption of drinking water containing radio nuclides from a postulated accidental airborne release from LGS would result in radiological doses to the population of Philadelphia. The method used to calculate these doses from the calculated concentrations in river water and the calculated concentrations arising from direct deposition onto raw water basins or other open water bodies at the City's water treatment works is described below. Doses resulting from water used outside the body make a very small contribution to total exposure and thus are not considered further here.

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16. First, the formulas given in Appendix 1 for the time dependent concentrations of strontium and cesium in the river water were used; the nuclides ^{137}Cs, ^{134}Cs, ^{90}Sr and ^{89}Sr were included. The population was assumed to consume this water for fifty years and the resulting population doses calculated in accordance with the methods outlined in NRC Regulatory Guide 1.109 as implemented in

the LADTAP II computer code (Ref. 15, Appl. Exh. ; Ref. 16, Appl. Exh.). An exception to the methods of Regulatory Guide 1.109 was the use of ingestion dose conversion factors as given in WASH 1400 (Ref. 4, Appl. Exh. , p. 8-24) so as to be consistent with the analysis of ingestion pathways given in SARA. The Regulatory Guide 1.109 conversion factors are based on recommendations of the International Commission on Radiological Protection, Publication 2, 1957 (ICRP 2), are much closer to the more recent recommendations of ICRP 30.

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17. The LADTAP II methodology was applied separately to the Delaware and Schuylkill rivers and to each fission product source term, since the proportions of strontium and cesium differ between the two rivers and between different source terms. It is likely that the Schuylkill would be more heavily contaminated than the Delaware (see paragraph 21). According to the City, in an emergency, the Baxter plant, which takes water from the Delaware, can supply the City's entire needs with the exception of the Belmont High Service District and the Roxborough High Service District, which represents about 21 mgd out of the City's total needs of 324 mgd; or about 7 percent (Ref. 17, Appl. Exh. , and Ref. 18, Appl. Exh.). Therefore, it was assumed that 7 percent of the City's population would be supplied by the Schuylkill and 93 percent by the Delaware.

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18. With the assumptions given in paragraphs 16 and 17, it is straightforward to calculate a CCDF of population dose starting from the initial probabilistic treatment of concentrations of radionuclides in the river water. Since the calculations were done on the basis of strontium and cesium, this CCDF represents the chronic or long term contribution to the population dose. With regard to the contribution of other more short-lived radionuclides, such as radioiodine, a simplified calculation was made as follows. For each source term, weather sequence and winds direction, the isotopes of iodine deposited on the Schuylkill or Delaware watersheds were assumed to pass into the rivers immediately at a rate approximately fifty times that of Strontium. This factor of fifty is a bounding factor, as approximatley 2 percent of the Strontium is expected to pass directly into the river (Ref. 12; Appl. Exh.). The population of Philadelphia was assumed to consume this water and the resulting increment in population dose was calculated using the methods of LADTAP II. In this way, the CCDF calculated for strontium and cesium was modified to include iodine.

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19. A further potential source of radiation dose would be the consumption of water from the City's treatment works that might be contaminated by direct deposition (dry or wet)

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on raw water or finished water basins. In practice, much or all of this contaminated water could be bypassed, discharged to the river or sewers, or flushed through fire hydrants (see paragraph 30). For the purposes of this calculation, however, it is assumed that all of the contaminated water is processed through the City's distribution system at the usual rate of consumption. Again, the LADTAP II methodology was used to calculate population doses arising from the consumption of this water. When combined with the probabilistic distribution of concentrations in water calculated by LIQPATH, a CCDF of population dose results, which was combined with the CCDF described in paragraph 18 to give an overall CCDF of population dose to the people of Philadelphia. This CCDF is shown in Figure 3.

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20. The area under this CCDF is 0.39 man-rem per reactor, which is made up of 0.01 man-rem per reactor year from the consumption of water contaminated by direct deposition into the system, 0.1 man-rem per reactor year from strontium and cesium deposited on the watershed and 0.28 man-rem per reactor year from the iodine deposited on the watershed. This figure of 0.39 man-rem per year is to be compared with 70 man-rem per year to the people of Philadelphia from the airborne pathway as considered in SARA. Note that the population dose via the water

pathway has been derived with many fewer assumptions about countermeasures than that via the atmospheric pathway; in CRAC2, protective actions such as interdiction of milk and decontamination of land are routinely assumed. As described below, countermeasures are possible in the liquid pathway case which could give further reduction in risk. Overall, it is concluded that the public risk via the water pathway is a small fraction of that via the atmospheric pathway. This conclusion is in agreement with that of other authors (Ref. 3, Appl. Exh.).

CONCENTRATIONS IN TAPWATER - RESULTS

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21. Figure 4 displays the complementary cumulative distribution function (CCDF) of the concentration of ^{90}Sr in drinking water obtained from the Schuylkill, averaged over the first month and averaged over the first year, and then at 1 month, 6 months, 1 year and 5 years after the initial deposition. Figure 5 provides the same information for the Delaware River. These curves give the frequency with which the corresponding concentration is equalled or exceeded. It is apparent that the concentration of ^{90}Sr during the first month is considerably higher than that at later times (the average over the first month is given, since the parameters in the empirical correlation cannot predict in greater detail than the original data, which is

averaged on a monthly basis). After 1 month, the concentration in the river declines slowly.

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22. In order to judge the significante of the concentrations require that it is necessary to compare them with Federal or State Guidelines. The Federal Government has published standards for normal releases in 10CFR20 Appendix B and the values for ^{90}Sr, ^{137}Cs, ^{134}Cs, ^{133}I and ^{131}I are reproduced in Table 1. The Commonwealth of Pennsylvania Emergency Management Agency (PEMA) has published Protective Action Guides (PAGs) (Ref. <u>19</u>, Appl. Exh.) which are also reproduced in Table 1. PEMA's PAGs are based on the USEPA National Interim Drinking Water Regulations, EPA-570/9-76-003, Appendix B; see also 40 CFR 141.16. As can be seen from Table 1, PEMA has two sets of PAGs which are applicable to the situation being considered. For uncontrolled discharges to surface water, and in circumstances where the water supply is influenced by contaminated run-off and fallout, the USEPA Appendix B concentrations multiplied by 12 will apply. This assumes that the exposure time will not exceed one year. The associated dose commitment to any organ is 50 mrem. Second, PEMA states that, for acute crisis conditions where no other water supply is available and the duration is less than thirty days, the average concentration may reach 1,000 times the USEPA Appendix B concentrations.

The associated dose commitment to any organ is 330 mrem. For accidents affecting Philadelphia drinking water, the PEMA standards have been assumed to apply.

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23. Returning to Figures 4 (Schuylkill) and 5 (Delaware), since ^{90}Sr is principally considered as a contributor to the long term accumulation of radiation dose, the most appropriate PEMA guide for comparison with ^{90}Sr concentrations is that for circumstances in which the water supply is influenced by contaminated run-off and fall-out, i.e. 96 pCi/l averaged over 12 months. The probability that the Schuylkill will be contaminated above this guide is one in 500,000 per reactor year, and the probability that the Delaware will be contaminated above this guide is one in 14 million per reactor year.

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24. The above probabilities have been obtained by assuming that no preventive actions take place. As discussed in paragraph 34 preventative measures which could substantially reduce the long term impact of ^{90}Sr are possible. Assuming that such procedures could be implemented in one month, the probability of exceeding the PEMA one year limit in the subsequent year would be in the range of one in three million to one in 30 million per reactor year for the Schuylkill and about one in a hundred million to less than one in a billion per reactor

year for the Delaware. It should be noted that, as indicated in paragraph 20, even if the countermeasure are not taken, the man-rem contribution is a small fraction of that from other pathways.

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25. The discussion given in paragraphs 23 and 24 shows that the probability that there will be long term contamination of the Delaware even in the absence of protective actions is quite small, and that the probability that such contamination could not be dealt with using available techniques is vanishingly small (one in a hundred million per reactor year or less). For the Schuylkill, the corresponding probabilities are about a factor of thirty higher, but even so the implementation of reasonable countermeasures reduces the probability of exceeding the PEMA long term guide to one in fifty million per reactor year. Thus, there is a very small probability that long term interdiction of the Schuylkill would be required, and a vanishingly small probability that long term interdiction of the Delaware would be required. Note that the calculations show that there is less than one chance in a billion per reactor year that either the Schuylkill or Delaware will be contaminated above PEMA one year PAGs by radiocesium.

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26. In the short term, the PEMA one-month PAG (8000pCi/l of ^{90}Sr) applies. For ^{90}Sr alone, the probability of exceeding this limit is about once chance in 5 million per reactor year in the Schuylkill and less than one chance in a billion per year for the Delaware. However, the one month average is complicated by the fact that other radionuclides, such as ^{131}I, cannot be neglected; it is expected that the radioiodines will be significant (perhaps dominant) contributors to the dose (330rem in one month) that is the basis for PEMA's PAG. The calculation of the rate at which iodine, deposited on a watershed, leaches into the river is not as well understood as for strontium. Therefore, a detailed quantitative analysis is not possible. However, using the model for iodine concentration averaged over the first month, as described in paragraph 18, the iodine would determine if the PEMA short-term PAGs were exceeded. There would be a chance of about one in a hundred thousand per reactor year that the PEMA short-term PAGs might be exceeded in the Schuylkill River, and about one in two hundred thousand that they might be exceeded in the Delaware River. These are upper bound probabilities and, furthermore, take no account of the possibility of countermeasures (see paragraph 30).

DEPOSITION ON WATER BASINS AND RESERVOIRS

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27. The problem described above is one of long term contamination of the rivers as a result of deposition of long lived radionuclides such as strontium and cesium on the watershed. A short term problem may exist if radionuclides are deposited directly onto the surface of the raw water basins at Baxter, Queen Lane and Belmont or the filtered water reservoir at East Park. (The Oak Lane and half of the East Park filtered water reservoirs are protected by floating covers with provisions to drain rain water to the sewers so that the filtered water would not be contaminated.) CCDFs of instantaneous ^{90}Sr, ^{137}Cs and ^{131}I concentration in these reservoirs are shown in Figures 6 and 7. Note that all three plants and the reservoirs are so close together (compared to a typical plume width) that they have essentially the same CCDF and would be contaminated at the same time.

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28. As noted the concentrations given in Figures 6 and 7 are instantaneous values in the raw water in the basins. If this water were to be processed (without removal of any radioactivity) and distributed at the normal rate the contaminated water would be all gone after approximately 3 days. The 30 day average concentration would therefore be one tenth of that given in Figures 6 and 7. The likelihood that the PEMA 30 day PAG will be exceeded is

therefore approximately one chance in a million per reactor year based on ^{131}I. As described in paragraph 30 countermeasures based on available techniques are possible in this unlikely event. Again as noted in paragraph 20 the risk from contaminated water is small compared to that from other pathways.

POSSIBLE COUNTERMEASURES

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29. The preceeding testimony shows that the risk resulting from the contamination of the City of Philadelphia water supply is a small fraction of the risk from other pathways. In making this assessment the only action assumed to be taken was to maximize the use of Delaware River water. No credit was taken for countermeasures to either prevent the use of contaminated water or to remove activity from the water. The following section discusses, in general, possibly counter-measures in order to place some perspectives on the risks involved. This discussion centers on short and intermediate term measures.

30. Countermeasures could be implemented in the unlikely event of an accident resulting in contamination of either the Schuylkill or Delaware River water sources or treatment plants, depending upon the nature and severity of the contamination. For those occurrences which result in the early contamination of a water supply in excess of

the PEMA 30 day PAG, the interdiction of that source would be possible with replacement water provided from the other sources, albeit with some usage restrictions likely. Direct deposition into the uncovered portion of the East Park Reservoir can be accommodated by isolating and bypassing this reservoir. Direct deposition in a raw water basin would be most readily accommodated by bypassing the basin and processing raw water without the pre-sedimentation provided by the raw water basins. The contaminated water could also be returned to the river or flushed from the system using, for example, fire hydrants. It should be noted that the water system has uncovered filtered water storage facilities with approximately two days supply of water (at normal usage rate) which would not be contaminated and could continue to be used. In addition, if the water to local areas is excessively contaminated, distribution of clean drinking water by trucks is possible while continuing to use the normal water supply for other purposes.

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31. At lower contamination levels involving watershed deposition which are likely to persist for more extended periods of time, the affected water source would require some modifications in the water treatment processes to provide reductions in the finished water concentrations.

The treatment processes currently in use (Ref. 14, Appl. Exh.) include:

- Pre-sedimentation of some suspended matter in the raw water.
- Chlorination to destroy taste and odor causing materials and for control of bacteria.
- Chemical addition of carbon or sodium chlorite for taste and odor control, lime for pH control, and alum or ferric chloride as flocculants.
- Flocculation and sedimentation to remove suspended impurities.
- Sand filtration to remove remaining suspended impurities.

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32. Extensive research on removal of various fission products from water was conducted from the early 1950s to the mid 1960s largely as a result of concern about fallout from atmospheric weapons testing during that period (Ref. 20, Appl. Exh.). As a result of that research, the decontamination factor provided by the current treatment processes can be anticipated to be no more than 2 (i.e.,

50% removal) for total radioactivity, and less than that for dissolved strontium, cesium and iodine. As stated in paragraph 13 no credit was taken for any removal in the treatment process.

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33. Modifications to the current treatment process are feasible which could achieve reductions in the concentration of certain nuclides by factors of from 5 to 10. The addition of activated carbon with the other chemicals prior to flocculation gives a decontamination factor for iodine of from 4 to 5 (Ref. 20, Appl. Exh. , Table 8.3). Adding a layer of activated carbon to the surfaces of the sand filters would provide additional decontamination, perhaps by a factor of 2, for a total DF for radioiodine of from 8 to 10.

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34. Dissolved strontium can be effectively removed by the use of a lime-soda softening process normally employed to remove dissolved calcium and magnesium carbonates and sulfates from "hard" water, due to the chemical similarity between magnesium, calcium and strontium (all are Group IIA elements). Decontamination factors of from 5 to 10 can be obtained by co-precipitation in an initial softening step with dosages of soda ash (sodium carbonate) in excess of those indicated by stoichiometric requirements alone. "Repeated-precipitation", in which a small quantity of calcium is added and

removed provides an equal decontamination factor in each step. Thus, a second step in which a DF of between 5 and 10 is obtained, would produce an overall process DF of between 25 and 100 (Ref. 20, Appl. Exh.). If it were necessary to provide this second stage of processing without constructing a major plant addition, the affected plant could be operated as two sequential process lines. That is, the treated effluent from one half of the plant would be returned to the rapid mixing stage of the other half to provide the second stage of treatment. This would, of course, also reduce the throughput capacity of the affected plant by half and would probably require additional pumping capacity.

CONCLUSION

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35. The contribution to the public risk via the drinking water pathway is small relative to that predicted for the City of Philadelphia via the airborne pathways. The probability that there will be long term contamination of the Delaware River by ^{90}Sr and ^{137}Cs even in the absence of protective measures is small, and the probability that such contamination could not be dealt with using available techniques, is vanishingly small (one in a hundred million per reactor year or less). For the Schuylkill River, the corresponding

probabilities are higher, but even so the implementation, of reasonable countermeasures reduces the probability of exceeding the PEMA long term guide to one in thirty million per reactor year. Thus, there is a very small probability that long term interdiction of the Schuylkill River would be required, and a vanishingly small probability that long term interdiction of the Delaware River would be required. The probability that short term concentrations in excess of the PEMA one month PAG might occur has also been shown to be small. If the raw and finished water basins were to be contaminated by direct deposition, the probability tht the PEMA short term PAGs would be exceeded is small and the resulting contribution to public risk is small. Countermeasures to reduce or eliminate this source of risk are possible.

APPENDIX 1

DISCUSSION OF THE EXPRESSION RELATING THE RATE OF DEPOSITION OF A RADIONUCLIDE ONTO A WATERSHED TO THE TEMPORAL VARIATION OF ITS CONCENTRATION IN TAPWATER

B.W. Bartram
G.D. Kaiser
A. Toblin

1. An integral part of the model described in the foregoing testimony relates the transient concentrations of radiostrontium (and radiocesium) in drinking water to the time history of the deposition of these nuclides. The relationship calculates the quantity of a radionuclide accumulated on land in a watershed by functionally relating the rate at which the nuclide is accumulated to both the rate at which it is deposited and its removal rate. The drinking water concentration is then considered to have components related to the immediate deposition rate (e.g., direct deposition on the water surface) and the quantity of nuclide on the watershed (e.g., erosion). Each of the functional relationships contain coefficients so that mathematical equations describing these relationships can be written. The following equations are taken from Codell's work (Ref. 2, Appl. Exh. p. 12) and are applicable to any watershed and any radionuclide, although the coefficients may change;

$$\frac{dM}{dt} = AR\ (1-k_1) - (\lambda_1 + \lambda_2)\ M \tag{1}$$

$$C = k_2\ AR + Mk_3$$

where

M is the accumulated activity of a radionuclide on land in the watershed, which is available for transport to surface water, Curies

C is the surface water concentration, curies/liter

A is the area of the watershed, m^2

R is the rate of fallout, curies/(yr-m^2)

k_1 is the fraction of the affected watershed covered by open water

k_2 is the coefficient relating the rate of fallout to surface water concentration, yr/liter

k_3 is the coefficient relating available accumulated fallout on land to surface water concentration, $liter^{-1}$

λ_1 is the radiological decay rate, yr-1

λ_2 is the effective loss of available fallout from land due to all causes other than radiological, yr^{-1}

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2. For the case of an instantaneous deposition of an amount $\bar{D}$ Curies/m^2 of a radionuclide within a watershed of area A, the solution to equation 1 is

$$C = \bar{D}A\ k_3\ (1-k_1)\ \exp\ (-\ (\lambda_1 + \lambda_2)t) \qquad (2)$$

at time t years after the deposition takes place; t should exceed the averaging period for the data on which the correlation is based, in this case one month. The average tap water concentration over time t is given by

$$\bar{C} = \frac{\bar{D}A}{t}(k_2 + k_3(1-k_1)\ (1-\exp(-(\lambda_1 + \lambda_2)t))/\ (\lambda_1 + \lambda_2)\ ) \qquad (3)$$

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3. As noted in the testimony at paragraph 14, the parameters in eqs. (1) through (3) were obtained after first correlating New York City tapwater data on radiostrontium with HEW data on radiostrontium concentrations in the Schuylkill and Delaware rivers. Figure 2 shows how closely the Delaware and Schuylkill data track the New York City data. Figures 8 and 9 show these correlations. Table 2 gives the values of these parameters for radiostrontium and radiocesium, the radionuclides of interest for long term contamination of the water supplies.

4. The correlation analysis leading to the coefficients for radiocesium was performed in a manner similar to that for radiostrontium. Deposition rates for ^{137}Cs were found by proportioning the ^{90}Sr rates by the ratio of ^{137}Cs to ^{90}Sr concentrations in surface air. This ratio (1.8) was found to be practically constant with time (implying equal deposition velocities for these nuclides) (Ref. 21, Appl. Exh.). New York City tapwater concentrations for ^{137}Cs are shown in Figure 2. It can be seen that these concentrations track the corresponding ^{90}Sr concentrations quite well, albeit at a much lower level. The ratio of ^{137}Cs to ^{90}Sr concentrations in New York City water (0.10) were applied to the derived Delaware and Schuylkill rivers ^{90}Sr concentration data bases in order to obtain the ^{137}Cs concentration data bases needed to find the radiocesium coefficients of Table 2.

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20. Straub, C.P., 1964 Low-Level Radioactive Wastes, Their Handling, Treatment and Disposal, Division of Technical Information, United States Atomic Energy Commission.

21. Hardy, E.P., Jr., 1981, *Environmental Measurements Laboratory Environmental Report*, EML-390, Environmental Measurements Laboratory, U.S. Department of Energy, New York, New York 10014.

Table 1

Protective Action Guides for Drinking Water
Concentrations (pCi/Liter)

	^{90}Sr	^{137}Cs	^{134}Cs	^{131}I	^{133}I
10CRF Part 20	300	20,000	9,000	300	1,000
PEMA - uncontrolled discharges to surface water and in circumstances where the water supply is influended by contaminated run-off and fallout-exposure time not to exceed 1 year	96	2,400	240,000	36	120
PEMA - acute crisis conditions where no other water supply is available-exposure time not to exceed 30 days	8,000	200,000	2×10^7	3,000	10,000

Table 2

Coefficients Used to Relate Deposition and Surface Water Concentrations

(based on monthly average data)

	Schuylkill River				Delaware River			
	Sr-89	Sr-90	Cs-134	Cs-137	Sr-89	Sr-90	Cs-134	Cs-137
k_1	0.0096	0.0096	0.0096	0.0096	0.0207	0.0207	0.0207	0.0207
A (m^2)	4.903+9	4.903+9	4.903+9	4.903+9	2.015+10	2.015+10	2.015+10	2.015+10
λ_1 (yr^{-1})	4.804+0	2.502-2	3.388-1	2.310-2	4.804+0	2.502-2	3.388-1	2.310-2
λ_2 (yr^{-1})	7.209-2	7.209-2	7.392-2	7.392-2	9.178-2	9.178-2	9.360-2	9.360-2
k_2 (yr/l)	2.978-15	2.978-15	1.732-16	1.732-16	6.486-16	6.486-16	3.773-17	3.773-17
k_3 (l^{-1})	4.335-15	4.335-15	2.517-16	2.517-16	1.032-15	1.032-15	5.989-17	5.989-17

*4.903+9 = 4.903 x 10^9

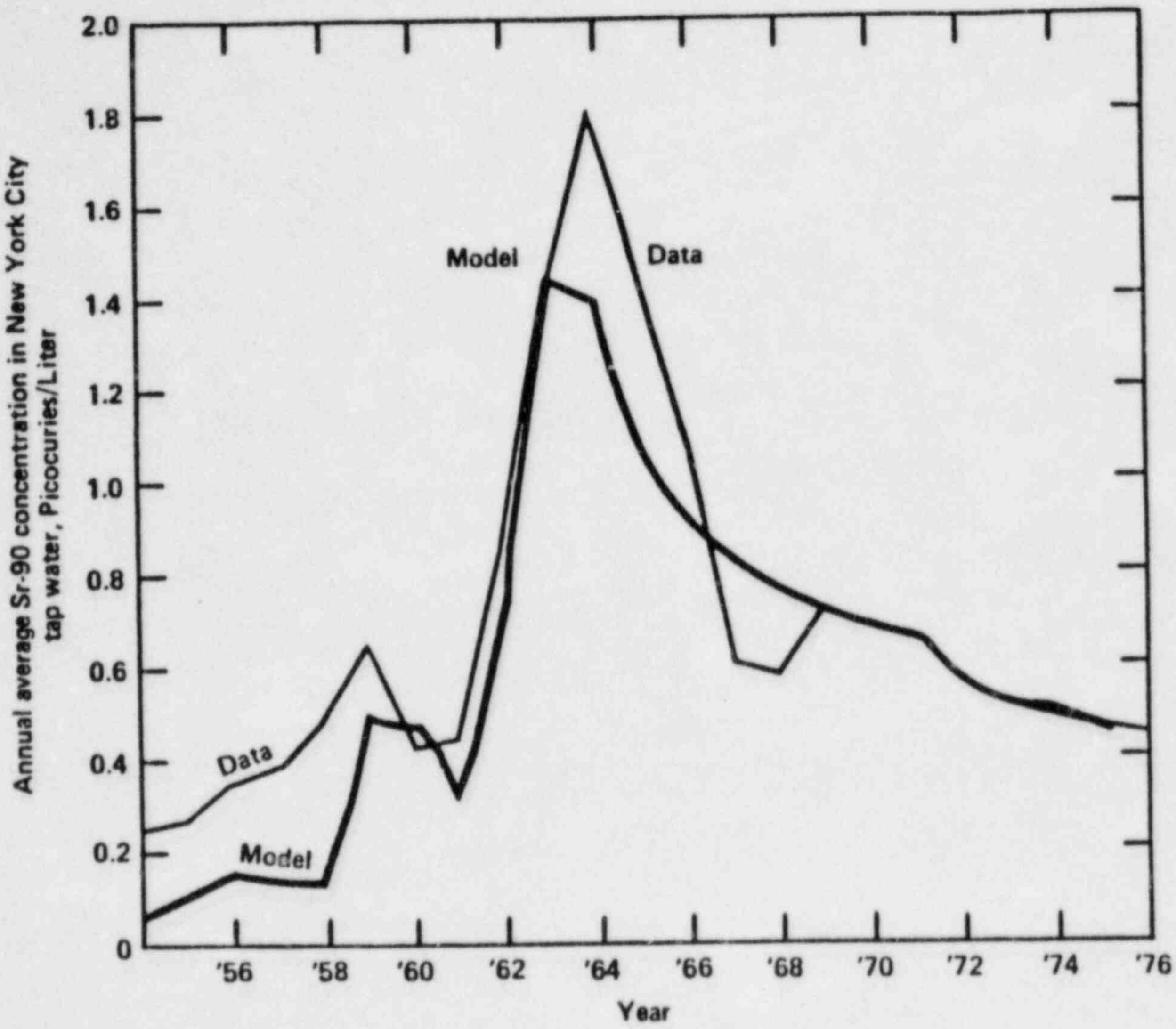


Figure 1 - Comparison Of Empirical Correlation Relating Rate Of Fallout To Concentration in Tapwater-New York City Data (Table 2 of Ref. 1, Appl. Exh.)

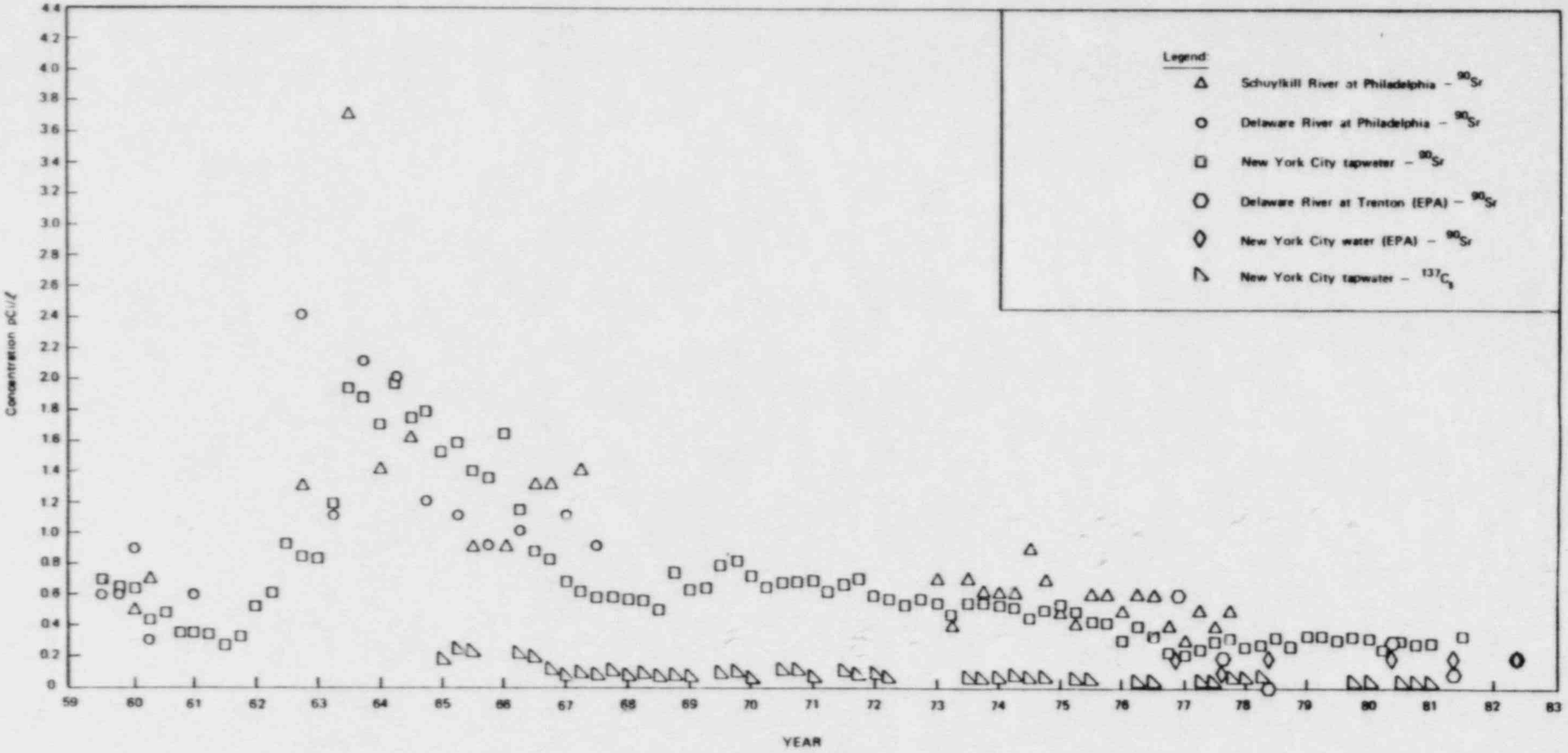
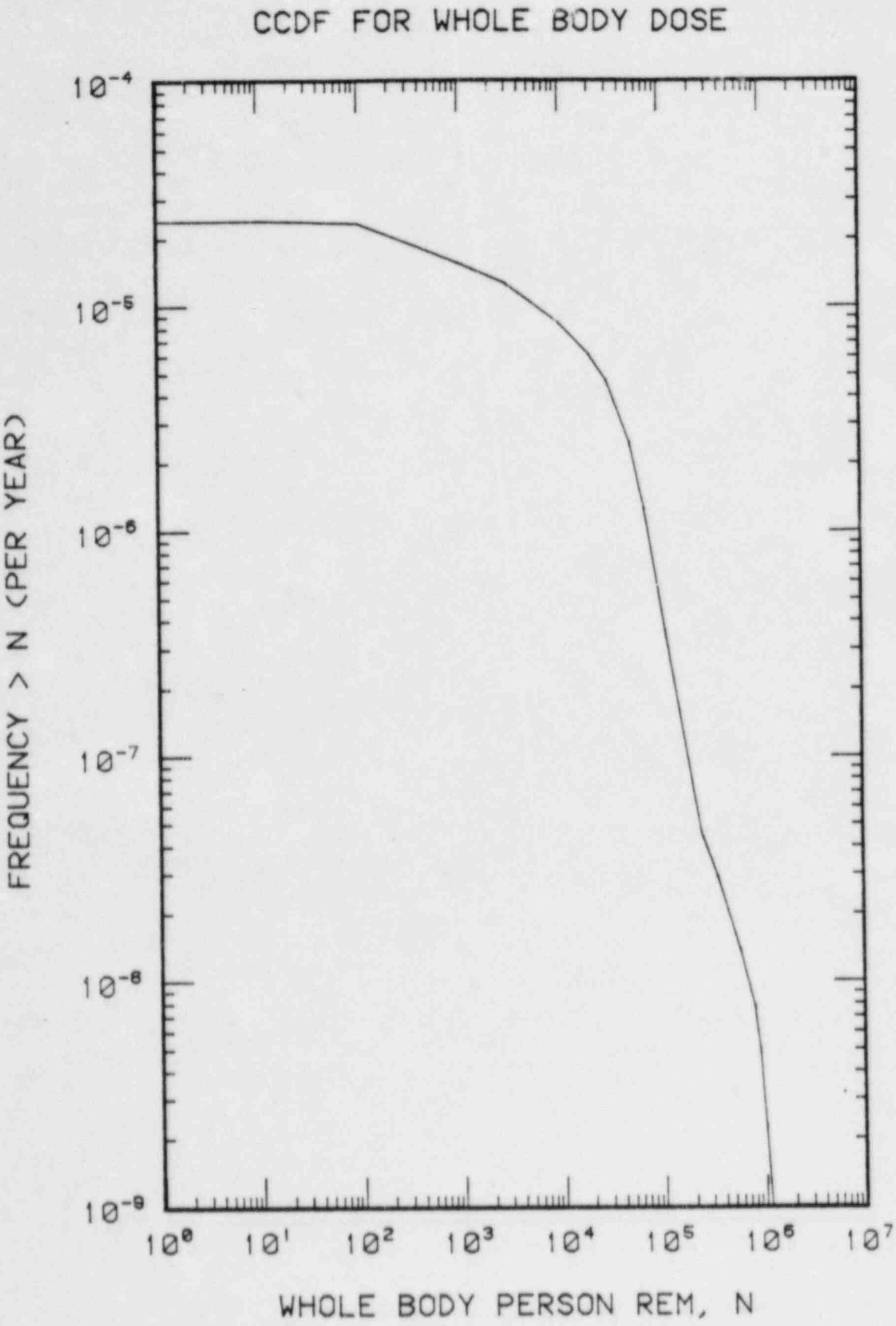


Figure 2. Time history of $^{90}Sr/^{137}C_s$ concentrations.



CCDF FOR WHOLE BODY DOSE

Figure 3 CCDF For Whole Body Dose - Drinking Water Pathway - City of Philadelphia Only

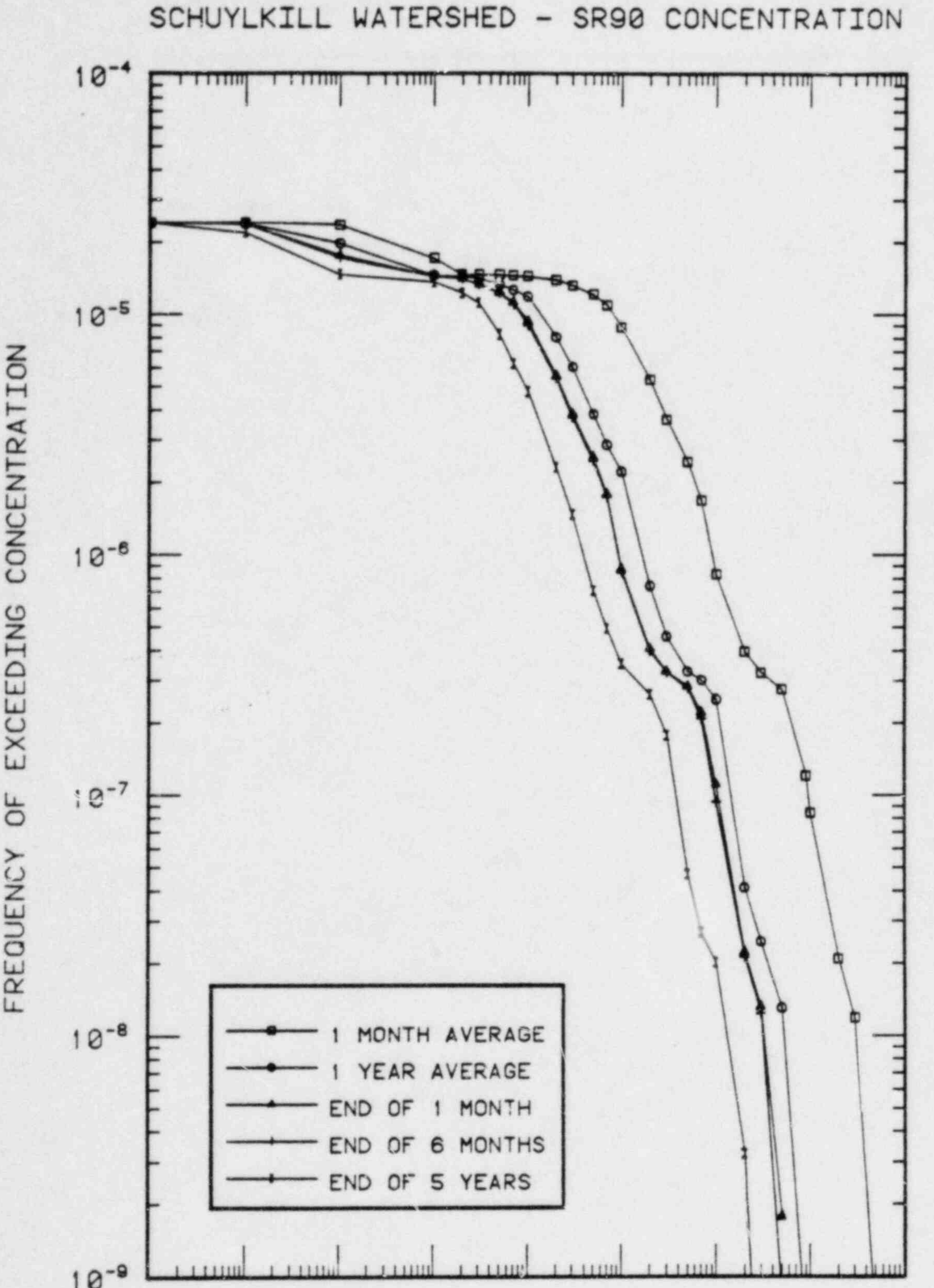


Figure 4(a) - CCDF of Concentration of ^{90}Sr in Schuylkill Water

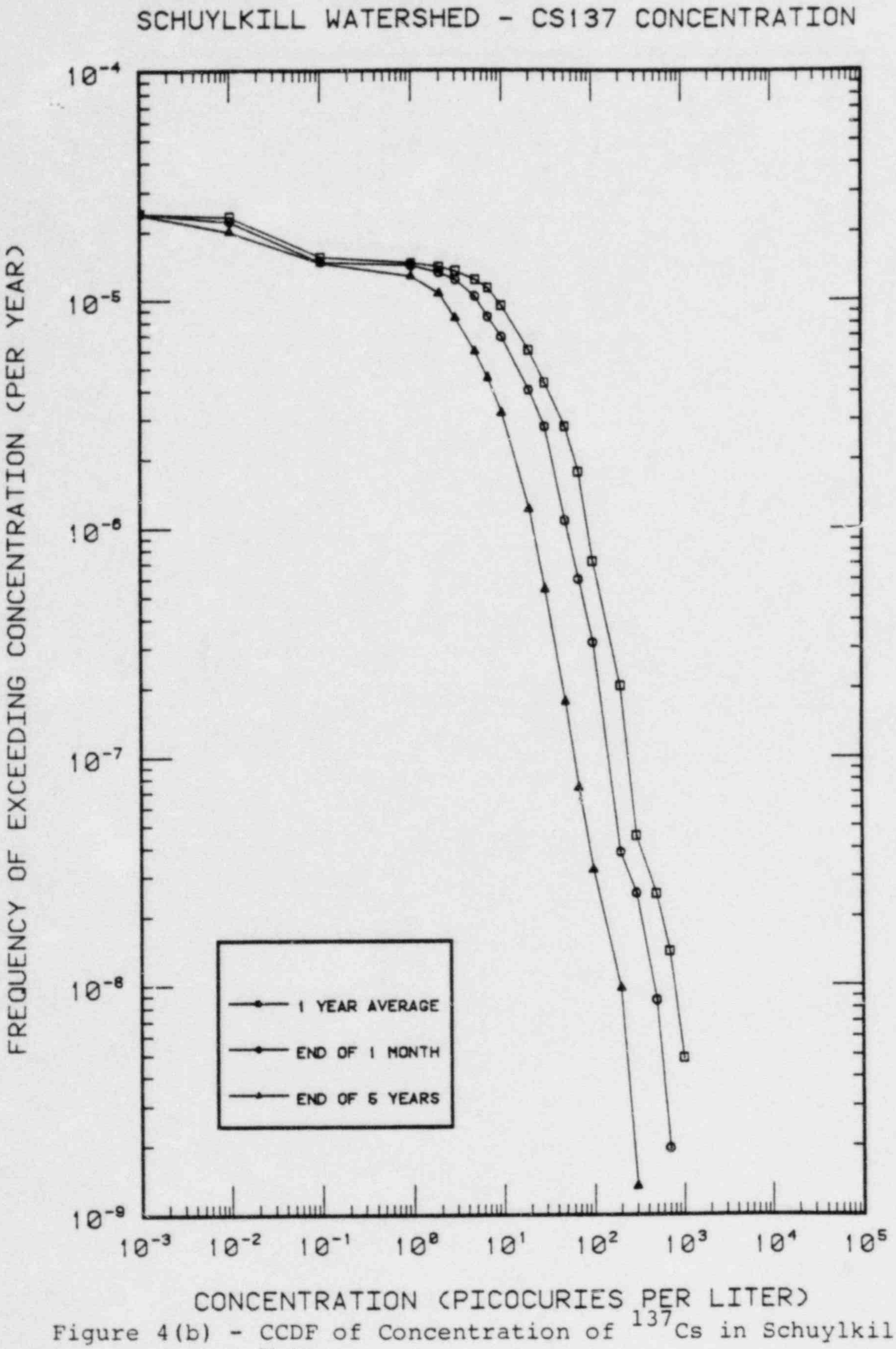


Figure 4(b) - CCDF of Concentration of ^{137}Cs in Schuylkill Water

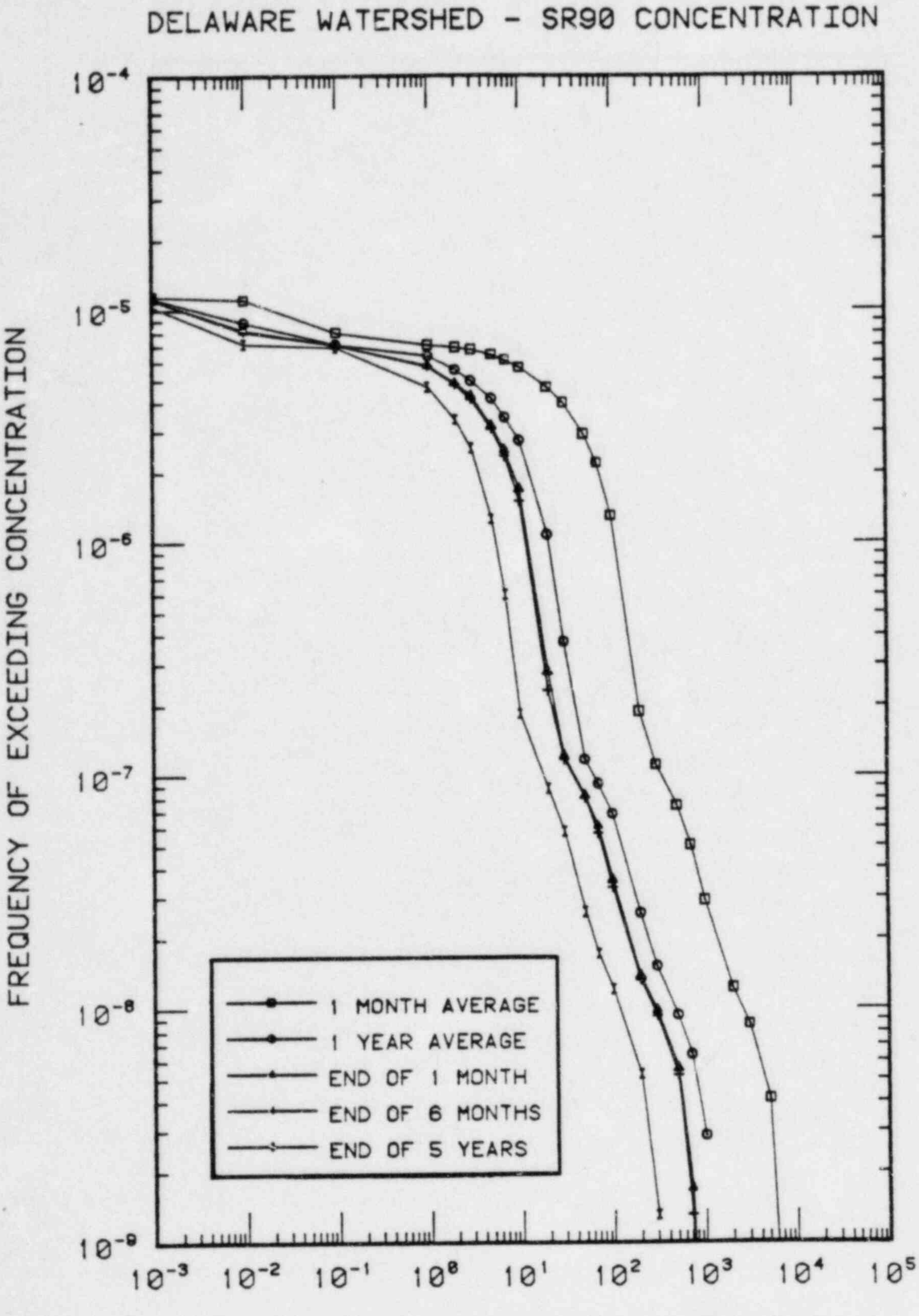


Figure 5(a) CCDF of ^{90}Sr Concentration in Delaware watershed

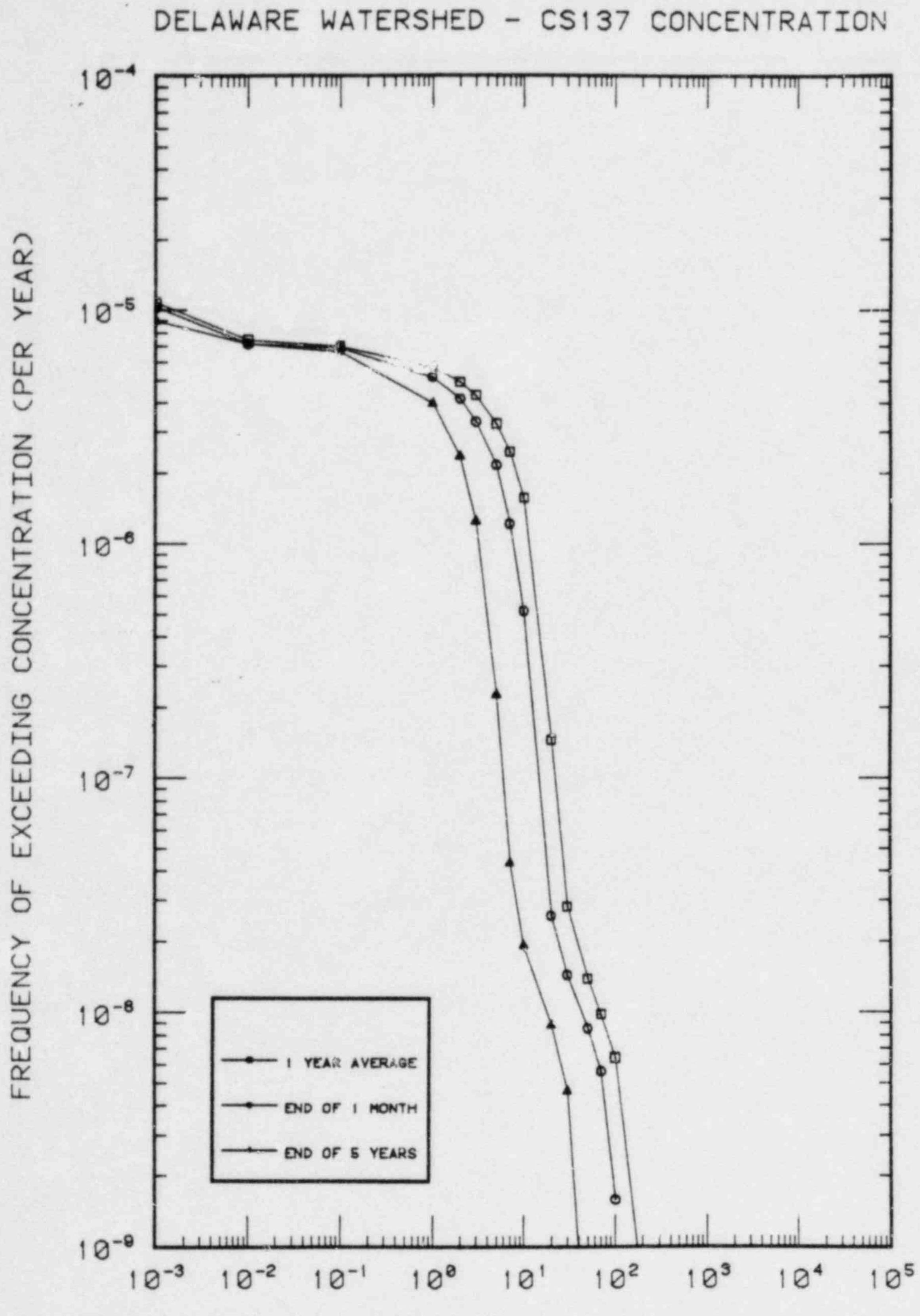


Figure 5(b) CCDF of Concentration of ^{137}Cs in Delaware water

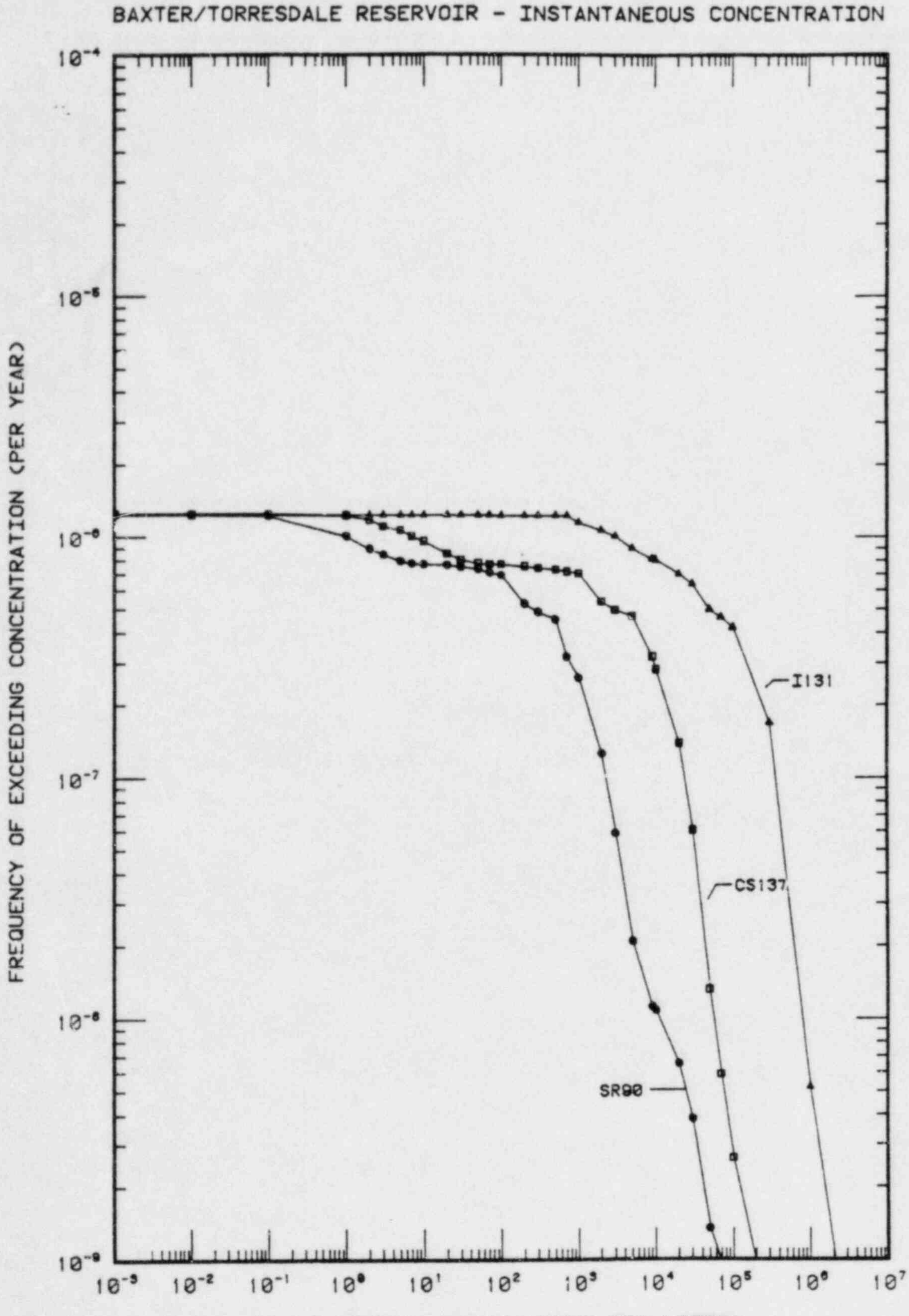


Figure 7 CCDF of ^{131}I, ^{137}Cs and ^{90}Sr Concentrations in the Baxter Reservoir

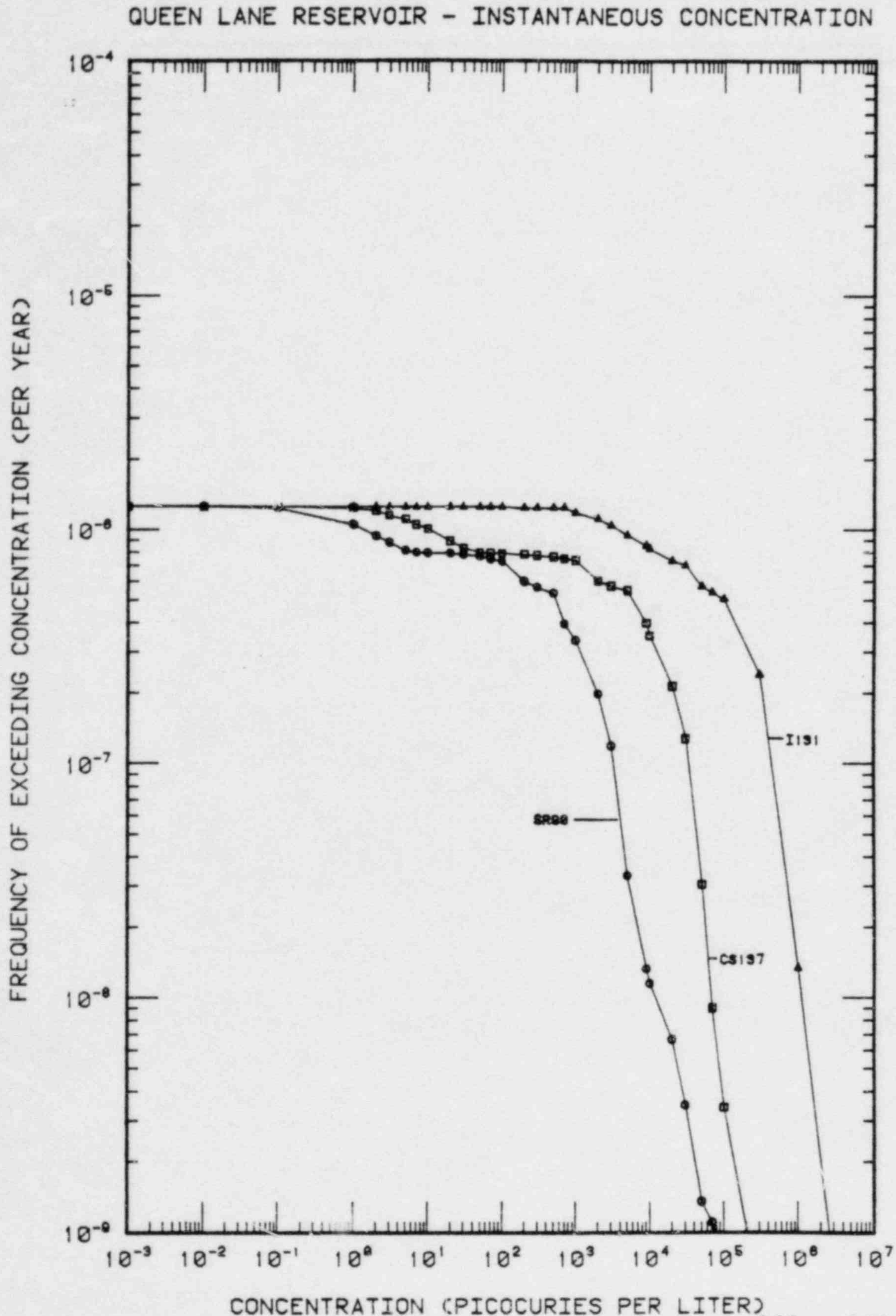


Figure 6 CCDF of Instantaneous Concentration of ^{131}I, ^{137}Cs and ^{90}Sr in the Queen Lane (and Belmont) Raw Water Basins

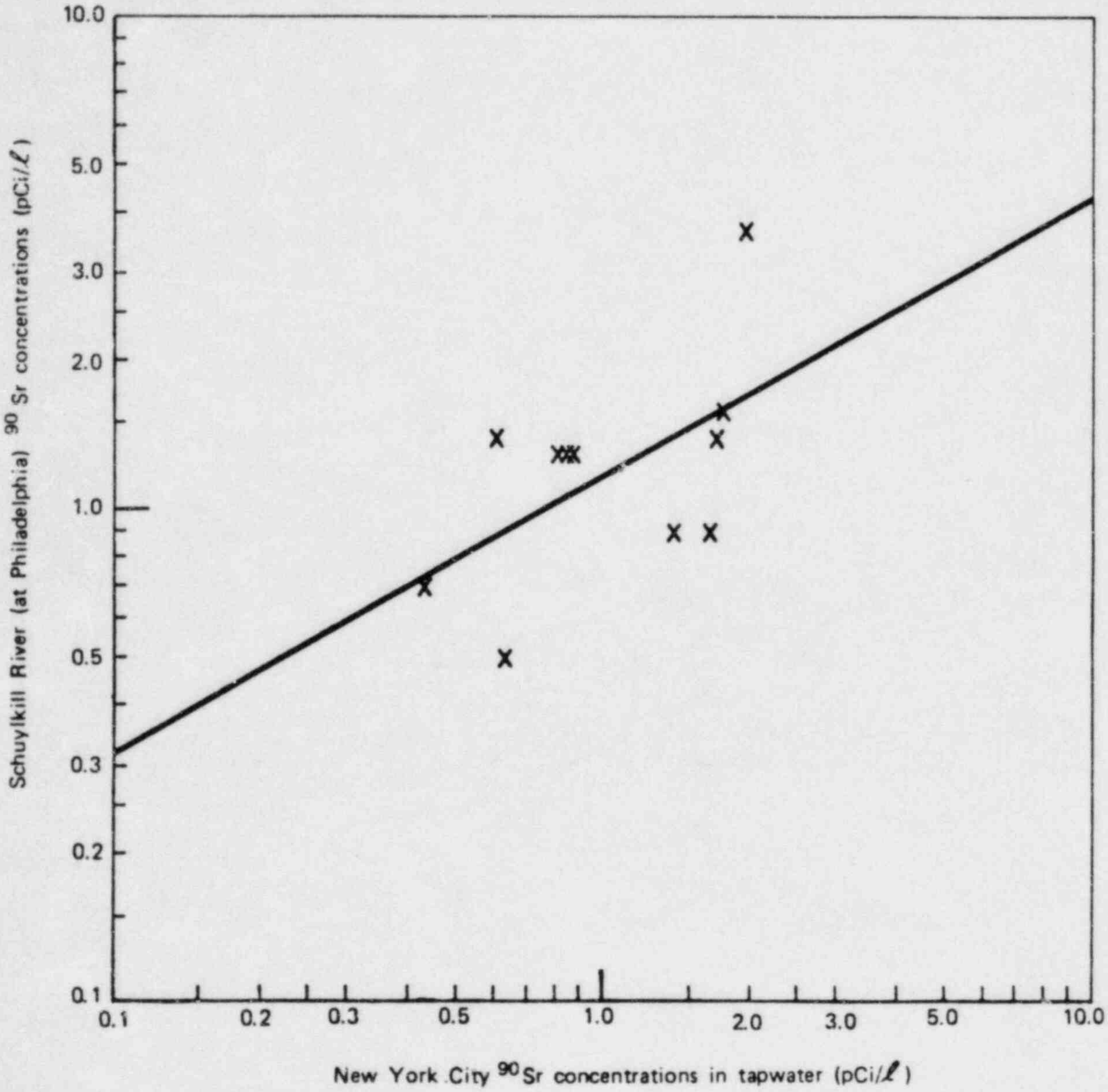


Figure 8. Correlation between ^{90}Sr concentrations in Schuylkill River water and New York City tapwater.

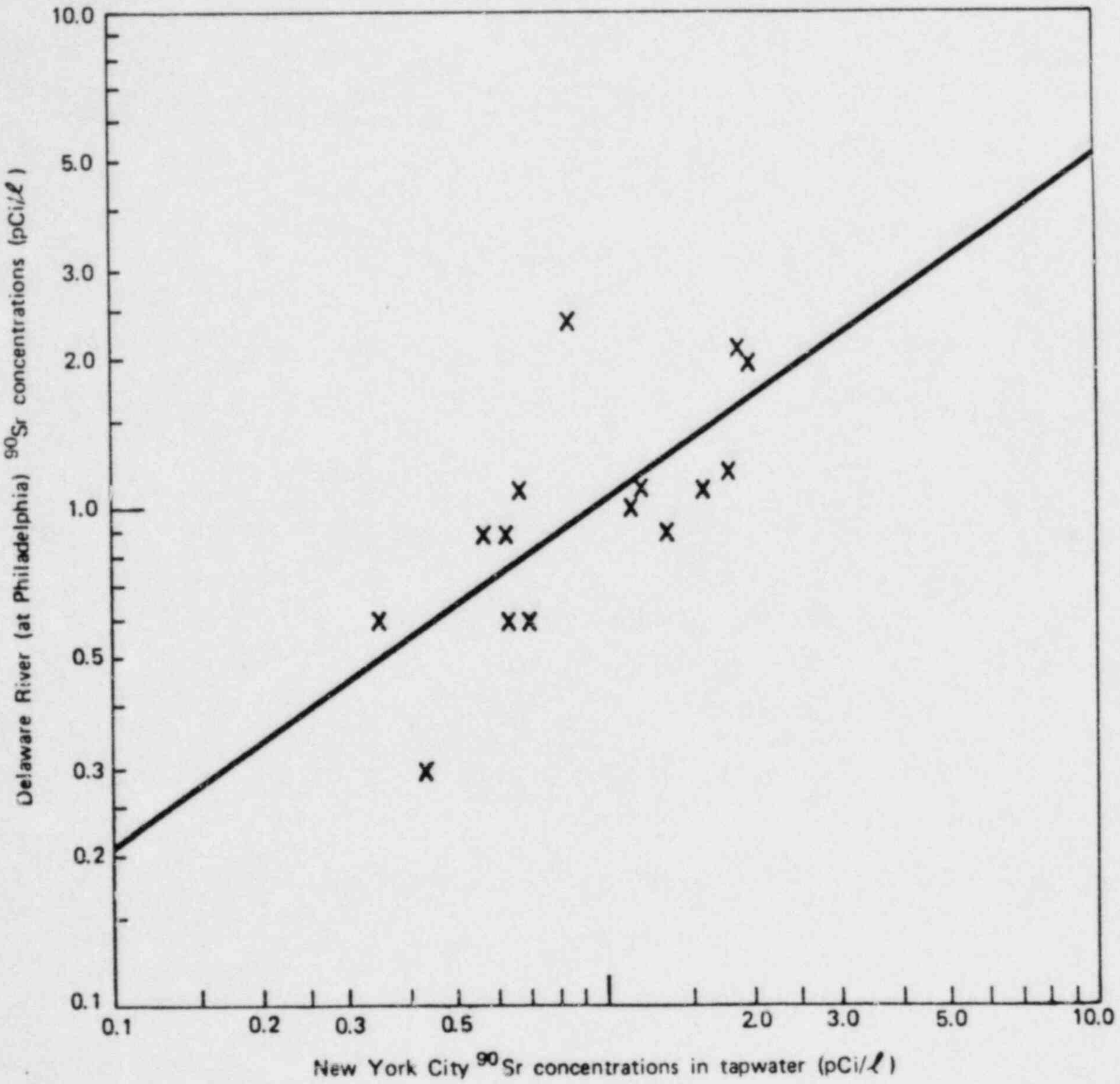


Figure 9. Correlation between ^{90}Sr concentrations in Delaware River water and New York City tapwater.

PROFESSIONAL QUALIFICATIONS

BART W. BARTRAM
Manager, Radiological Programs Department
NUS Corporation

My name is Bart W. Bartram. My business address is 910 Clopper Road, Gaithersburg, Maryland 20878. I am manager of the Radiological Programs Department. In this position, I am responsible for the performance of radiological dose assessments and providing general consulting services in support of uranium fuel cycle facilities, including nuclear power plants, and other nuclear facilities.

I received a Bachelor of Science degree in Physics from Mount Union College in 1967, a Master of Science degree in Physics from the University of Washington in 1971, and a Master of Science degree in Mechanical Engineering from George Washington University in 1976.

From 1971 to 1972, I worked for the Custom Stack Analysis Company. I conducted pilot plant studies used in the development of a new type of venturi scrubber and a lime wet scrubbing system for removing sulfur dioxide from the flue gases.

I have been with NUS Corporation since 1972. I was responsible for the noise impact analysis of nuclear and fossil-fueled power plants and other industrial facilities. I performed background noise surveys, computer analysis of plant-contributed noise during construction and operation, analysis of alternative cooling system noise, analysis of transmission line electrical effects, and noise impact assessments.

I am involved in licensing and permitting activities associated with uranium mining and milling operations, including the preparation of U.S. Environmental Protection Agency (EPA) Prevention of Significant Deterioration permit applications, state air permit applications, source material license applications, and environmental reports. In addition, I was responsible for preparing the radiological inputs to an environmental impact statement for remedial actions on the Grand Junction and Rifle uranium mill tailings sites in response to the Uranium Mill Tailings Remedial Action Program under contract to Sandia National Laboratories.

Other areas of work include radiological dose assessments of Savannah River Plant facilities and operations, high-level waste repositories, and risk assessments of fission-reactors and plutonium-fueled space nuclear systems.

PROFESSIONAL QUALIFICATIONS

CARMEN F. GUARINO
President of Carmen F. Guarino Engineers Ltd.

EDUCATION

LaSalle College, B.A., Chemistry and Biology,
Engineering and Related Courses at Drexel University,
Temple University, Pennsylvania State College,
Manhattan College

PROFESSIONAL STATUS

Registered Professional Engineer in Pennsylvania (By Exam.)
Diplomate, American Academy of Environmental Engineers
Certified Sewage Treatment Operator, Class "A", Pennsylvania

EXPERIENCE

Employed by Philadelphia Water Department, 1950 to 1980. Held following positions; Chief Chemist, Water Pollution Control Plant; Superintendent, Northeast Water Pollution Control Plant; Superintendnet, Southeast and Southwest Water Pollution Control Plants; Assistant Chief, Water Pollution Control Plants (3); Chief, Water Pollution Control Division (Includes Water Pollution Control Plants, Industrial Waste Control, Sewer Maintenance, and Administration).

January 1, 1968 - Assumed duties as Deputy Commissioner

January 3, 1972 - Appointed Commissioner of the Philadelphia Water Department. Appointment terminated January 7, 1980.

June 1, 1980 - Founded Carmen F. Guarino Engineers Ltd. Presently serving as President.

January 1, 1981 - Technical Director of S.E.L.E.C.; a design construction firm in Torino, Italy.

PROFESSIONAL OFFICES

Advisor to the Governor of Pennsylvania in his capacity as a Member of the Delaware River Basin Commission, 1972 to 1980.

Commissioner, Fairmount Park Commission, 1972 to 1980

Trustee-at-Large, American Academy of Environmental Engineers, 1979-1980.

President, Engineers' Club of Philadelphia, 1979
Vice-President, Engineers' Club of Philadelphia, 1978

President, Water Pollution Control Federation, 1980-1981
President-Elect, Water Pollution Control Federation, 1979-1980

Vice-President, Water Pollution Control Federation, 1978-1979

President, Water Pollution Control Association of Pennsylvania, 1968-1969

President, Eastern Pennsylvania Water Pollution Control Operators Association, 1965

ASSOCIATIONS

WATER POLLUTION CONTROL FEDERATION

President, 1980-1981
President-Elect, 1979-1980
Vice-President, 1978-1979
Vice-Chairman, Technical Practice Committee, 1977-1980
Chairman, National Conference, 1977
Chairman, Committee on Operation of Wastewater Treatment Plants, Manual of Practice No. 11, 1974 to 1978
Executive, Committee Member
Board of Control Member
Pennsylvania Director, 1971

WATER POLLUTION CONTROL ASSOCIATION OF PENNSYLVANIA

President, 1968-1969

EASTERN PENNSYLVANIA WATER POLLUTION CONTROL OPERATORS ASSOCIATION

President, 1965

AMERICAN SOCIETY OF CIVIL ENGINEERS

Chairman, Water Pollution Management Committee, 1975-1976
Chairman, Urban Wastewater Engineering Committee, 1974
Representative to WPCF - Manforce Program, 1970
Committee on Sewerage and Sewage Treatment, 1968-1970

Philadelphia Section:
  Board of Directors, 1970
  Secretary, 1965-1968
  Chairman, Hydraulic and Sanitary Engineering Division, 1966

AMERICAN ACADEMY OF ENVIRONMENTAL ENGINEERS

Trustee-at-Large, 1979-1980
Trustee-in-Charge, Committee on Upgrading Examinations-General Sanitary and Environmental, 1979
Trustee-in-Charge, Committee on Upgrading Examinations-Water Supply and Wastewater, 1979

INTERNATIONAL ASSOCIATION OF WATER POLLUTION RESEARCH

U.S. Chairman, "Instrumentation and Automation Workshop", Munich/Rome, 1981

U.S. Chairman, "Instrumentation and Control of Water and Wastewater and Transport Systems Workshop", London/Stockholm, 1977

U.S. Chairman, "Instrumentation and Automation Workshop", London/Paris, 1973

ASSOCIATION OF METROPOLITAN SEWERAGE AGENCIES

Board of Directors, 1978 to 1980

Member, National Society of Professional Engineers
Member, American Water Works Association
Member, American Public Works Association
Member, Instrument Society of American, Water and Wastewater Industries Division

PROFESSIONAL ACTIVIITES

Consulting Editoral Staff, Water & Sewage Works Journal, 1978-1982

Consulting Board Member, Milwaukee Water Pollution Abatement Program 1978 to 1980

Member, EPA-National Drinking Water Advisory Council, 1977-1979

Member, Mayor's Science and Technology Advisory Council, 1973 to 1980

Member, State Board of Certification of Sewage Treatment Plants and Water Works Operators

Chairman, "Water Plant Instrumentation and Automation Seminar", American Water Works Association Annual Meeting, New Orleans, Louisiana, 1976

Consulting for World Health Organization/Plan American Heath Organization - Prepared Pollution Control Abatement Plans for Rio de Janeiro, Brazil, 1975 & 1976

Participant, United States/Republic of China, "Environmental Pollution Seminar", Sponsored by National Science Foundation and National Science Council, Taipei, Taiwan, 1974

Participant, Technical Symposium, "Pure Oxygen in Sewage Treatment", Sponsored by Union Carbide Company, London, England, 1973

Consultant for EPA, Region III. Review Land Disposal of Sludge Process, London, England (and Environs), 1972

Consultant Work in Italy, Japan, Sweden, Switzerland and Africa

AWARDS

Simon W. Feese Lecture Award, American Society of Civil Engineers, 1979-1980

Morgan Award, Exemplary Inovative Treatment Technology, Water Pollution Control Federation, 1980

Instrument Society of America, Water and Wastewater Industries Division (Contributions to the Advancement of Automation Technology), 1978

George Washington Medal, Engineers' Club of Philadelphia, 1977

Haseltine Award, Pennsylvania Water Pollution Control Association (Outstanding Accomplishments in Solving Water Pollution Control Problems in Pennsylvania), 1977

Rudolph Herring Award, American Society of Civil Engineers (Technology Contributions), 1971

Arthur Sidney Bedell Award, Water Pollution Control Federation (Outstanding Service in the Field of Water Pollution Control and in the Operation of the Association), 1971

High Hat Award, Pennsylvania Water Pollution Control Association (Outstanding Service to the Water Pollution Control Profession), 1965

PAPERS AND PUBLICATIONS

Over 80 technical papers on water pollution control, municipal and industrial waste treatment, instrumentation, management, treatment and disposal of sludge and other related subjects.

PATENTS

Patent No. 685,723 issued June 6, 1978: Modification of Activated Sludge Process.

PROFESSIONAL QUALIFICATIONS

ALAN L. TOBLIN
Environmental Services Division
NUS Corporation

My name is Alan L. Toblin. My business address is 910 Clopper Road, Gaithersburg, Maryland 20878. I am a consulting engineer in the Radiological Programs Department.

I received a Bachelor of Engineering degree in Chemical Engineering from the Cooper Union in 1968 and a Master of Science degree in Chemical Engineering from the University of Maryland in 1970. I have taken additional graduate courses in Chemical Engineering at the University of Maryland.

At NUS Corporation since 1971, I have performed analytical and developmental work on computer codes for many projects. I have developed mathematical models of subsurface discharges of heated water in the presence of cross flows and physical boundaries in order to calculate the thermal and concentration distributions in the receiving water. I developed a mathematical model and a computer code for calculating the dispersion from a continuous point source of radioactive material in an aquatic environment, and I performed analytical and developmental work on a computer code to calculate the thermal and concentration contours due to heated surface discharges. I also worked on computer codes to calculate the ground-level deposition for the high altitude and low altitude release of particulates.

I coordinate efforts to meet water quality and quantity requirements for construction and operating licenses for power plants and other industrial facilities. I also perform analyses of heated water discharges and cooling water intake velocities for power plants, and I analyze experimental procedures and results of operation of thermal-hydraulic modeling of heated water intakes and discharges.

Recent projects have included the development of a computer code and analyses of the groundwater transport of chemically reactive species; the development of a methodology and a computer code to model the sediment transport in a river due to bottom disturbance; and the development of a methodology and corresponding computer code for calculating the transient behavior of a closed-cycle cooling system including any arbitrary configuration of cooling ponds, spray canals, and cooling towers, under varying meteorological conditions.

PROFESSIONAL QUALIFICATIONS

ROBERT WALLER
Director, Gaithersburg Office, PEC Division
NUS Corporation

My name is Robert Waller. My business address is 910 Clopper Road, Gaithersburg, Maryland 20878. I am Director of the Gaithersburg Regional Office of the PEC Division of NUS.

I received a Bachelor of Science degree in Chemical Engineering from Rensselaer Polytechnic Institute in 1958, a Master of Science degree in Environmental Engineering from Rensselaer in 1961, and a Doctor of Philosophy in Environmental Engineering Science from the John Hopkins University in 1966.

After receiving my Bachelor's degree, I worked for the New York State Department of Health in the Water Supply Section from 1958 to 1962. My primary responsibilities included the review and evaluation of the design and operation of new and existing water supply treatment plants throughout the New York State. Other areas of activity included the collection of data, evaluation of new water treatment techniques, establishment of emergency water supplies, and presentation of training courses.

From 1966 to 1969, I worked for E. I. du Pont de Nemours Company, Inc. I was responsible for technical assistance on more than 60 different problems involving over 30 different plants that manufactured a wide variety of organic and inorganic chemicals, as well as explosives, plastics, ammunition, paints, and pesticides. I developed waste treatment facility designs, planned and directed waste characterization and pollution abatement programs for individual plants, provided assistance for resolution of treatment plant operational problems, and provided liaison with regulatory agencies.

Working for Hittman Associates, Inc., from 1969 to 1972, I was responsible for all technical activities relating to water pollution control. These included industrial waste treatment consulting and process development, advanced waste treatment system development, planning and direction of governmental and industrial research and demonstration projects, and corporate research programs. I made technical contributions to the following projects: (1) environmental aspects of alternatives to the internal combustion engine, (2) alternative approaches to storm water management and erosion control, and (3) evaluation of the potential of desalting technology for meeting water resource needs.

From 1972 to 1980, I had overall corporate responsibility for program management, operations, and production for Environmental Quality Systems, Inc. I was project manager for more than 25 different projects and made significant technical and policy contributions to more than 20 other projects. Special areas of expertise included waste treatment process development and design, management of toxic and hazardous materials, process residue treatment and disposal, industrial waste treatment, emergency water and waste systems, areawide water quality planning, evaluation of emerging technology, control of non-point-source pollutants, and environmental impact analysis. In addition, I was a special UNESCO Consultant to the Kingdom of

Morocco and a member of a National Science Foundation Inspection Team evaluating damages to the water and sewage systems of Sendai, Japan after a major earthquake.

Since joining NUS Corporation in 1980, I have been responsible for the management and technical direction of projects involving hazardous, industrial, and municipal wastes. I act as principal-in-charge (PIC) on projects performed in the PEC Gaithersburg office as well as project manager on larger projects. Areas of responsibility include impact evaluation, problem definition, technology assessment, planning, evaluation and design of remedial action alternatives, and program planning. I managed a multidisciplined Public Works Group that completed over 40 facility planning and design assignments for government clients.