

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

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Before the Atomic Safety and Licensing Board JUN 13 12:02

In the Matter of)

Philadelphia Electric Company)
(Limerick Generating Station,)
Units 1 and 2)

DOCKET Nos. 50-352
50-353

OFFICE OF SECRETARY
DOCKETING & SERVICE
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6/12/84

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 ground-water (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
G.F. Daebeler risk associated with the contamination of the City of

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G.D. Kaiser
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E.R. Schmidt
A.L. Toblin

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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S. Levine
E.R. Schmidt
A.L. Toblin

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. 153; Ref 2, Appl. Exh. 154). 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.

B.W. Bartram 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 water 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.

G.F. Daebeler
C.F. Guarino
G.D. Kaiser
S. Levine
E.R. Schmidt
A.L. Toblin
R. Waller

DESCRIPTION OF MODEL

B.W. Bartram 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 radio-toxicity, they dominate the long term contamination of ingestion pathways (Ref. 2, Appl. Exh. 154; Ref. 3, Appl. Exh. 155). 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. 156). 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 Appendix F of the Severe Accident Risk

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.

G.D. Kaiser 6. The LIQPATH code is a modification by NUS of the code
E.R. Schmidt IPRES that was used at the Indian Point Hearings (Ref. 1,
A.L. Toblin Appl. Exh. 153; Ref. 2, Appl. Exh. 154). 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.

B.W. Bartram 7. Once the total amount of each radionuclide that has been
G.D. Kaiser deposited within each watershed has been calculated, the
E.R. Schmidt LIQPATH code predicts the subsequent temporal variation
A.L. Toblin 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.

B.W. Bartram 8. The LIQPATH code contains an empirical correlation that
G.D. Kaiser relates the quantity of a radionuclide deposited in the
A.L. Toblin 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. 154), 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. 154) that are
determined by fitting the data as described in
Appendix 1.

B.W. Bartram 9. A correlation similar to that given for New York City
G.D. Kaiser drinking water is applicable to any watershed and
A.L. Toblin 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.

B.W. Bartram 10. With regard to data on which to base the correlation
G.D. Kaiser parameters, a long term, continuous monthly record
A.L. Toblin of fallout rate is available as a function of latitude
(Refs. 5, 6 and 7, Appl. Exh. 157, 158 and 159) 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 con-
tinuous, monthly data base of ^{90}Sr from 1954 through late
1981, and a seventeen-year data base of ^{137}Cs (Ref. 8,
Appl. Exh. 160). This New York City tapwater concentra-
tion 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. 161) measured quarterly
 ^{90}Sr concentrations in the Delaware and Schuylkill Rivers
at Philadelphia (and other rivers such as the Susque-
hanna) sporadically from the third quarter of 1959
through the third quarter of 1967. The Philadelphia

Electric Company (PECo; Ref. 10, Appl. Exh. 162) 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. 163) 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).

B.W. Bartram 11. Figure 2 shows the comparability of the concentrations in
G.D. Kaiser the Schuylkill, Delaware, and New York City tapwater.
A.L. Toblin The Susquehanna River data indicate similar comparability.
This is expected for the following reasons;

- o The deposition (fallout) rate is latitude dependent (Ref. 7, Appl. Exh. 159); 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).

- o 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. 164).
- o The flow rates per unit watershed area are approximately equal for these systems, (Ref. 13, Appl. Exh. 165).

B.W. Bartram 12. In order to extend the limited Schuylkill and Delaware
 G.D. Kaiser River radionuclide water concentration data bases (to
 A.L. Toblin obtain a long continuous record which can be used to find
 the appropriate coefficients of the equations in Appen-
 dix 1), the 1959 through 1967 HEW data for each river
 were correlated with the New York City tapwater concen-
 trations. Since the range of HEW concentrations is much
 larger than 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.

B.W. Bartram 13. It is important to note that the New York City tapwater
G.D. Kaiser data have been correlated with the Schuylkill and
A.L. Toblin 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. 166). 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.

B.W. Bartram 14. As noted in paragraph 7, the expression relating the
G. D. Kaiser amount of each radionuclide deposited in the watershed
A.L. Toblin 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 combination 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

B.W. Bartram 15. The consumption of drinking water containing radio-
G.D. Kaiser nuclides from a postulated accidental airborne release
S. Levine from LGS would result in radiological doses to the
E.R. Schmidt population of Philadelphia. The method used to calculate
A.L. Toblin 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.

B.W. Bartram 16. First, the formulas given in Appendix 1 for the time
G.D. Kaiser dependent concentrations of strontium and cesium in the
A.L. Toblin 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 pop-
ulation 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. 167; Ref. 16, Appl. Exh. 168). 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. 156, 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), whereas the WASH-1400 conversion factors are much closer to the more recent recommendations of ICRP 30.

B.W. Bartram 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. 169, and Ref. 18, Appl. Exh. 170). Therefore, it was assumed that 7 percent of the City's population would be supplied by the Schuylkill and 93 percent by the Delaware.

B.W. Bartram 18. With the assumptions given in paragraphs 16 and 17, it is
G.D. Kaiser straightforward to calculate a CCDF of population dose
A.L. Toblin 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 approximately 2 percent of the Strontium is expected to pass directly into the river (Ref. 12; Appl. Exh. 164). 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.

B.W. Bartram 19. A further potential source of radiation dose would be the
G.F. Daebeler consumption of water from the City's treatment works that
C.F. Guarino 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.

B.W. Bartram 20. The area under this CCDF is 0.65 man-rem per reactor year, which is made up of 0.02 man-rem per reactor year from the consumption of water contaminated by direct deposition into the system, 0.16 man-rem per reactor year from strontium and cesium deposited on the watershed and 0.47 man-rem per reactor year from the iodine deposited on the watershed. This figure of 0.65 man-rem per reactor year is to be compared with 70 man-rem per reactor 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. 155).

CONCENTRATIONS IN TAPWATER - RESULTS

B.W. Bartram 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, 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.

B.W. Bartram 22. In order to judge the significance of the concentrations
G.D. Kaiser it is necessary to compare them with Federal or State
S. Levine Guidelines. The Federal Government has published
E.R. Schmidt standards for normal releases in 10CFR20 Appen-
A.L. Toblin dix 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. 19, Appl.
Exh. 171) 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.

B.W. Bartram 23. Returning to Figures 4 (Schuylkill) and 5 (Delaware),
G.D. Kaiser since ^{90}Sr is principally considered as a contributor to
S. Levine the long term accumulation of radiation dose, the most
E.R. Schmidt appropriate PEMA guide for comparison with ^{90}Sr concentra-
A.L. Toblin tions 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 300,000 per reactor year, and the probability that
the Delaware will be contaminated above this guide is one
in 7 million per reactor year.

B.W. Bartram 24. The above probabilities have been obtained by assuming
G.D. Kaiser that no preventive actions take place. As discussed in
S. Levine paragraph 34 preventative measures which could sub-
E.R. Schmidt stantially reduce the long term impact of ^{90}Sr are
A.L. Toblin 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 2-1/2 million to one in 17 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 countermeasures are not taken, the man-rem contribution is a small fraction of that from other pathways.

B.W. Bartram 25. The discussion given in paragraphs 23 and 24 shows that
G.D. Kaiser the probability that there will be long term contamina-
S. Levine tion of the Delaware even in the absence of protective
E.R. Schmidt actions is quite small, and that the probability that
A.L. Toblin 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 seventeen
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.

B.W. Bartram 26. In the short term, the PEMA one-month PAG (8000pCi/l of
G.D. Kaiser ^{90}Sr) applies. For ^{90}Sr alone, the probability of
S. Levine exceeding this limit is about once chance in 3 million
E.R. Schmidt per reactor year in the Schuylkill and less than one
A.L. Toblin 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 (330mrem 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 a hundred and fifty 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

B.W. Bartram 27. The problem described above is one of long term
G.F. Daebeler contamination of the rivers as a result of
C.F. Guarino deposition of long lived radionuclides such as
G.D. Kaiser strontium and cesium on the watershed. A short term
S. Levine problem may exist if radionuclides are deposited directly
E.R. Schmidt onto the surface of the raw water basins at Baxter, Queen
A.L. Toblin Lane and Belmont or the filtered water reservoir at East
A. Waller 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
the 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.

B.W. Bartram 28. As noted the concentrations given in Figures 6 and 7 are
G.D. Daebeler instantaneous values in the raw water in the basins. If
C.F. Guarino this water were to be processed (without removal of any
G.D. Kaiser radioactivity) and distributed at the normal rate the
S. Levine contaminated water would be all gone after approximately
E.R. Schmidt 3 days. The 30 day average concentration would therefore
A.L. Toblin be one tenth of that given in Figures 6 and 7. The
R. Waller 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

B.W. Bartram 29. The preceding 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 covered 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.

- E.R. Schmidt 31. At lower contamination levels involving watershed deposi-
A.L. Toblin tion which are likely to persist for more extended
C.F. Guarino periods of time, the affected water source would require
R. Waller 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. 166) include:

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

E.R. Schmidt 32. Extensive research on removal of various fission products
A.L. Toblin from water was conducted from the early 1950s to the mid
C.F. Guarino 1960s largely as a result of concern about fallout from
A. Waller atmospheric weapons testing during that period (Ref. 20,
Appl. Exh. 172). 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.

E.R. Schmidt 33. Modifications to the current treatment process are
A.L. Toblin feasible which could achieve reductions in the concentra-
C.F. Guarino tion of certain nuclides by factors of from 5 to 10.
A. Waller 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. 172,
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.

E.R. Schmidt 34. Dissolved strontium can be effectively removed by
A.L. Toblin the use of a lime-soda softening process normally
C.F. Guarino employed to remove dissolved calcium and magnesium
A. Waller 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-precipita-
tion in an initial softening step with dosages of soda
ash (sodium carbonate) in excess of those indicated by
stoichiometric requirements alone. "Repeated-precipita-
tion", 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. 172). 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

B.W. Bartram 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

G.F. Daebeler
C.F. Guarino
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S. Levine
E.R. Schmidt
A.L. Toblin
A. Waller

probabilities are higher, but even so the implementation, of reasonable countermeasures reduces the probability of exceeding the PEMA long term guide to one in seventeen 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 that 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 1. An integral part of the model described in the foregoing
G.D. Kaiser testimony relates the transient concentrations of radio-
A. Toblin strontium (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. 154 p. 12) and are applicable to any watershed
and any radionuclide, although the coefficients may
change;

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

$$C = k_2 AR + Mk_3$$

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, m²

R is the rate of fallout, curies/(yr-m²)

k₁ is the fraction of the affected watershed covered by open water

k₂ is the coefficient relating the rate of fallout to surface water concentration, yr/liter

k₃ is the coefficient relating available accumulated fallout on land to surface water concentration, liter⁻¹

λ₁ 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}

- B.W. Bartram 2. For the case of an instantaneous deposition of an amount
G.D. Kaiser \bar{D} Curies/ m^2 of a radionuclide within a watershed of
A. Toblin area A, the solution to equation 1 is

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

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

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

- B.W. Bartram 3. As noted in the testimony at paragraph 14, the parameters
G.D. Kaiser in eqs. (1) through (3) were obtained after first
A. Toblin 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. 173). 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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Table 1

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

	^{90}Sr	^{137}Cs	^{134}Cs	^{131}I	^{133}I
10CFR Part 20	300	20,000	9,000	300	1,000
PEMA - uncontrolled discharges to surface water and in circumstances where the water supply is influenced 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 = 4.903×10^9

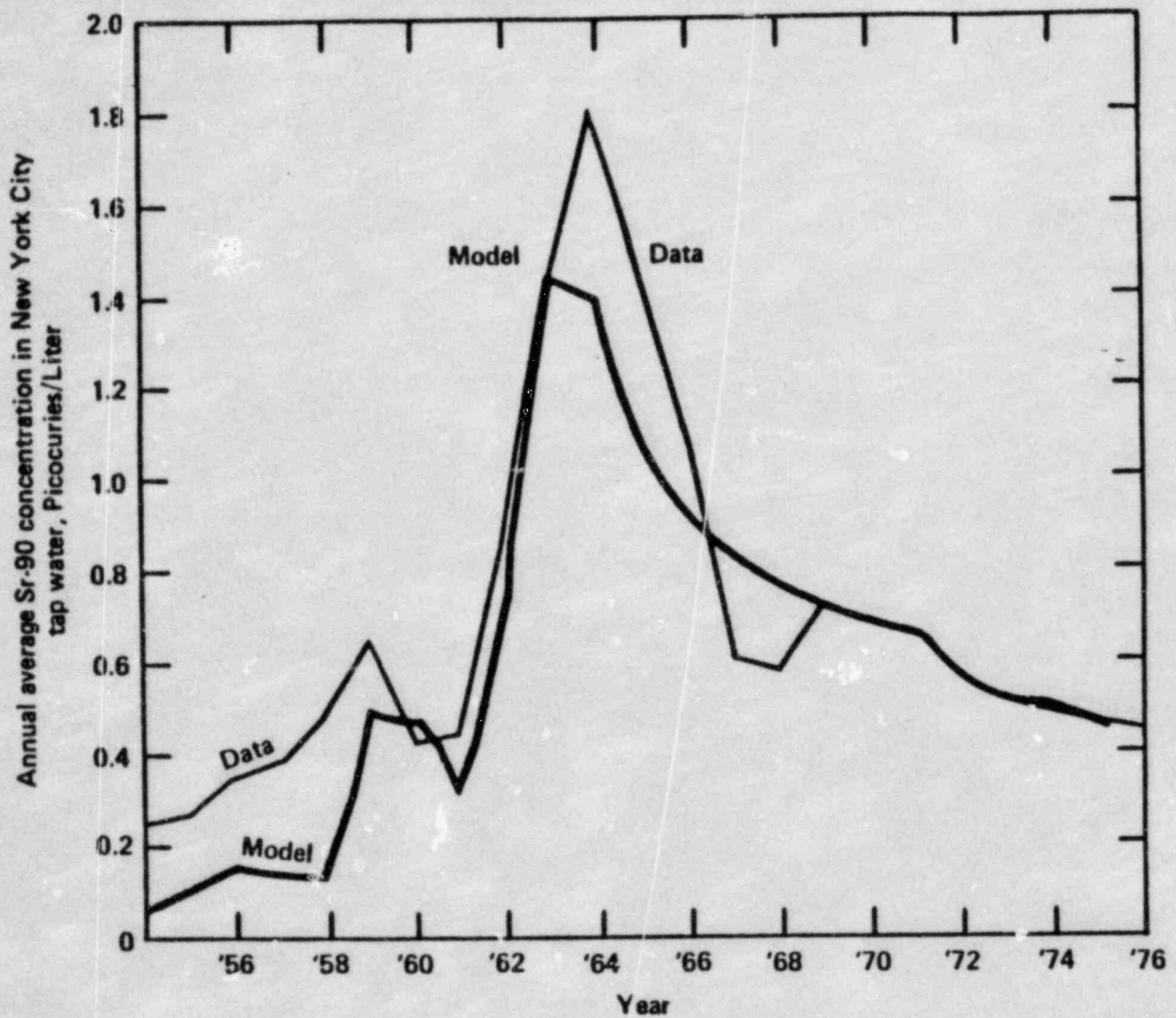


Figure 1 - Comparison of Empirical Correlation Relating Rate of Fallout to Concentration in Tapwater- New York City Data (Table 2 of Ref. 1, Appl. Exh. 153)

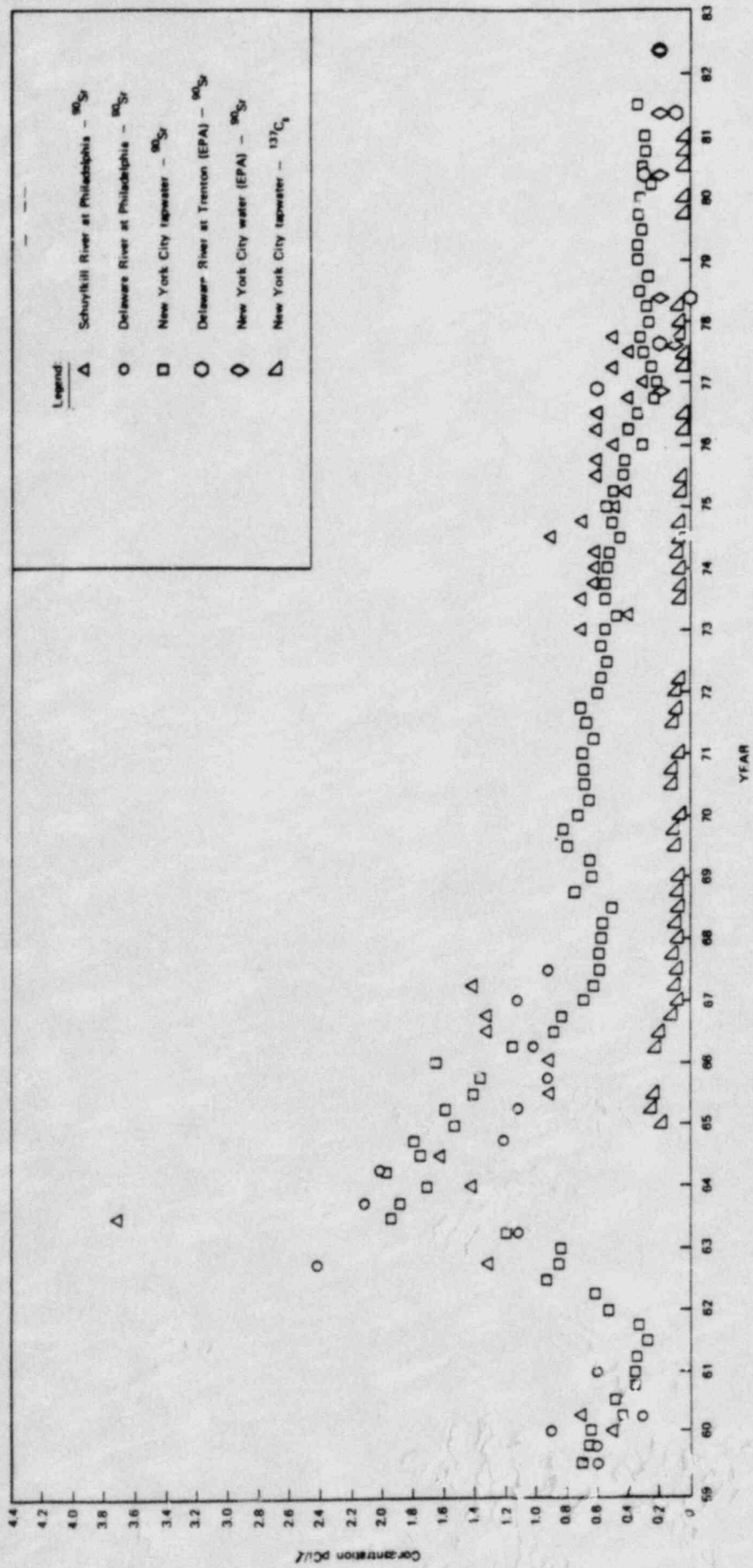


Figure 2. Time history of $^{90}\text{Sr}/^{137}\text{Cs}$ concentrations.

CCDF FOR WHOLE BODY DOSE

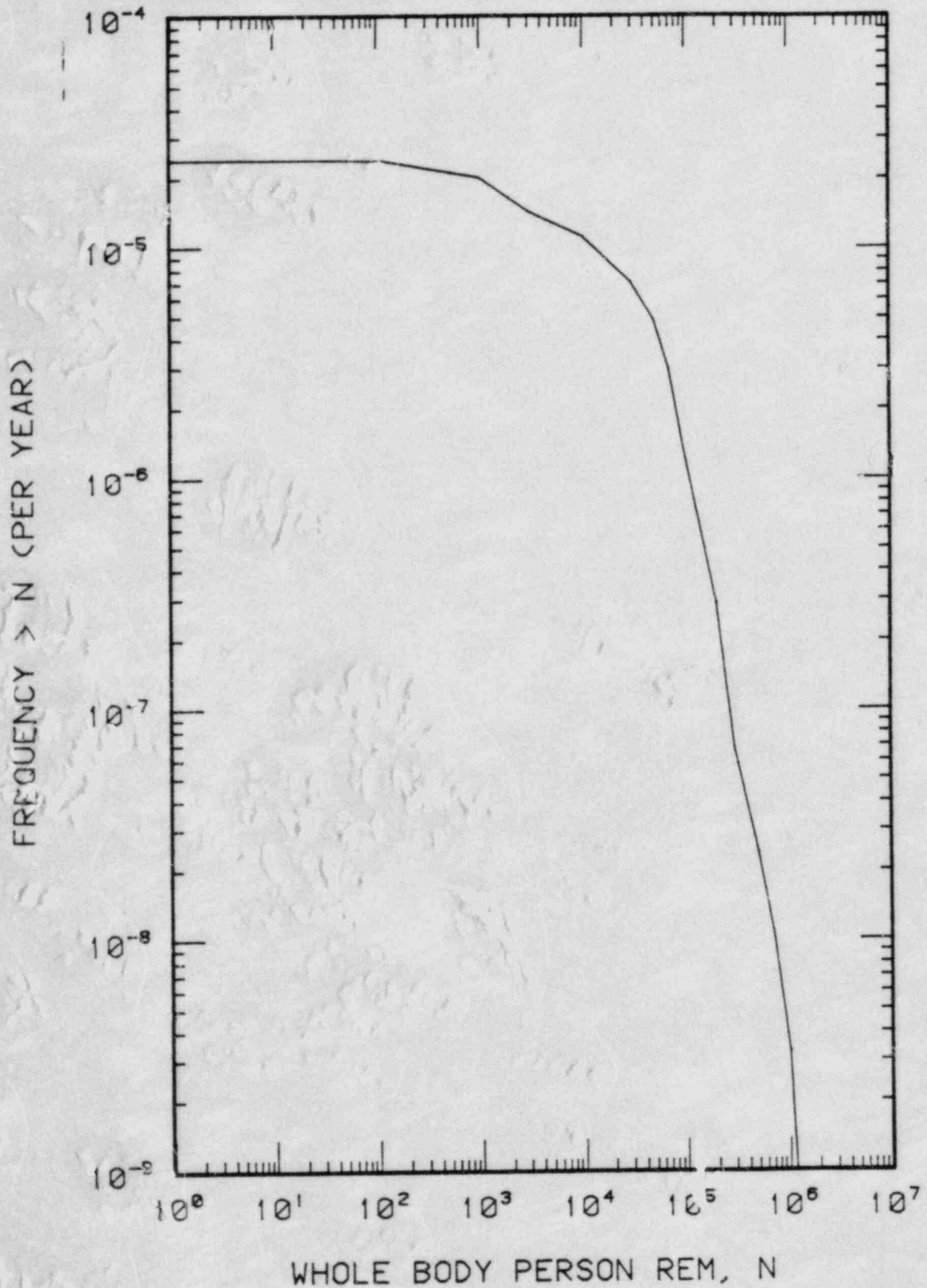


Figure 3 CCDF For Whole Body Dose - Drinking Water Pathway - City of Philadelphia Only

SCHUYLKILL WATERSHED - SR90 CONCENTRATION

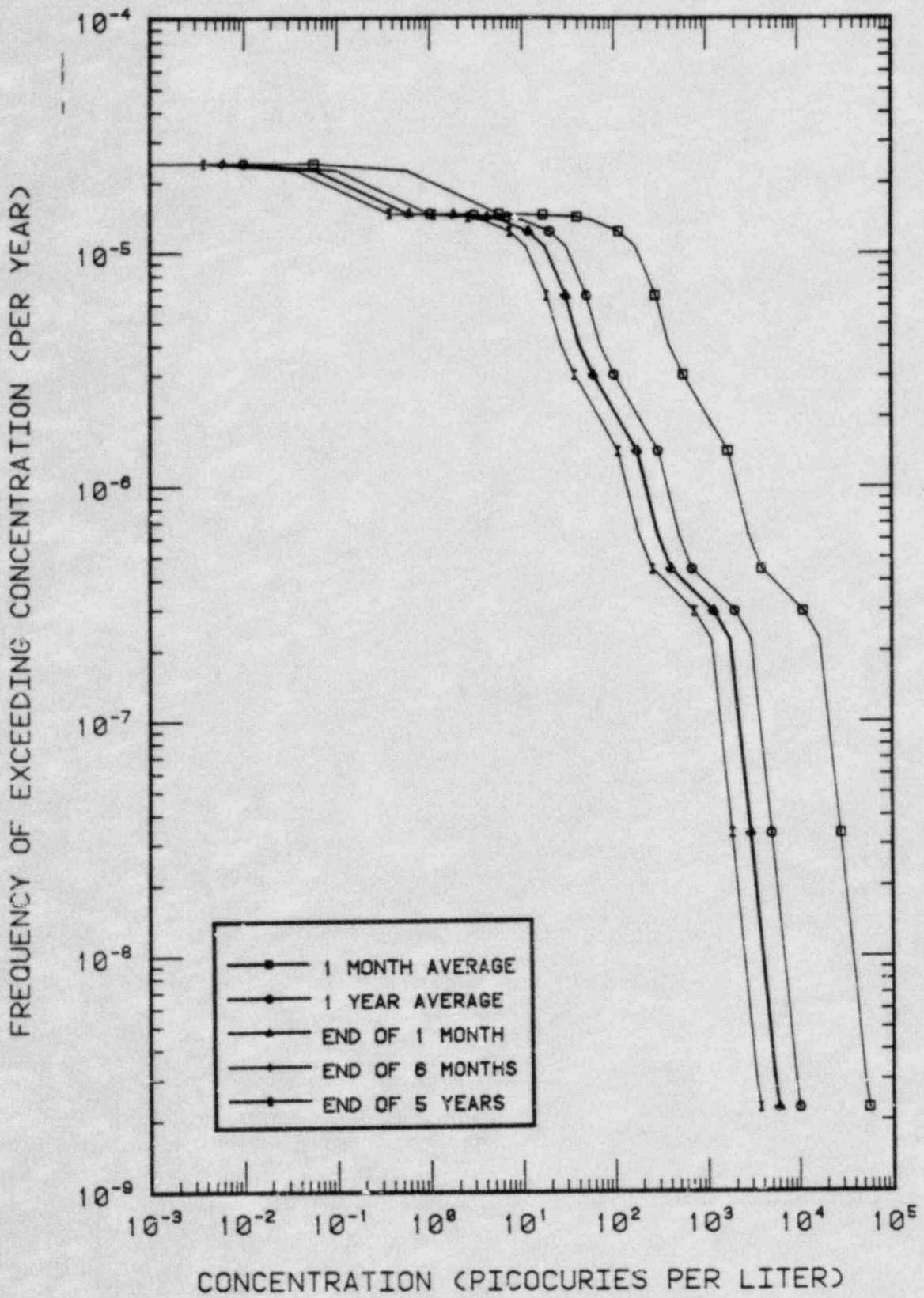


Figure 4(a) - CCDF of Concentration of ^{90}Sr in Schuylkill Water

SCHUYLKILL WATERSHED - CS137 CONCENTRATION

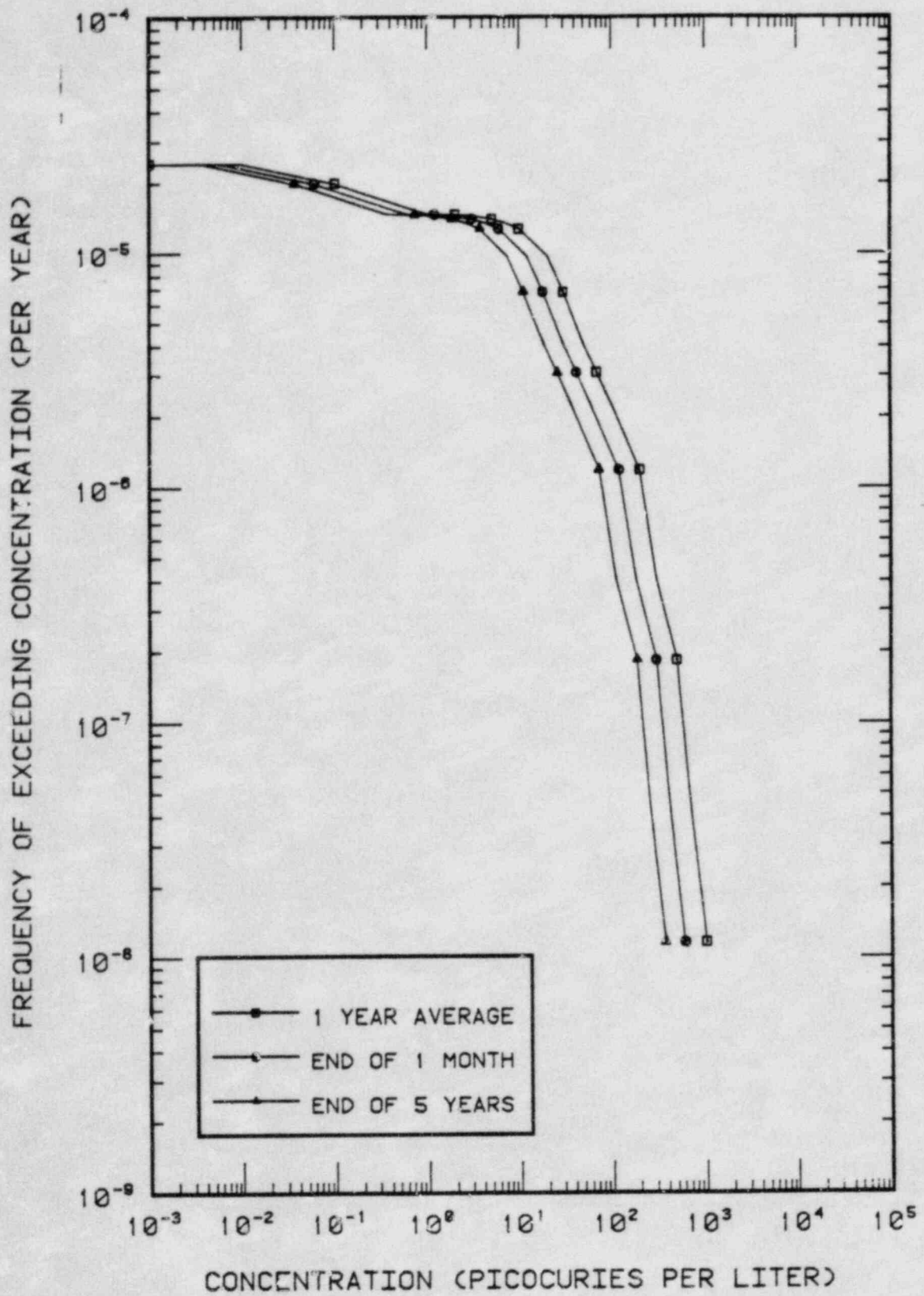


Figure 4(b) - CCDF of Concentration of ^{137}Cs in Schuylkill Water

DELAWARE WATERSHED - SR90 CONCENTRATION

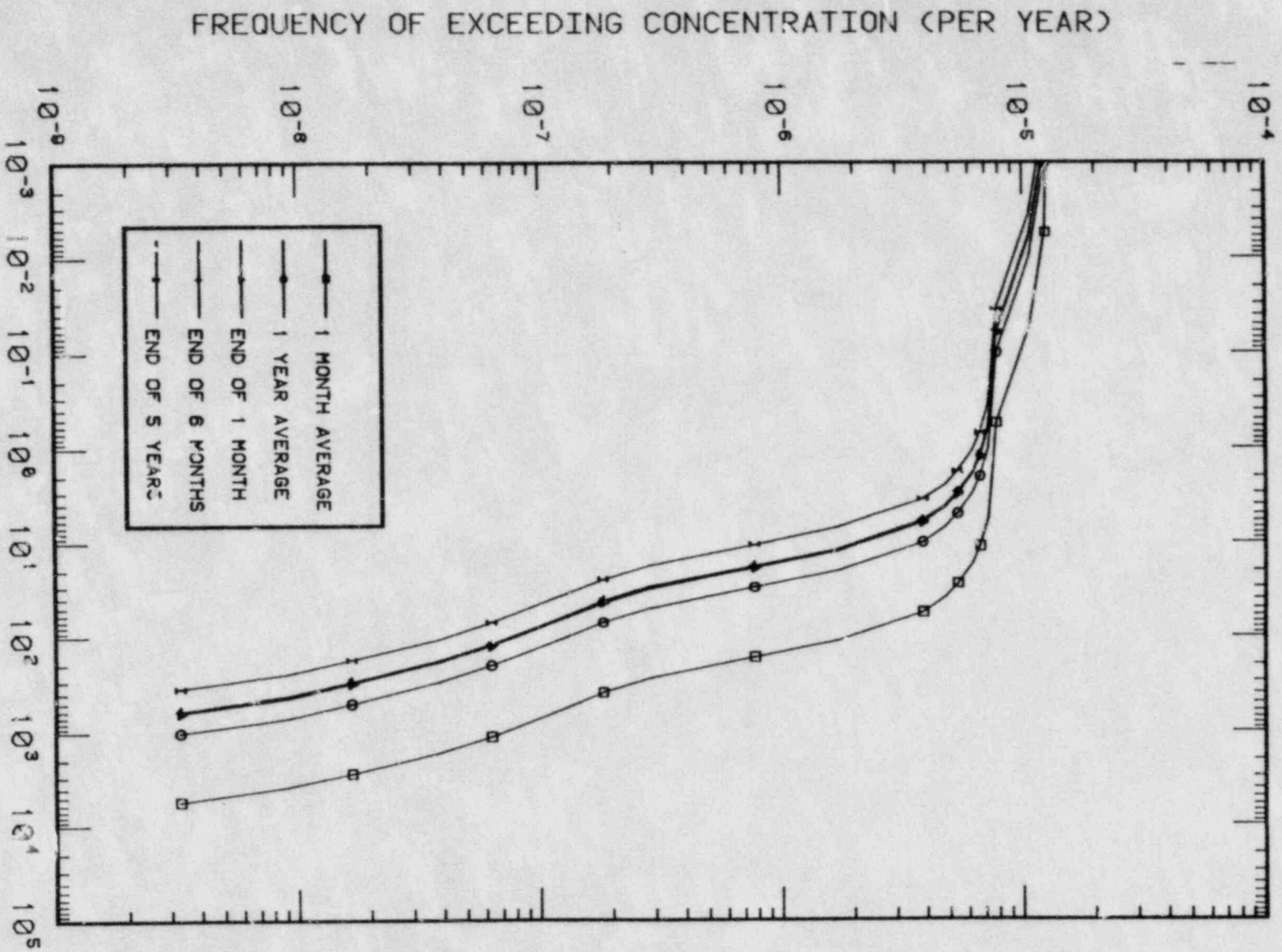


Figure 5 (a) CCDF of ⁹⁰Sr Concentration in Delaware watershed

DELAWARE WATERSHED - CS137 CONCENTRATION

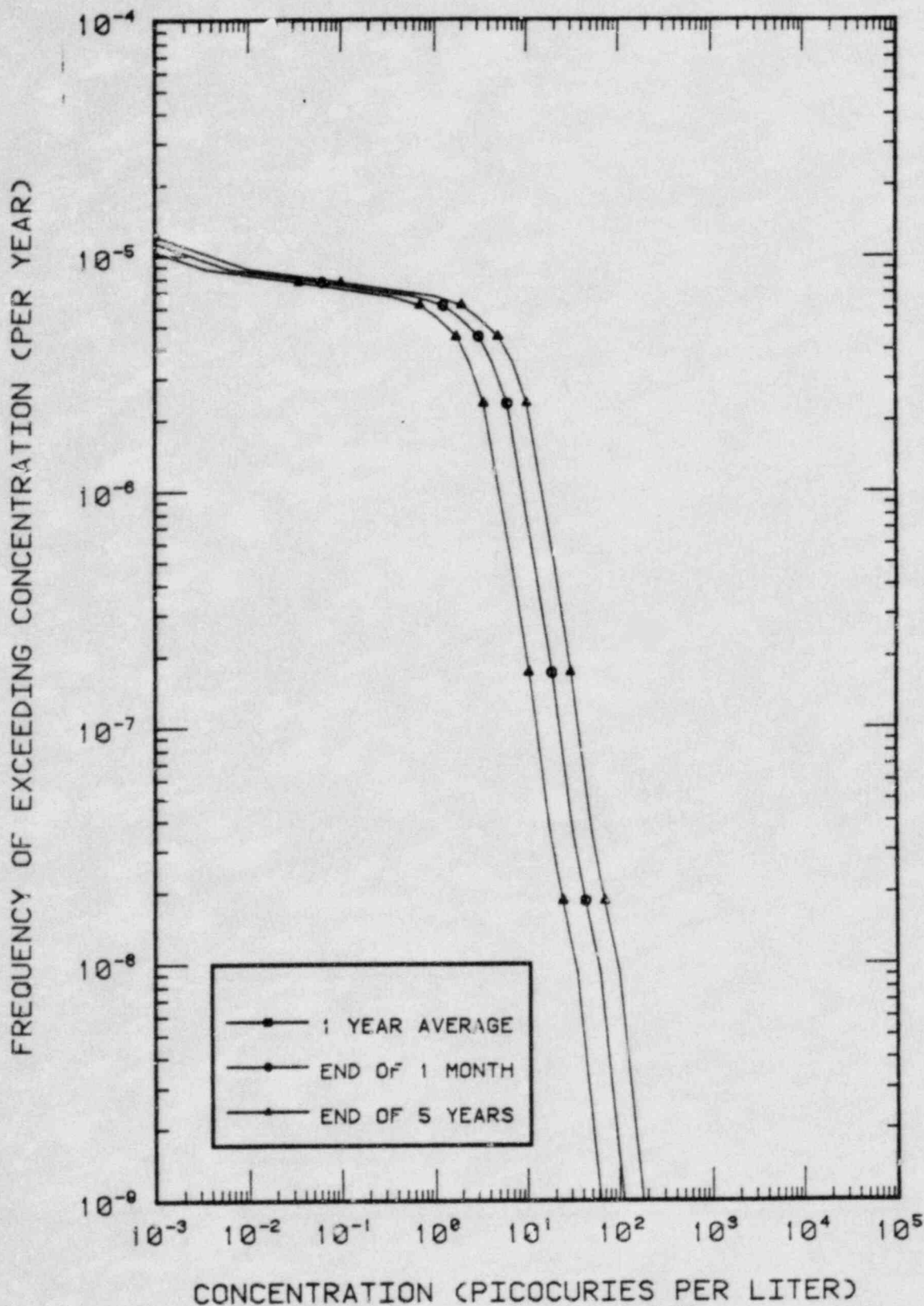


Figure 5(b) CCDF of Concentration of ^{137}Cs in Delaware water

QUEEN LANE RESERVOIR - INSTANTANEOUS CONCENTRATION

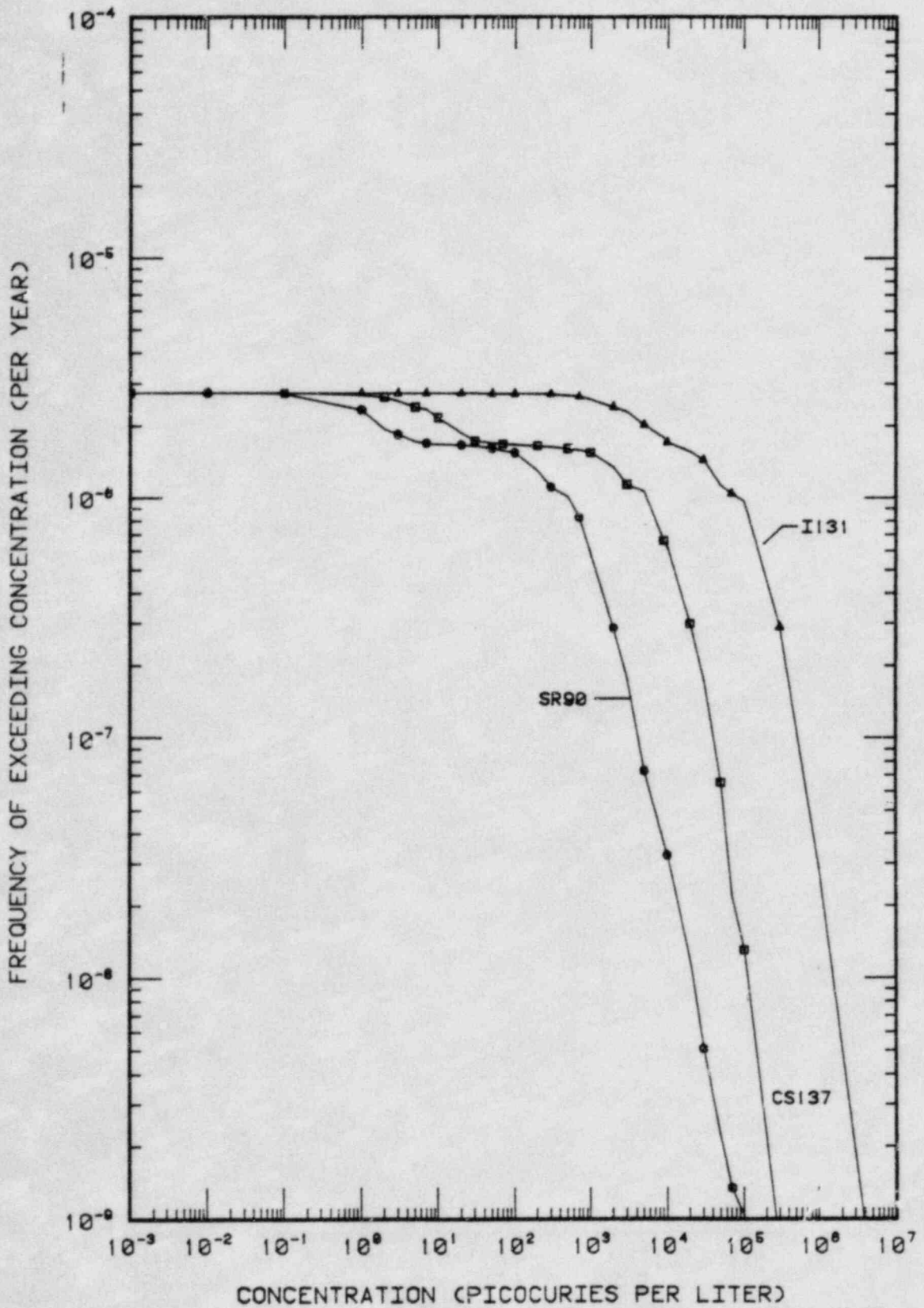


Figure 6 CCDF of Instantaneous Concentration of ^{131}I , ^{137}Cs and ^{90}Sr in the Queen Lane (and Belmont) Raw Water Basins

BAXTER/TORRESDALE RESERVOIR - INSTANTANEOUS CONCENTRATION

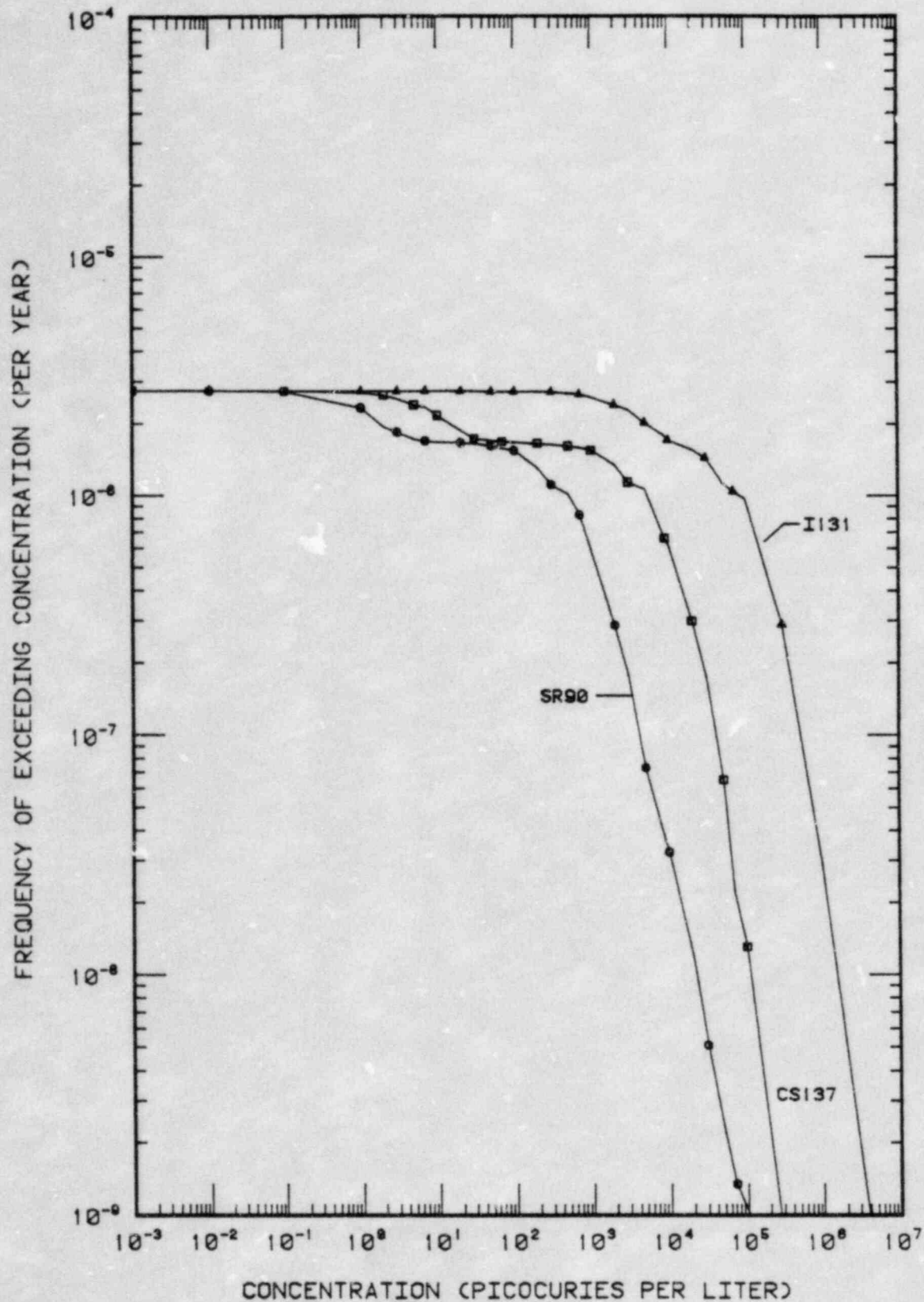


Figure 7 CCDF of ¹³¹I, ¹³⁷Cs and ⁹⁰Sr Concentration in the Baxter Reservoir

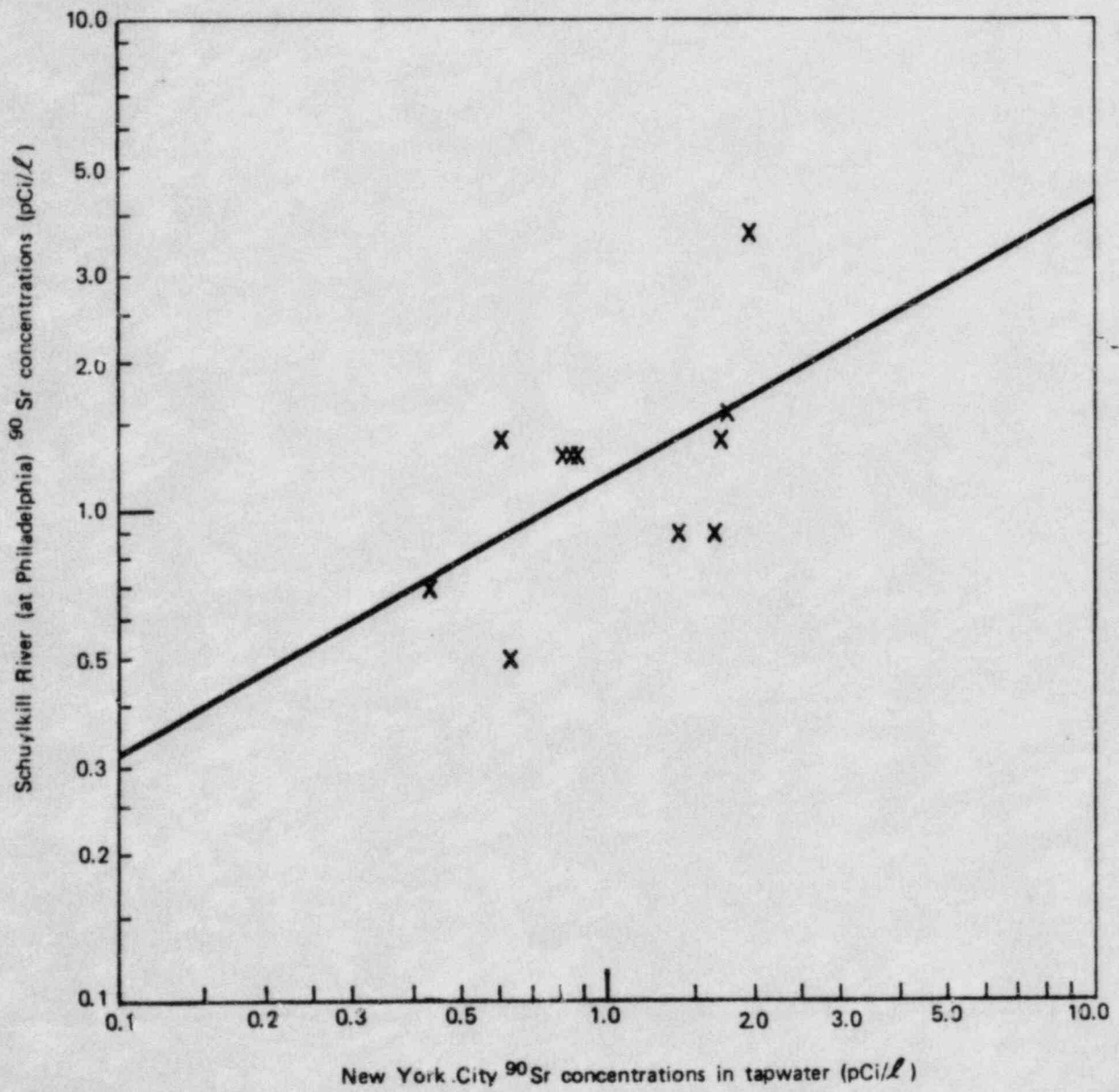


Figure 8. Correlation between ⁹⁰Sr concentrations in Schuylkill River water and New York City tapwater.

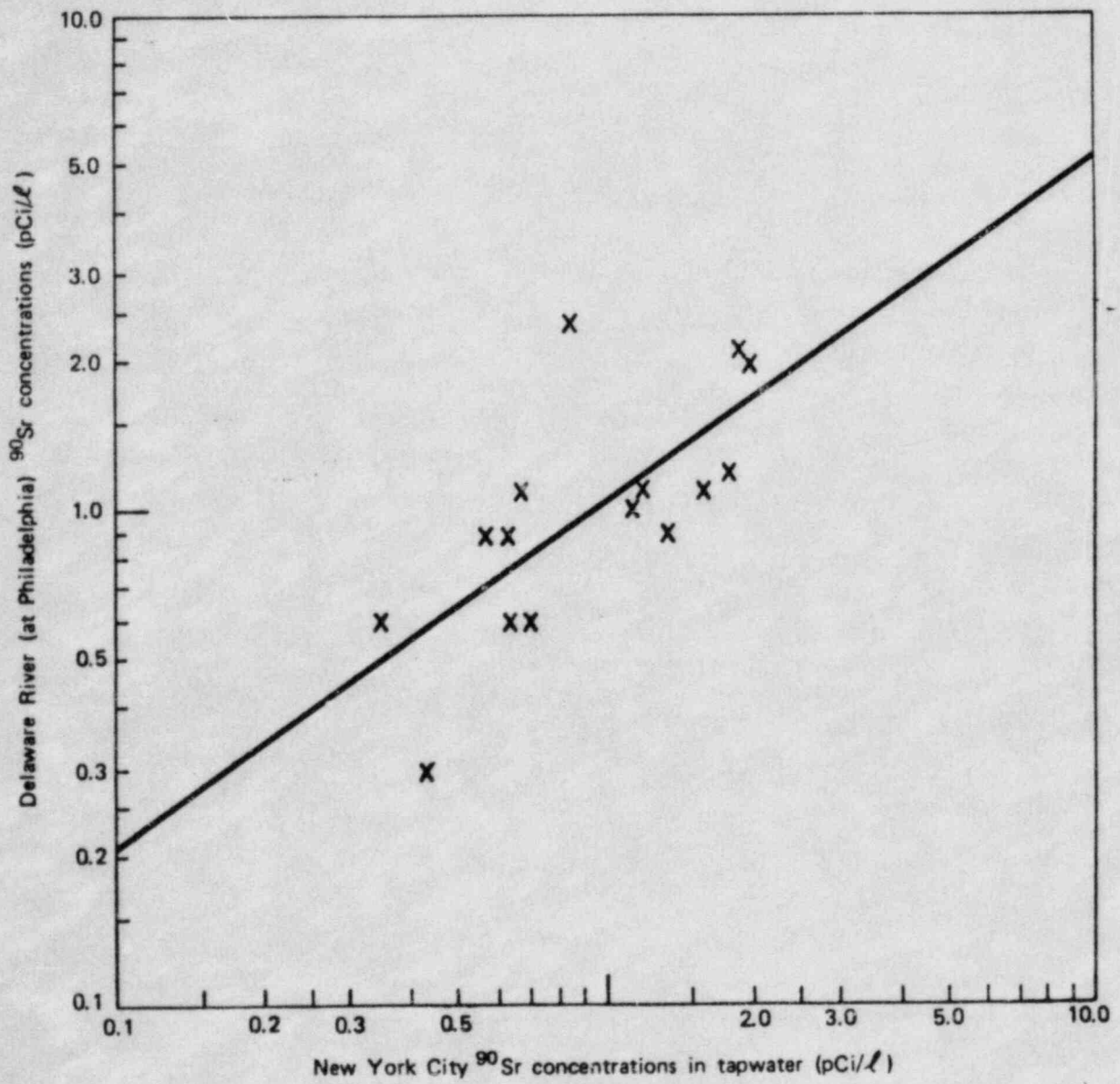


Figure 9. Correlation between ⁹⁰Sr concentrations in Delaware River water and New York City tapwater.

ERRATA TO APPLICANT'S TESTIMONY
RELATING TO CONTENTION CITY 15

<u>PAGE NO.</u>		<u>DESCRIPTION</u>
3	Line 10	Add the word "water" to end of line
4	Last line	Add the phrase "Appendix F of the Severe Accident Risk"
10	Last line	Change "combinaition" to "combination"
11	Line 5	Change "radio" to "radio-"
12	Line 9	Add the phrase "whereas the WASH-1400 conversion factors" before "are"
13	Line 15	Change "approximatley" to "approximately"
14	Line 16	Add the word "year" before the comma at the end of the line
14	Line 22	Add the word "reactor" after "per"
14	Line 23	Add the word "reactor" after "per"
15	Line 16	Delete "1 year" from line
16	Line 3	Change "significante" to "significance"
16	Line 4	Delete "require that" from line
19	Line 9	Change "(330rem" to read "(330mrem"
22	Line 13	Change "uncovered" to "covered"
Table 1	Line 7	Change "10CRF" to read "10CFR"
Table 1	Line 11	Change "influended" to "influenced"