GSC-TR8711

GROUNDWATER SCENARIOS FOR SCREENING LEVEL ASSESSMENTS OF COMPOUNDS RELEASED TO LAND

Prepared for:

U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF PESTICIDES AND TOXIC SUBSTANCES
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II. CHEMISTRY

The dependence of results on both adsorption and volatility were to be studied. The nine sets of chemical properties presented in Table 1 were used as suggested by the task manager. Reasons for the choices are as follows.

The major variables influencing migration of persistent compounds are the adsorption coefficient (estimated from the organic carbon partitioning coefficient Koc) and the Henry's Law Constant H. The coefficient of diffusion in air, Da, varies inversely as the square root of molecular weight. Water solubilities are negatively correlated with Koc, although wide variations are possible. The choices of water solubilities are conservative, but they reflect the negative correlation.

The combinations of Koc and H were chosen to restrict simulations to reasonably probable and predictable situations. For compounds with low Koc, the higher water solubilities tend to limit H. For example, if log Koc = 1.5, a value of H as high as Ø.1 atm-M^3/mole will not occur unless vapor pressure takes on an improbable value. For compounds with high Koc, the water solubilities and vapor pressures often have low values with high percentage uncertainties, leading to high uncertainties in predicting volatilization. For these cases, adsorption has been assumed to be a more reliable indicator than volatility in limiting the rate of migration toward groundwater.

TABLE 1. Chemical Data.

Chem. No.	Molec. Weight (g/mole)	Log Koc (ug/g)/(ug/ml)	Henry's Constant H ($atm\text{-}M^3$/mole)	Water Sol. (mg/L)	Diffusion in air, Da (cm^2/sec)
1	100	0	10^{-5}	100,000	0.09
2	100	1.5	10^{-5}	75,000	0.09
3	100	1.5	10^{-3}	15,000	0.09
4	150	2.5	10^{-5}	5,000	0.07
5	150	2.5	10^{-3}	200	0.07
6	150	2.5	10^{-1}	200	0.07
7	250	3.5	10^{-5}	10	0.05
8	250	3.5	10^{-3}	2	0.05
9	250	4.5	10^{-5}	0.5	0.05

No significant degradation of the chemical was assumed to occur. The time available for degradation before reaching groundwater or a well depends on the time of migration, which can be estimated by examining the time profiles presented in this report.

III. CHEMICAL RELEASES AND APPLICATION AREAS

Chemical releases from unlined landfills not containing large quantities of sludge were considered. A continuous release rate of 1000 kg/yr per site was used. Due to the linear relationship between groundwater concentrations and source release rates, estimates of groundwater concentrations resulting from other release rates can be determined by proportional scaling as illustrated by GSC (1986a). The period of release to the same site was taken as ten years, as suggested by reviewers in the Exposure Assessment Branch.

For landfill sites, the chemical releases were assumed to occur from a source buried at a depth of 60 cm and having a thickness of 250 cm, based on previous studies (GSC, 1985; Versar, 1983).

An application area of 1 hectare (100m x 100m) was used for all simulations, at the suggestion of the exposure assessor. It was considered that increasing the application area would have the effect of causing more widespread exposure.

IV. CLIMATES AND SOILS

Two application sites were selected for this study having significantly different climatic and soil conditions: Boston, MA; and Wichita, KS. Both the climatic and soil data (unsaturated zone) for the two sites were accessed from the Cities Data Base of GEMS (GSC, 1984a). The important soil and climatic data which were used as input to SESOIL for the two sites are listed in Table 2.

The depths to groundwater for both sites were set to 8.Ø meters, as opposed to the actual depths of 3.Ø and 7.6 meters for Boston and Wichita, respectively. Equal groundwater depths were used in order to evaluate the model results for the different sites based solely on soils, climates and chemistry.

The organic carbon contents, OC, for the upper and middle soil layers were set to values suggested by the task manager. The OC value for the lower layer was assumed to contain one tenth that of the two upper layers. These OC values are reasonable estimates for landfills which do not contain sludge. For sludge landfills, the value of OC in layers containing the source load could be taken as a much higher value.

It should be noted that for the SESOIL model, the unsaturated zone is divided into three layers, and for this application the source is contained in the middle layer.

TABLE 2. Climatic and Soil Data Used in SESOIL.

Climatic Data	Boston	Wichita
Latitude (deg. N)	42.4	37.7
Mean Annual Temp. (^{o}C)	10.7	13.7
Mean Annual Cloud Cover (Frac.)	0.57	0.46
Mean Annual Rel. Humidity (Frac.)	0.58	0.55
Mean Annual Shortwave Albedo (-)	0.23	0.19
Mean Annual Precip. (cm)	108.0	77.8

SOIL DATA

Soil Name	Canton Sandy Loam	Blanket Slit Loam
Disconnectedness Index (Frac.)	6.0	5.5
Effective Porosity (Frac.)	0.26	0.35
Bulk Density (g/cm3)	1.35	1.35
Organic Carbon Content of		
Upper Layer (%)	0.5	2.0
Middle Layer (%)	0.5	2.0
Lower Layer (%)	0.05	0.2
Intrinsic Permeability of		
Upper Layer (cm2)	2.9×10^{-8}	4.9×10^{-9}
Middle Layer (cm2)	9.1×10^{-8}	2.9×10^{-9}
Lower Layer (cm2)	9.1×10^{-8}	2.9×10^{-9}
Thickness of		
Upper Layer (cm)	60.0	60.0
Middle Layer (source load)	250.0	250.0
Lower Layer (cm)	490.0	490.0
Depth to Groundwater (m)	8.0	8.0

V. GROUND WATER PARAMETERS

The major groundwater parameters required by the AT123D model are:

- o hydraulic conductivity
- o hydraulic gradient
- o porosity
- o dispersivities (longitudinal, transverse, and vertical)
- o aquifer depth

The interstitial water flow velocity (seepage velocity), V, is the product of the hydraulic conductivity and the hydraulic gradient divided by the porosity. This parameter is important to the model results.

In choosing groundwater parameter values for the assessment, the publication of "Ground Water Regions of the United States" (Heath, 1984) was consulted. The parameter ranges tabulated in the publication include extreme values of hydraulic conductivities. Other sources were consulted to obtain more typical ranges of values. The National Water Well Association (NWWA Draft Report, 1985) used the Heath's ranges in a study of groundwater vulnerability criteria, but has chosen more restricted hydraulic conductivity ranges. Hydraulic conductivities range over many orders of magnitude (10^{-5} to 10^{-1} cm/sec). In general, common groundwater flow velocities are considered to be from five ft/yr to five ft/day (Cleary, et al, 1980).

For this study, the hydraulic conductivity value for each site was within the range of values given by Heath (1984) and by the NWWA (1985).

Dispersivities reflect aquifer heterogeneities and flow variations, and the values have been found by fitting contaminant plumes. Values derived in a number of studies were reported by Anderson (1979). For this study, a constant value of dispersivity was chosen for all sites, as shown in Table 3.

Porosity values in the aquifer were taken to have a typical value of Ø.3Ø, which falls within Heath's ranges. The hydraulic gradient was chosen to have a typical value of Ø.Ø1 m/m for Boston, and a lower value of Ø.ØØ6 m/m for Wichita, which is proportional to the lower recharge. Degradation was assumed to be insignificant in the groundwater.

The organic carbon content, OC, of the aquifer soil was taken as one tenth that for the lower soil layer in the unsaturated zone for each site.

The aquifer depth and width are important, since boundaries restrict chemical dispersion and thus affect the concentrations in the aquifer. In this study, the aquifer was assumed to be infinite in both depth and width.

TABLE 3. Groundwater Parameters Used in AT123D.

	BOSTON	WICHITA
Hydraulic Cond. (m/hr)	2.0	2.0
Longitudinal Dispersivity (m)	30.0	30.0
Lateral Dispersivity (m)	10.0	10.0
Vertical Dispersivity (m)	10.0	10.0
Hydraulic Gradient (m/m)	0.01	0.006
Effective Porosity (-)	0.30	0.30
Organic Carbon Cont. (%)	0.005	0.02

VI. SIMULATION RESULTS

A total of 18 SESOIL model simulations were performed for all combinations of the nine chemicals and two sites for simulation periods of 99 years. The release rate used was 1000 kg/yr occurring during the first ten years of the simulation period, as stated in Section III. The resulting time profiles of the mass loading to groundwater directly under the application area are shown in Appendix A, Figures A-1 through A-18. These time profiles were produced using one-year time resolution output from SESOIL.

A total of 18 corresponding AT123D model simulations were performed using the mass-to-groundwater loading rates of SESOIL for a simulation period of 95 years. Due to model limitations, the output results were initially produced at five-year intervals; however, some additional AT123D runs were made using one-year output intervals during the first twenty years of the simulation period in order to obtain better resolution during the more critical period. For presentation of output, a well was considered to be located 200 meters downstream from the edge of the source in the X-direction, on the plume centerline in the Y-direction, and at a depth of twenty meters below the water table in the Z-direction. The time profiles showing the dissolved concentration at the well location are shown in Appendix A, Figures A-1 through A-18. In addition, distanceprofiles showing the dissolved concentration distribution along the plume centerline at the well depth (20 m) at the times when the maximum concentration was attained at the well location are shown in Appendix B, Figures B-1

through B-18. Seventy-year average dissolved concentrations at the well location for each of the 18 model simulations are presented in Table 4. It can be seen that the higher Koc values tend to decrease the average concentrations in the groundwater due to retardation of the rate of chemical transport. For some of the model simulations for the higher Koc values, the maximum concentrations at the well location was not attained (Chemical No. 9 for Boston, and Chemical No. 7, 8, and 9 for Wichita) by year 95, and seventy-year averages were computed using the 95 years of available output. These high Koc values produce long residence times for the chemical in the unsaturated and saturated soil zones which are in excess of an average human life span. If longer term simulations could be performed, it could be expected to obtain higher average concentrations for these four scenarios. The two simulations using the very high value of Henry's Law constant of 10^{-1} atm-m^3/mole (Chemical No. 6) show severe decreases in the average groundwater concentrations, since much of the chemical mass is lost to volatilization.

Examination of the Mass-to-Groundwater time profiles of Appendix A show constant low mass rates attained during the later part of the simulation period for most of the lower Koc chemicals. This portion of the curve is due to the slow desorption of chemical from the soil, following the cessation of application loading and washout of all dissolved chemical from the unsaturated zone.

A comparison of all output results for the two sites shows, for the most part, higher average concentrations for Wichita than for

TABLE 4. Maximal Seventy-Year Average Dissolved Groundwater Concentrations (MG/L) at Well Location.

Log Koc	Henry = 10^{-5} **		Henry = 10^{-3} **		Henry = 10^{-1} **	
	Boston	Wichita	Boston	Wichita	Boston	Wichita
0.0	3.65×10^{-2}	7.62×10^{-2}				
1.5	3.73×10^{-2}	7.55×10^{-2}	2.56×10^{-2}	5.98×10^{-2}		
2.5	3.75×10^{-2}	5.95×10^{-2}	2.82×10^{-2}	5.14×10^{-2}	7.03×10^{-4}	1.38×10^{-3}
3.5	2.67×10^{-2}	7.06×10^{-3}*	2.40×10^{-2}*	6.98×10^{-3}*		
4.5	1.65×10^{-3}*	7.14×10^{-5}*				

* Maximal concentration in well not attained by year 95.

** Henry's Law Constant in units of atm-m3/mole.

Boston. This can be attributed to the lower values of intrinsic permeability, higher organic carbon content, and dryer climate in Wichita, all of which tend to slow chemical transport and increase residence time in the unsaturated soil zone.

In an attempt to relate the seventy-year average groundwater concentrations at the well location to Koc values, a quadratic regression analysis was performed using the method of orthogonal polynomials. Two regression curves were obtained for each of the two sites, using the 5 Koc values having Henry's Law Constant of 10^{-5} atm-m^3/mole. The regression curves are shown in Figures 1 and 2. The high values of the regression coefficient, r, indicate good fits. Regression analysis could not be applied to the other values of Henry's Law constant due to limited data.

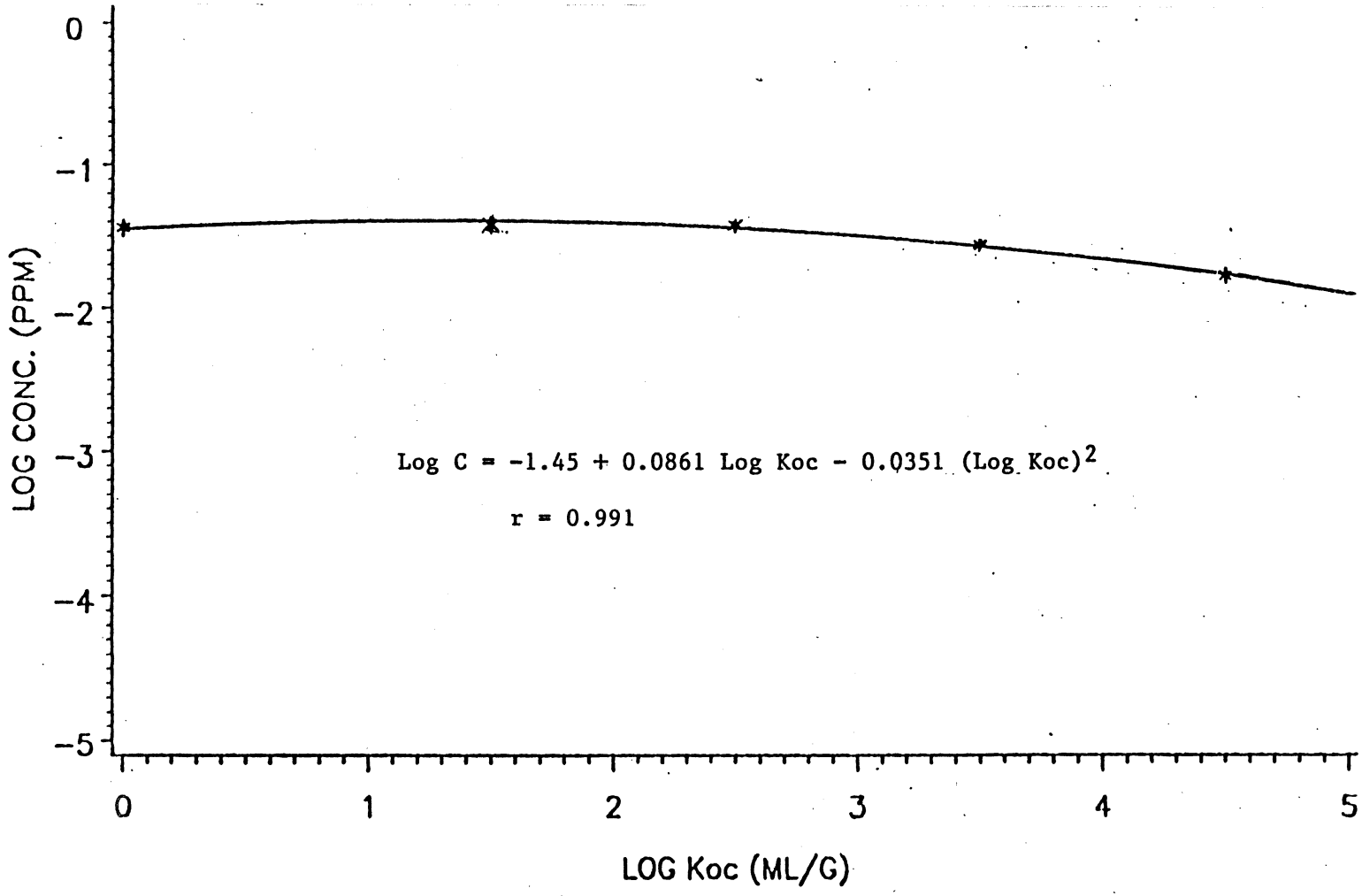

FIGURE 1. Quadratic Regression Curve of 70-Year Average Concentration at Well Location and Adsorption Coefficient, Koc, for Boston Site (Henry;s Law Const. = 10^{-5} atm-m^3/mole).

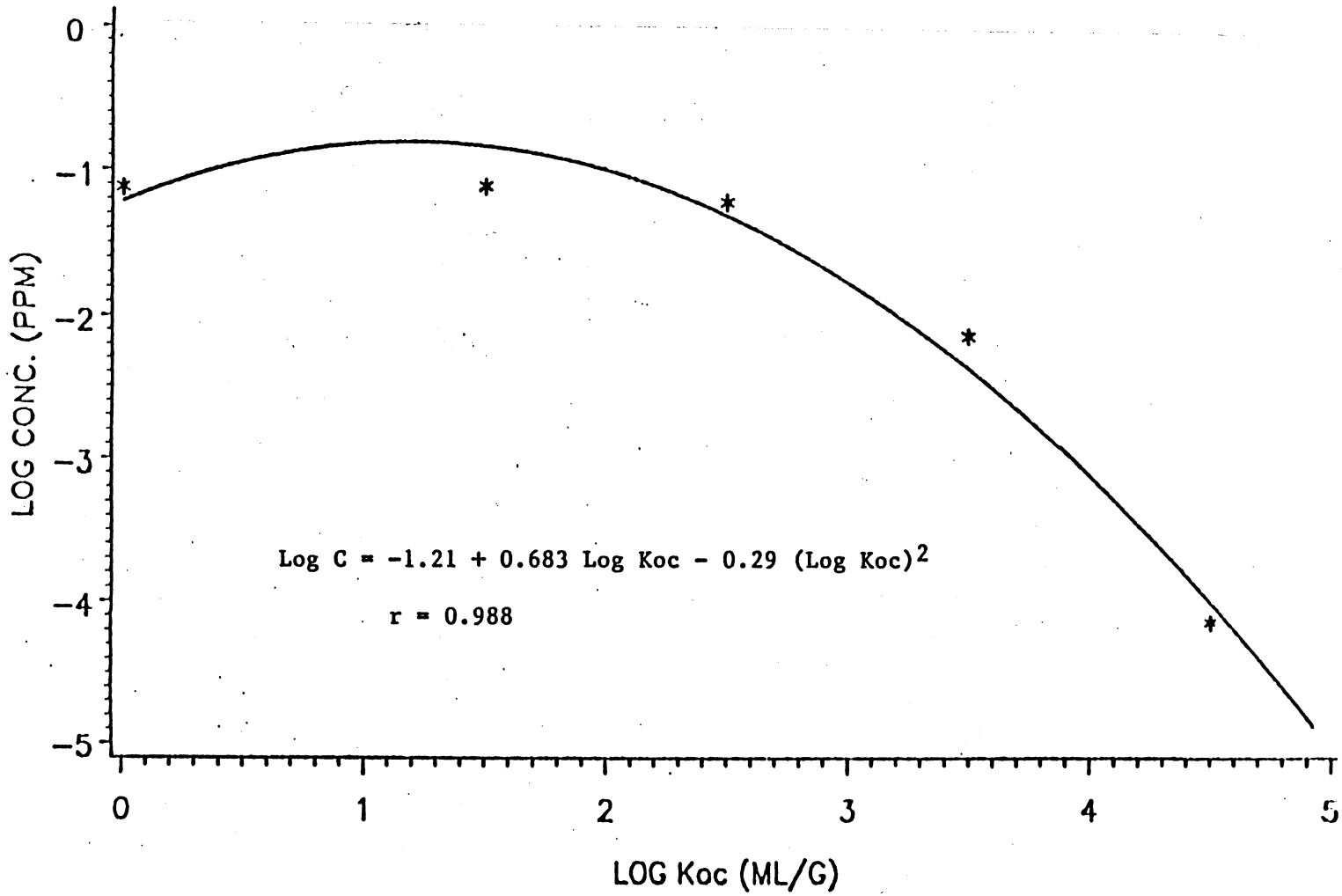

FIGURE 2. Quadratic Regression Curve of 70-Year Average Concentration at Well Location and Adsorption Coefficient, Koc, for Wichita Site (Henry's Law Const. = 10^{-5} atm-m^3/mole).

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APPENDIX A

TIME PROFILES OF MASS LOADINGS TO GROUNDWATER AND CONCENTRATIONS AT WELL LOCATION

FIG. A-1: TIME DISTRIBUTIONS OF: (A) MASS INTO GROUNDWATER AND (B) DISSOLVED CONCENTRATION IN GROUNDWATER AT WELL LOCATION (X=200 M, Y=PLUME CENTERLINE, Z=20 M BELOW WATER TABLE) FOR CHEMICAL #1 AT BOSTON SITE

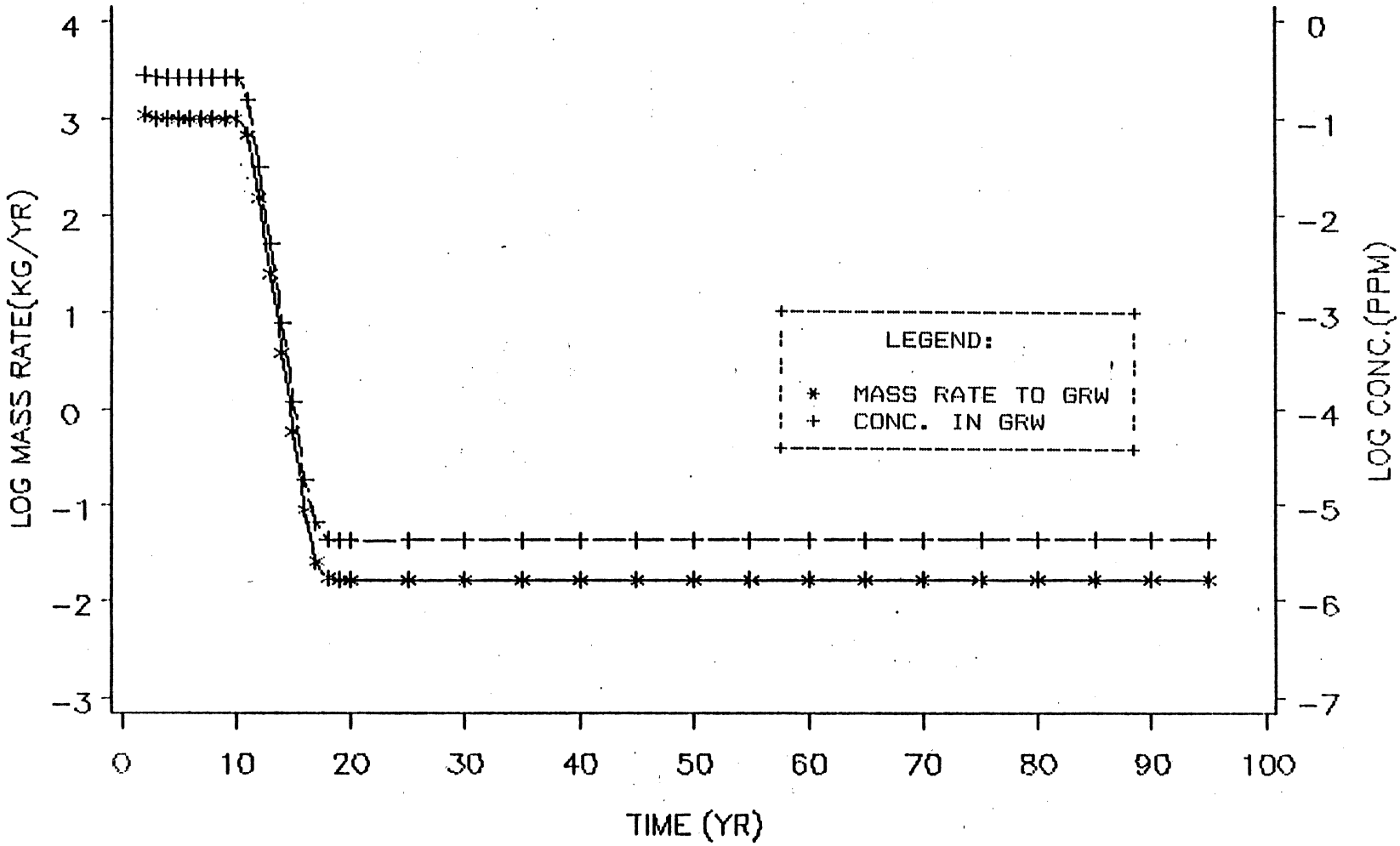


FIG. A-2: TIME DISTRIBUTIONS OF: (A) MASS INTO GROUNDWATER AND (B) DISSOLVED CONCENTRATION IN GROUNDWATER AT WELL LOCATION (X=200 M, Y=PLUME CENTERLINE, Z=20 M BELOW WATER TABLE) FOR CHEMICAL #2 AT BOSTON SITE

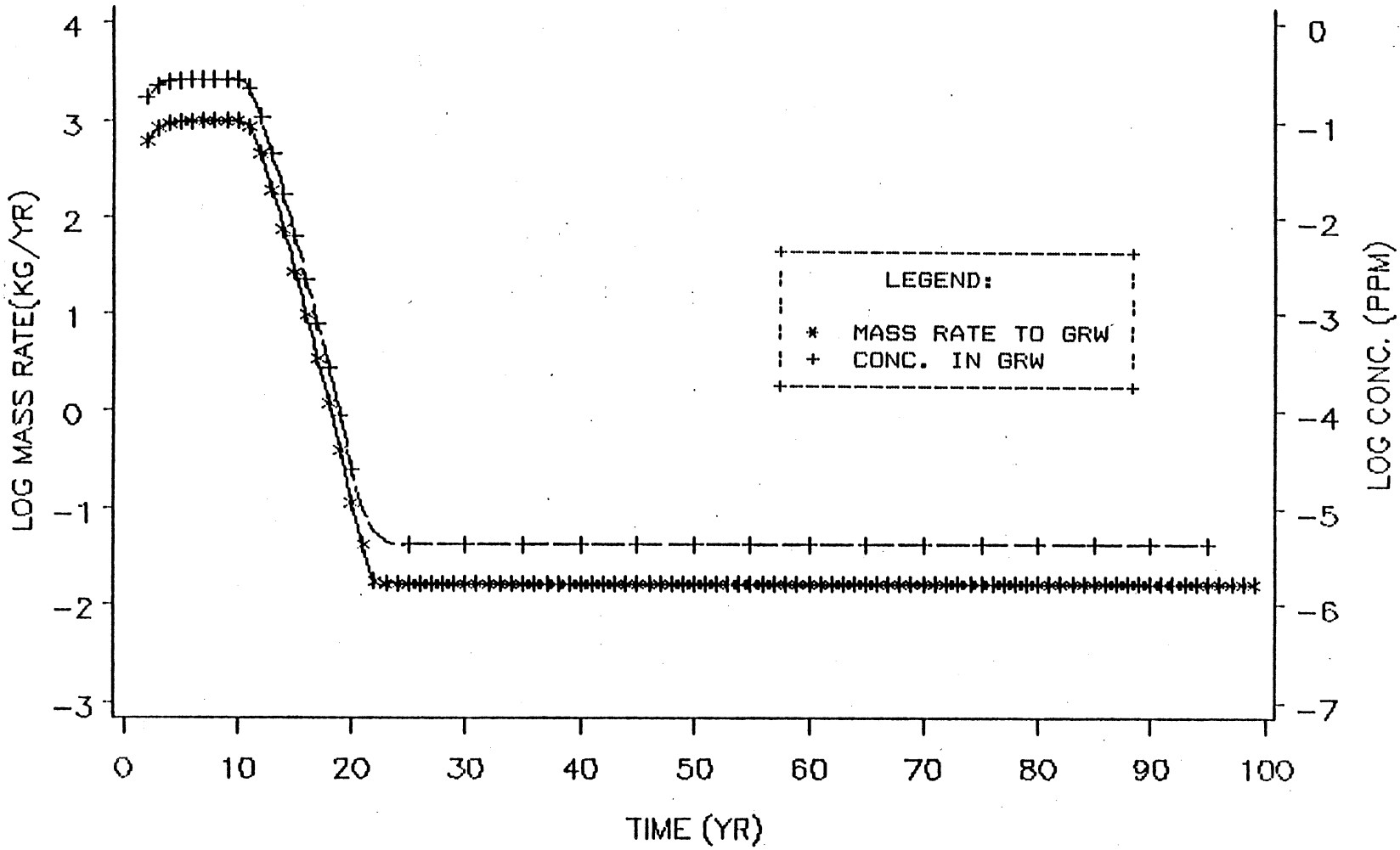


FIG. A-3: TIME DISTRIBUTIONS OF: (A) MASS INTO GROUNDWATER AND (B) DISSOLVED CONCENTRATION IN GROUNDWATER AT WELL LOCATION (X=200 M, Y=PLUME CENTERLINE, Z=20 M BELOW WATER TABLE) FOR CHEMICAL #3 AT BOSTON SITE

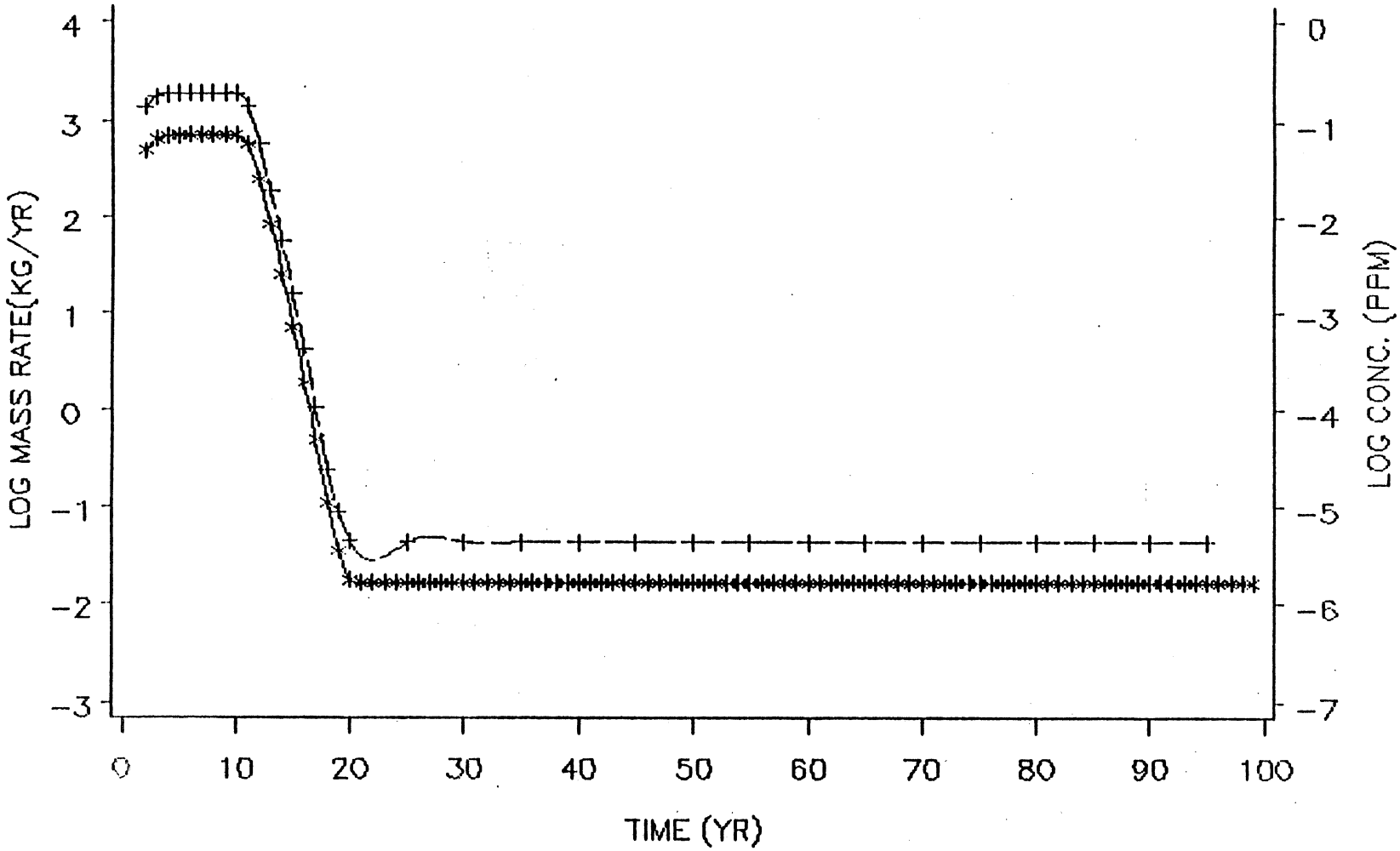


FIG. A-4: TIME DISTRIBUTIONS OF: (A) MASS INTO GROUNDWATER AND (B) DISSOLVED CONCENTRATION IN GROUNDWATER AT WELL LOCATION (X=200 M, Y=PLUME CENTERLINE, Z=20 M BELOW WATER TABLE) FOR CHEMICAL #4 AT BOSTON SITE

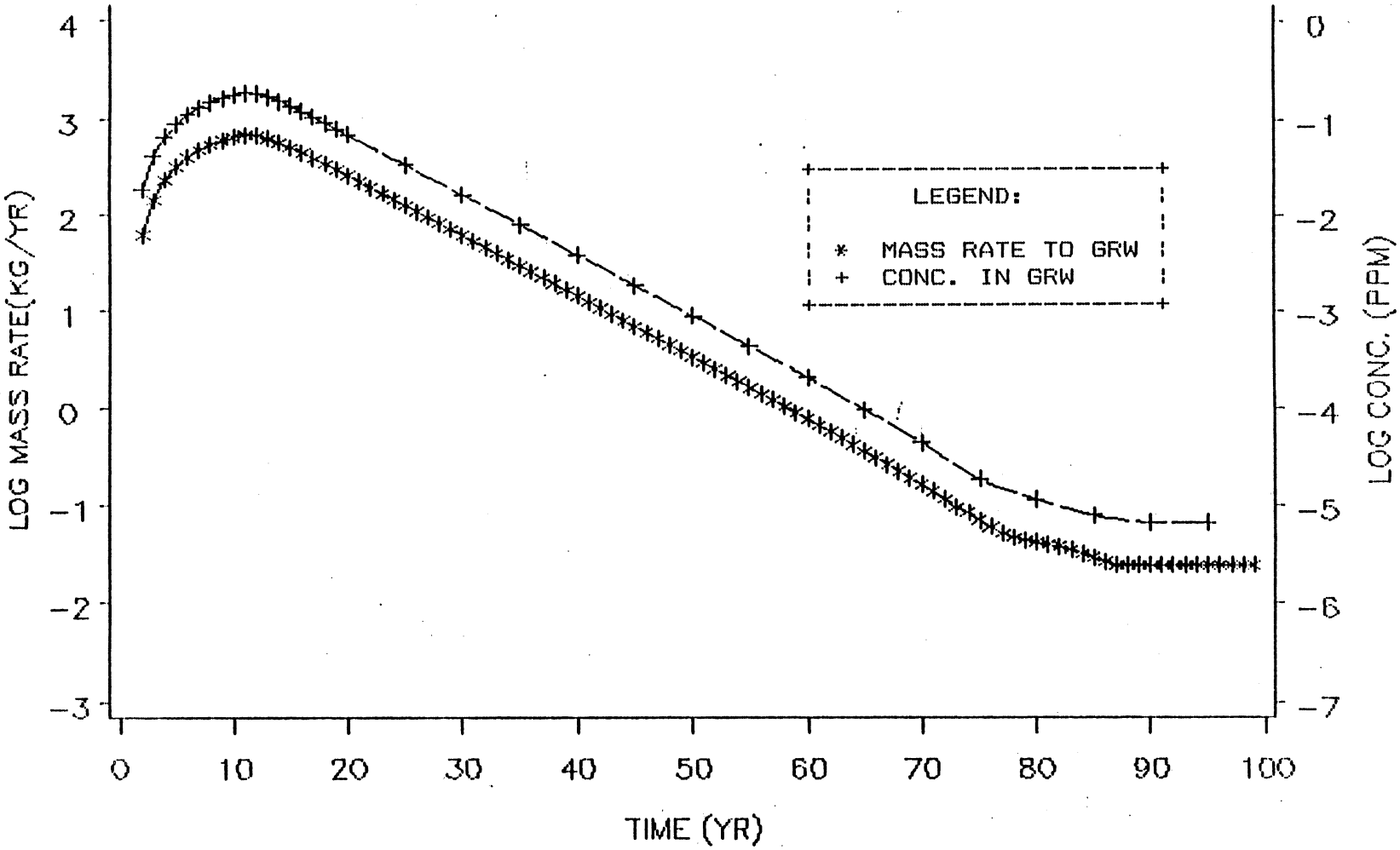


FIG. A-5: TIME DISTRIBUTIONS OF: (A) MASS INTO GROUNDWATER AND (B) DISSOLVED CONCENTRATION IN GROUNDWATER AT WELL LOCATION (X=200 M, Y=PLUME CENTERLINE, Z=20 M BELOW WATER TABLE) FOR CHEMICAL #5 AT BOSTON SITE

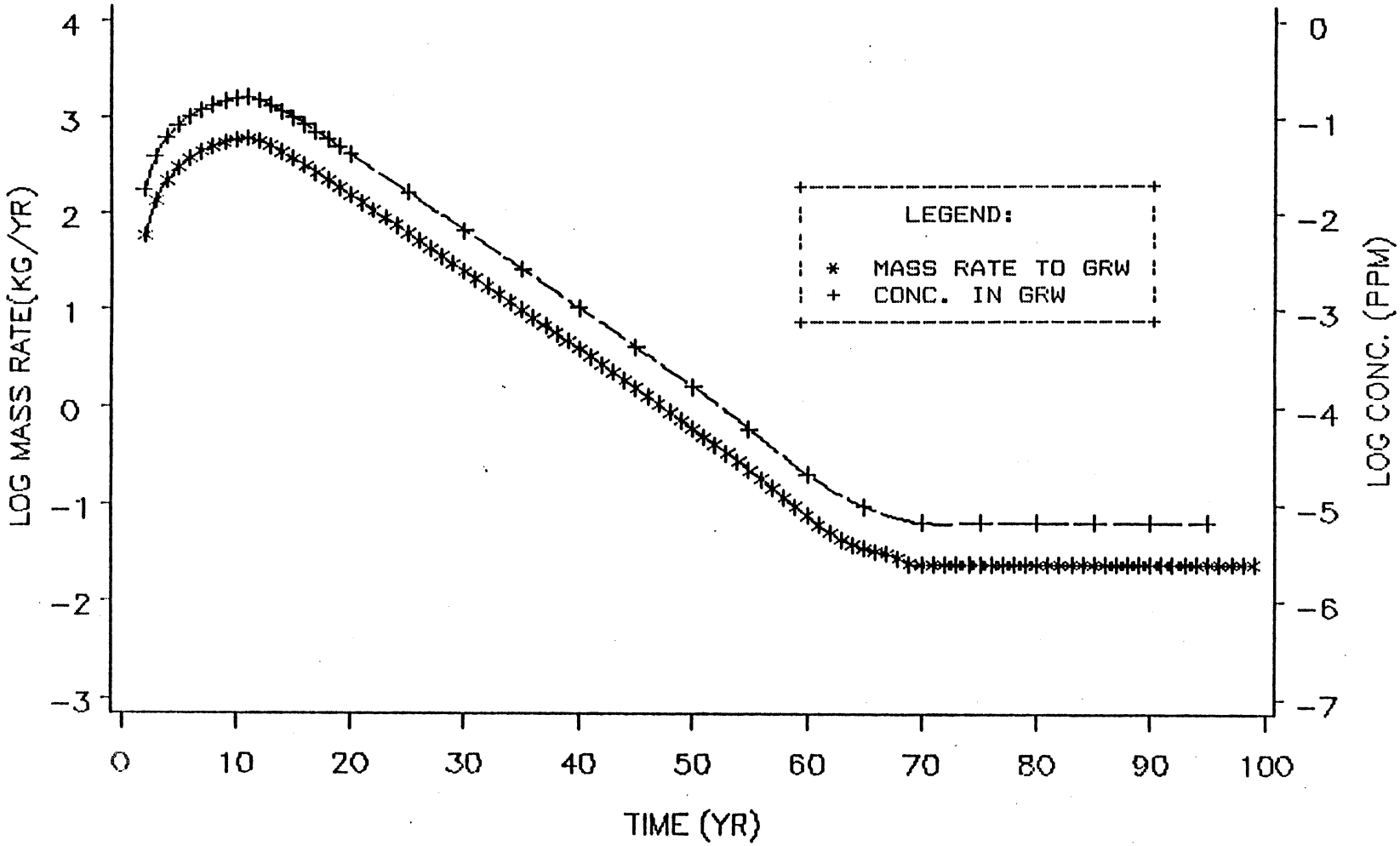


FIG. A-6: TIME DISTRIBUTIONS OF: (A) MASS INTO GROUNDWATER AND (B) DISSOLVED CONCENTRATION IN GROUNDWATER AT WELL LOCATION (X=200 M, Y=PLUME CENTERLINE, Z=20 M BELOW WATER TABLE) FOR CHEMICAL #6 AT BOSTON SITE

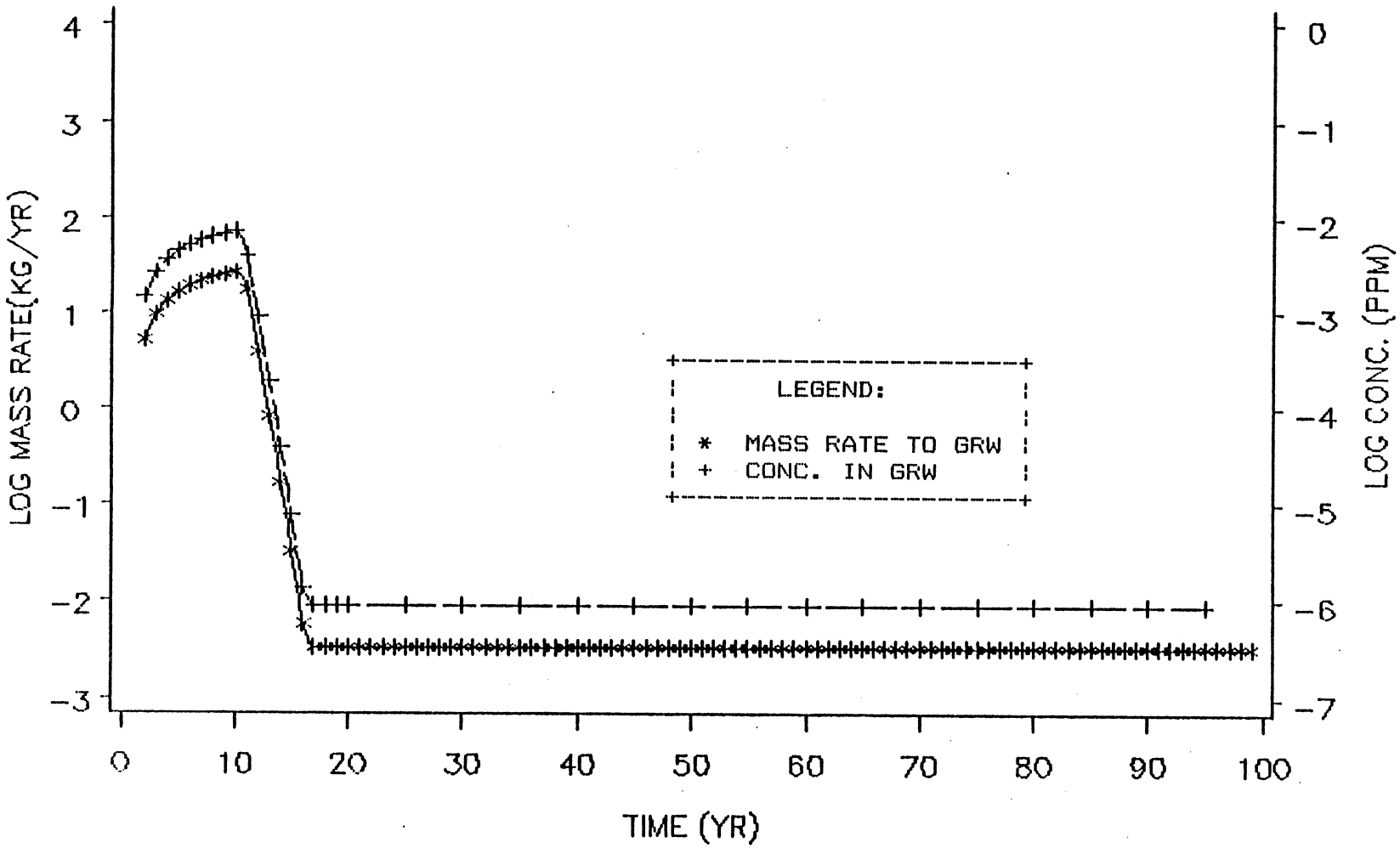


FIG. A-7: TIME DISTRIBUTIONS OF: (A) MASS INTO GROUNDWATER AND (B) DISSOLVED CONCENTRATION IN GROUNDWATER AT WELL LOCATION (X=200 M, Y=PLUME CENTERLINE, Z=20 M BELOW WATER TABLE) FOR CHEMICAL #7 AT BOSTON SITE

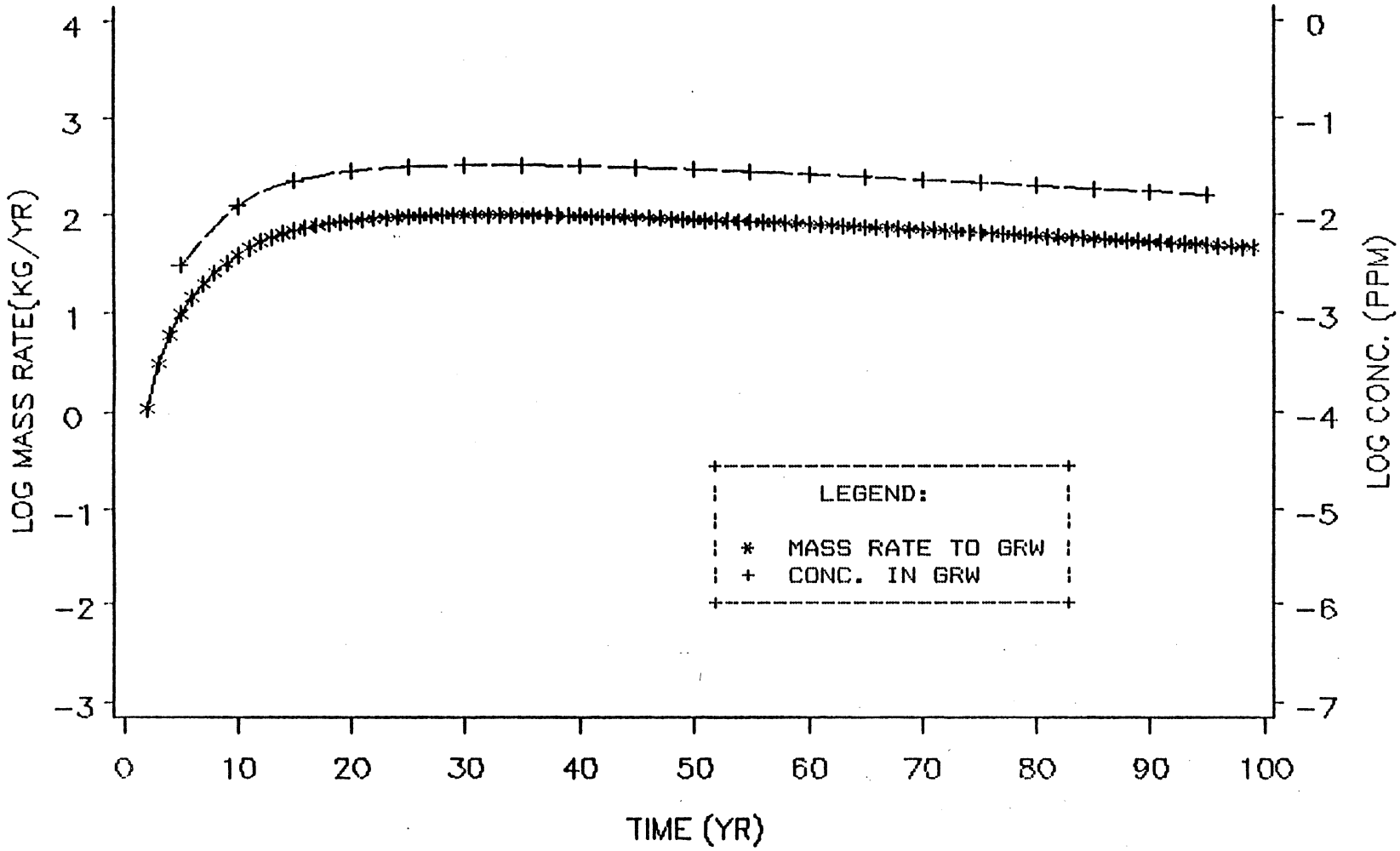


FIG. A-8: TIME DISTRIBUTIONS OF: (A) MASS INTO GROUNDWATER AND (B) DISSOLVED CONCENTRATION IN GROUNDWATER AT WELL LOCATION (X=200 M, Y=PLUME CENTERLINE, Z=20 M BELOW WATER TABLE) FOR CHEMICAL #8 AT BOSTON SITE

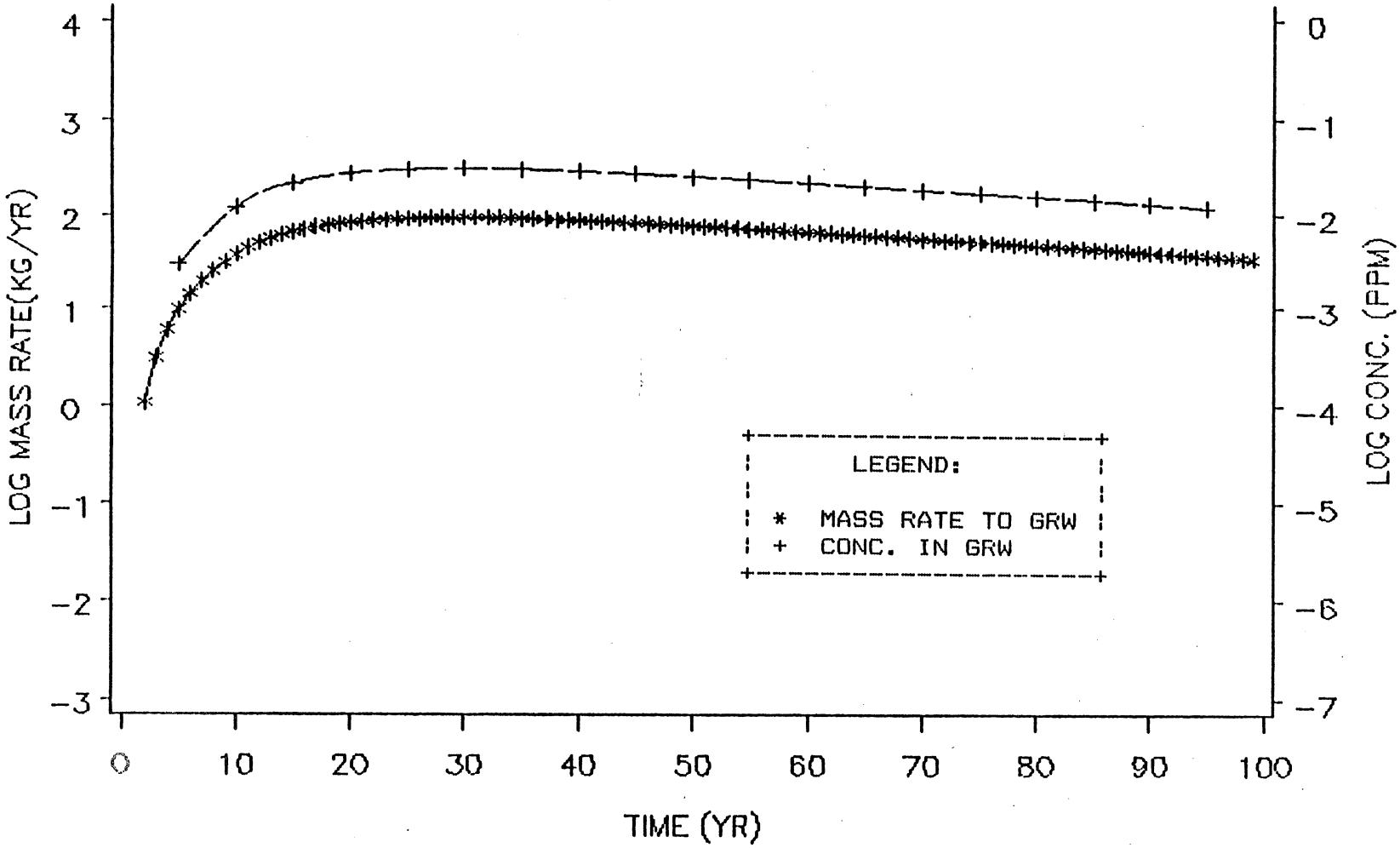


FIG. A-9: TIME DISTRIBUTIONS OF: (A) MASS INTO GROUNDWATER AND (B) DISSOLVED CONCENTRATION IN GROUNDWATER AT WELL LOCATION (X=200 M, Y=PLUME CENTERLINE, Z=20 M BELOW WATER TABLE) FOR CHEMICAL #9 AT BOSTON SITE

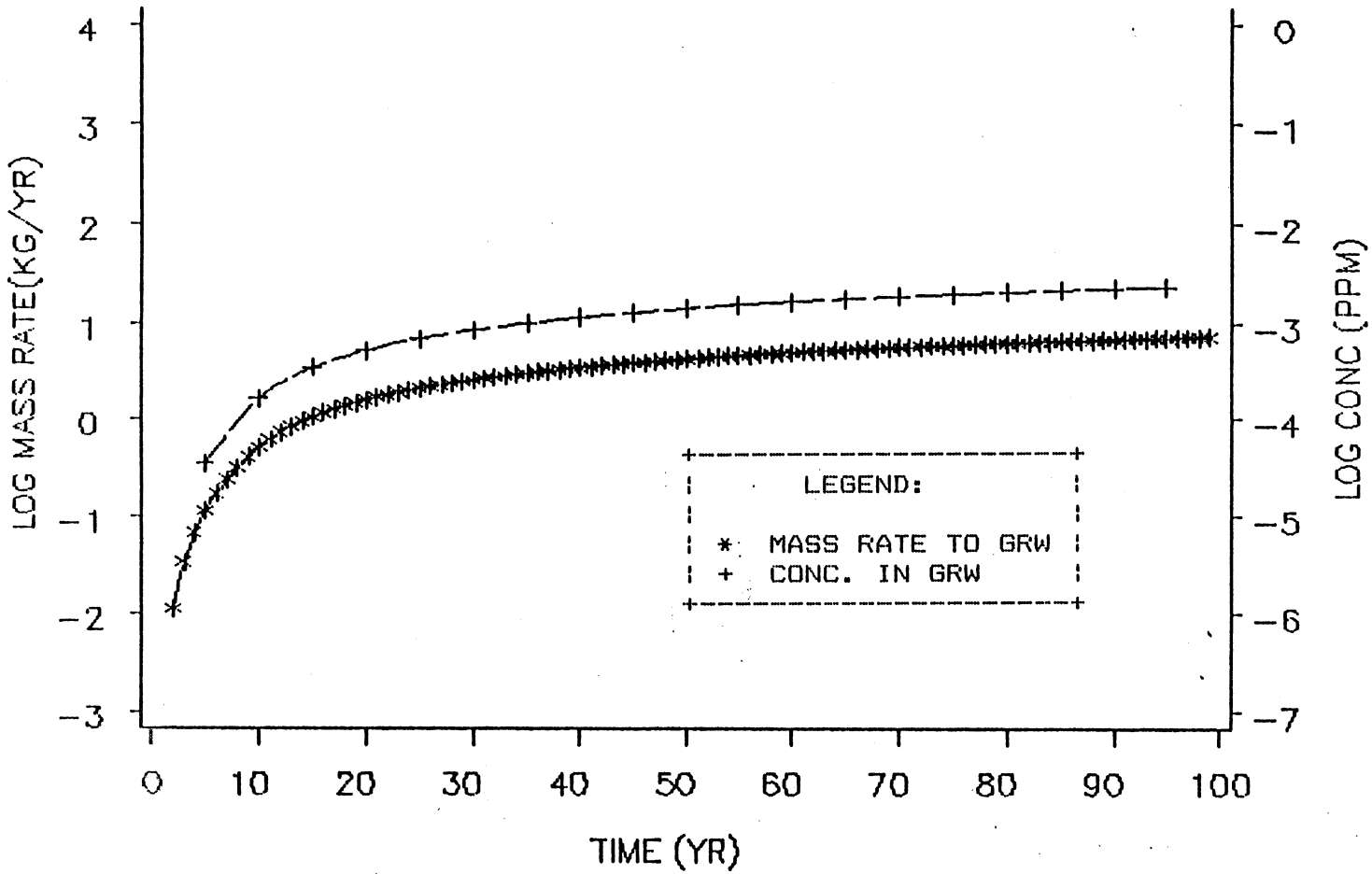


FIG. A-10: TIME DISTRIBUTIONS OF: (A) MASS INTO GROUNDWATER AND (B) DISSOLVED CONCENTRATION IN GROUNDWATER AT WELL LOCATION (X=200 M, Y=PLUME CENTERLINE, Z=20 M BELOW WATER TABLE) FOR CHEMICAL #1 AT WICHITA SITE

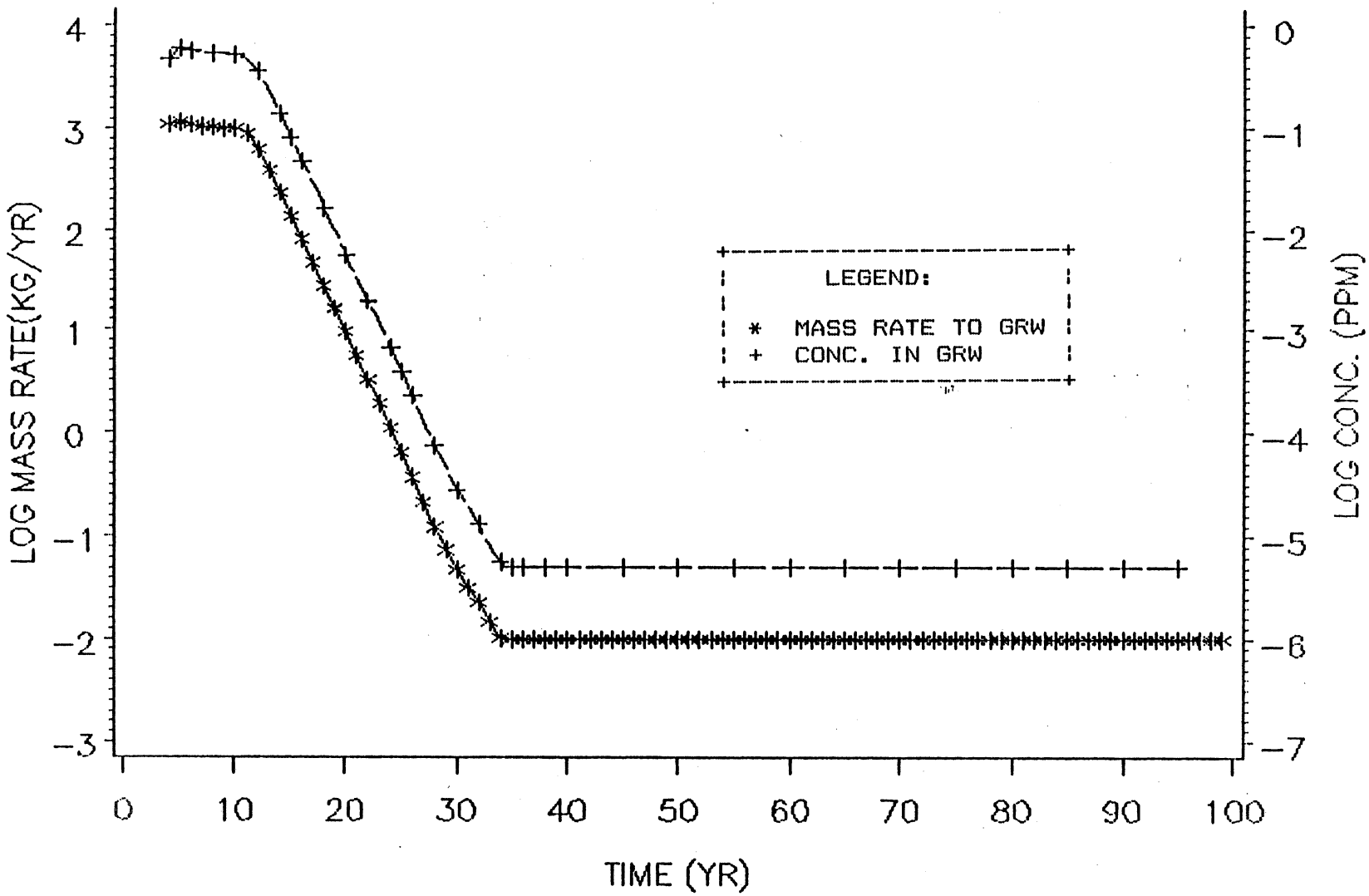


FIG. A-11: TIME DISTRIBUTIONS OF: (A) MASS INTO GROUNDWATER AND (B) DISSOLVED CONCENTRATION IN GROUNDWATER AT WELL LOCATION (X=200 M, Y=PLUME CENTERLINE, Z=20 M BELOW WATER TABLE) FOR CHEMICAL #2 AT WICHITA SITE

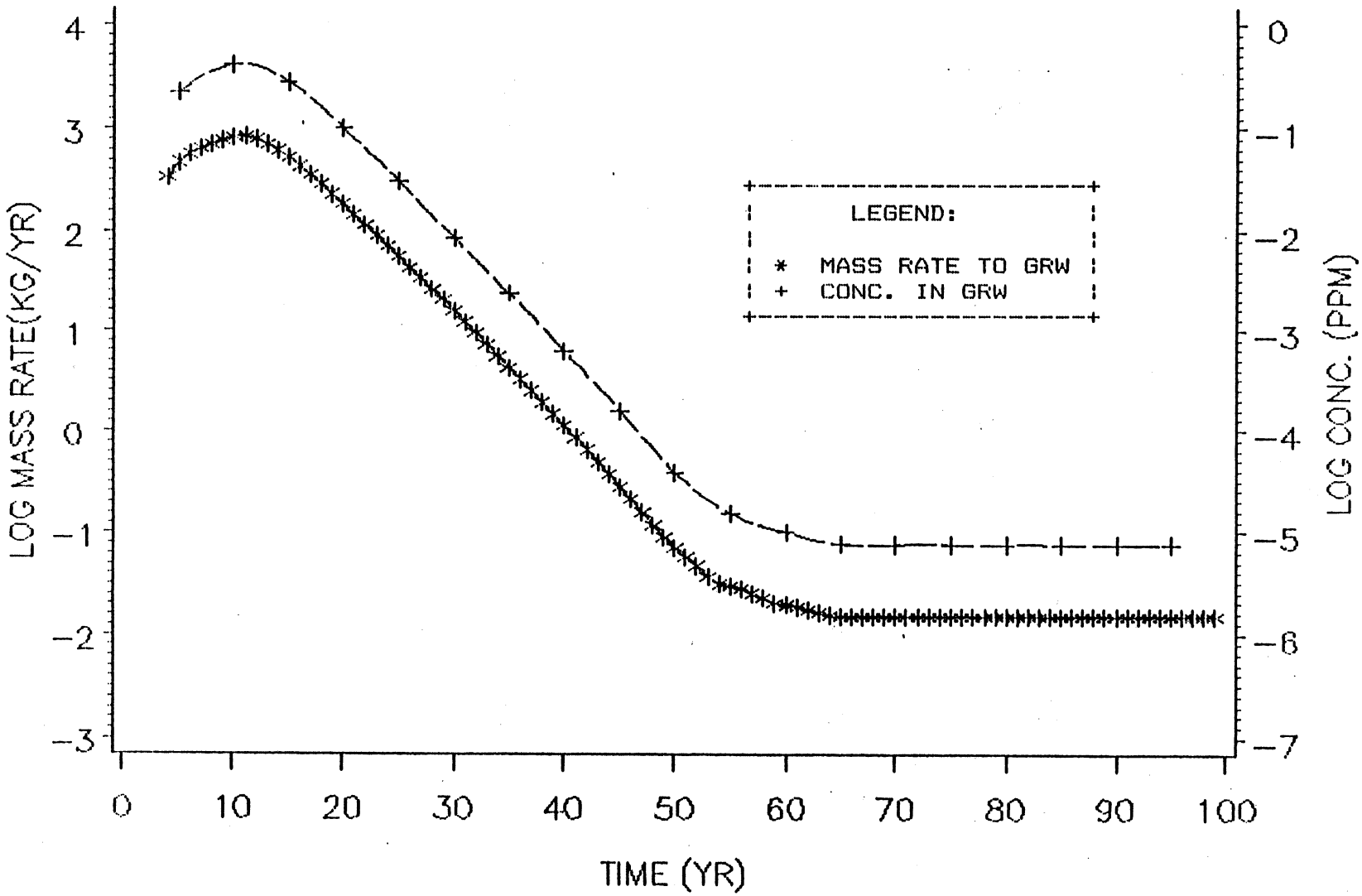


FIG. A-12: TIME DISTRIBUTIONS OF: (A) MASS INTO GROUNDWATER AND (B) DISSOLVED CONCENTRATION IN GROUNDWATER AT WELL LOCATION (X=200 M, Y=PLUME CENTERLINE, Z=20 M BELOW WATER TABLE) FOR CHEMICAL #3 AT WICHITA SITE

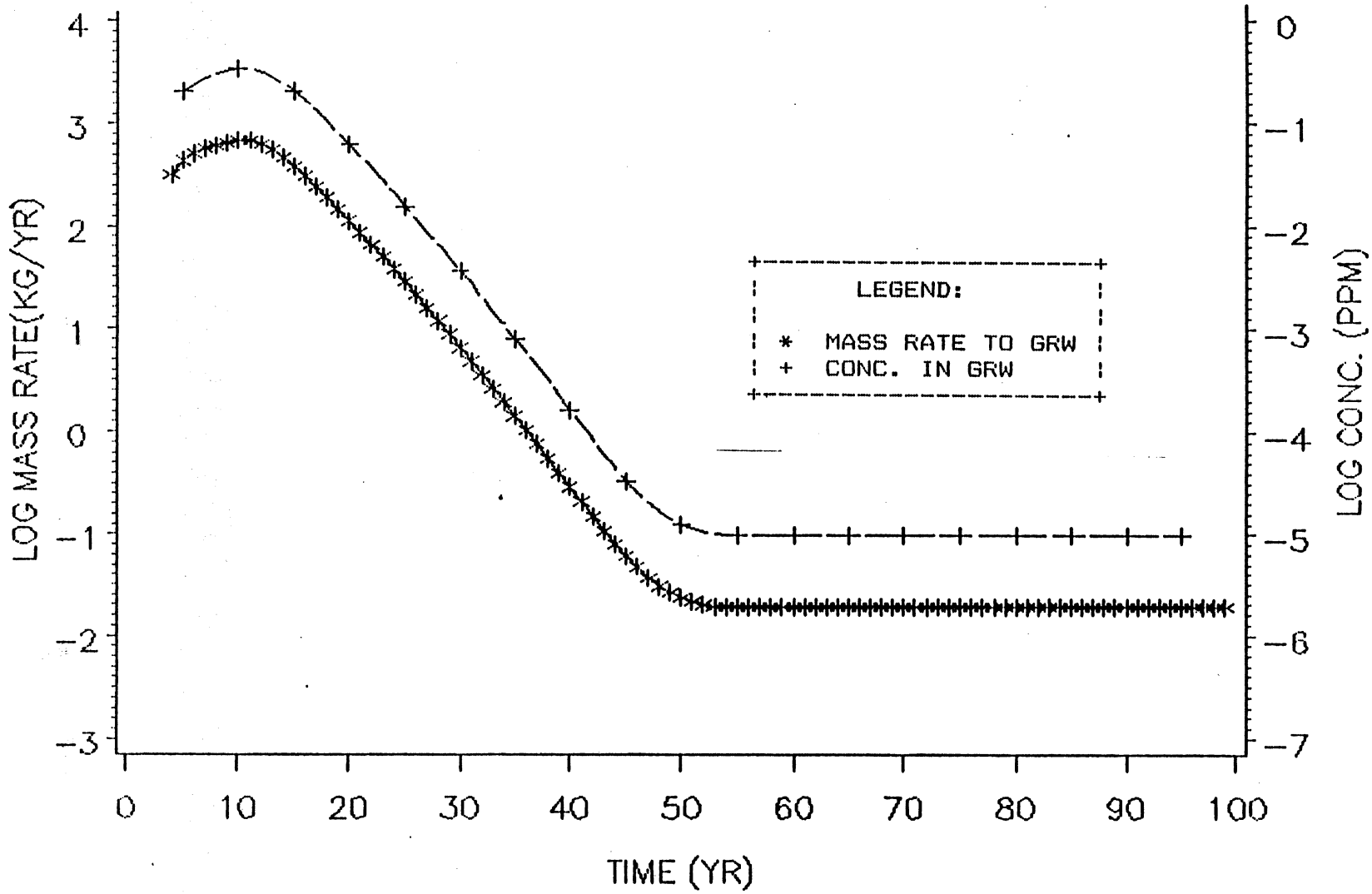


FIG. A-13: TIME DISTRIBUTIONS OF: (A) MASS INTO GROUNDWATER AND (B) DISSOLVED CONCENTRATION IN GROUNDWATER AT WELL LOCATION (X=200 M, Y=PLUME CENTERLINE, Z=20 M BELOW WATER TABLE) FOR CHEMICAL #4 AT WICHITA SITE

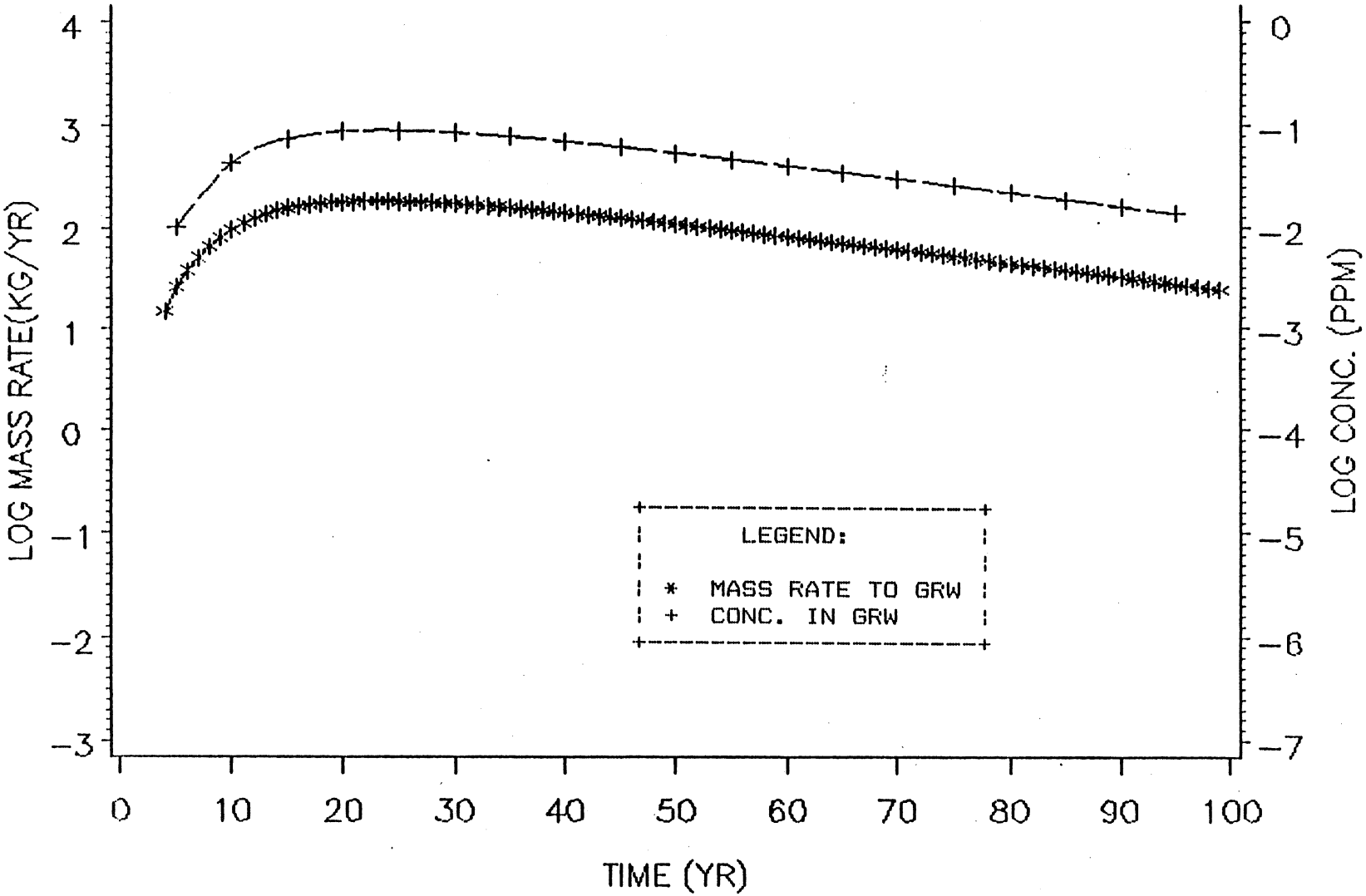


FIG. A-14: TIME DISTRIBUTIONS OF: (A) MASS INTO GROUNDWATER AND (B) DISSOLVED CONCENTRATION IN GROUNDWATER AT WELL LOCATION (X=200 M, Y=PLUME CENTERLINE, Z=20 M BELOW WATER TABLE) FOR CHEMICAL #5 AT WICHITA SITE

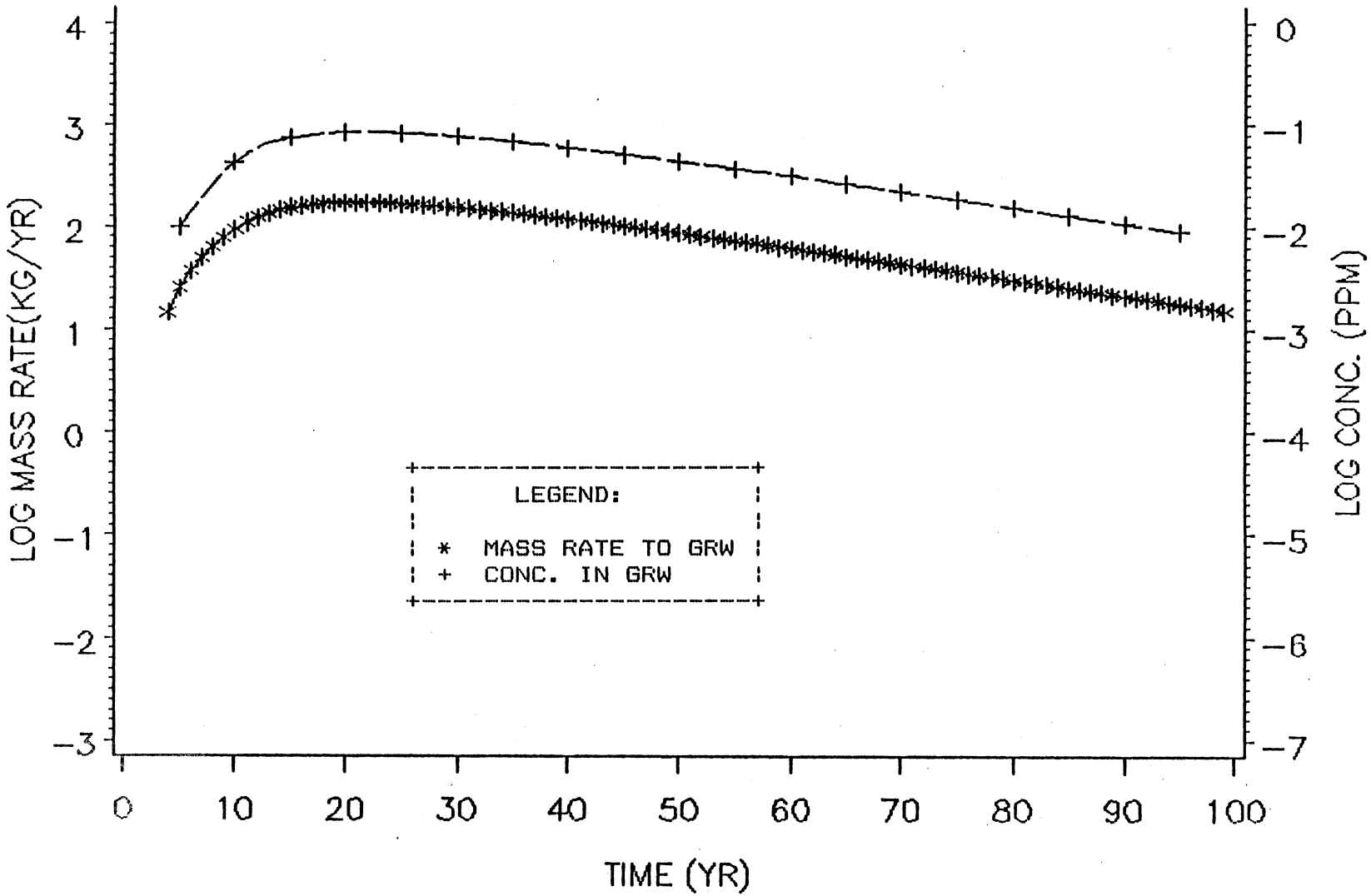


FIG. A-15: TIME DISTRIBUTIONS OF: (A) MASS INTO GROUNDWATER AND (B) DISSOLVED CONCENTRATION IN GROUNDWATER AT WELL LOCATION (X=200 M, Y=PLUME CENTERLINE, Z=20 M BELOW WATER TABLE) FOR CHEMICAL #6 AT WICHITA SITE

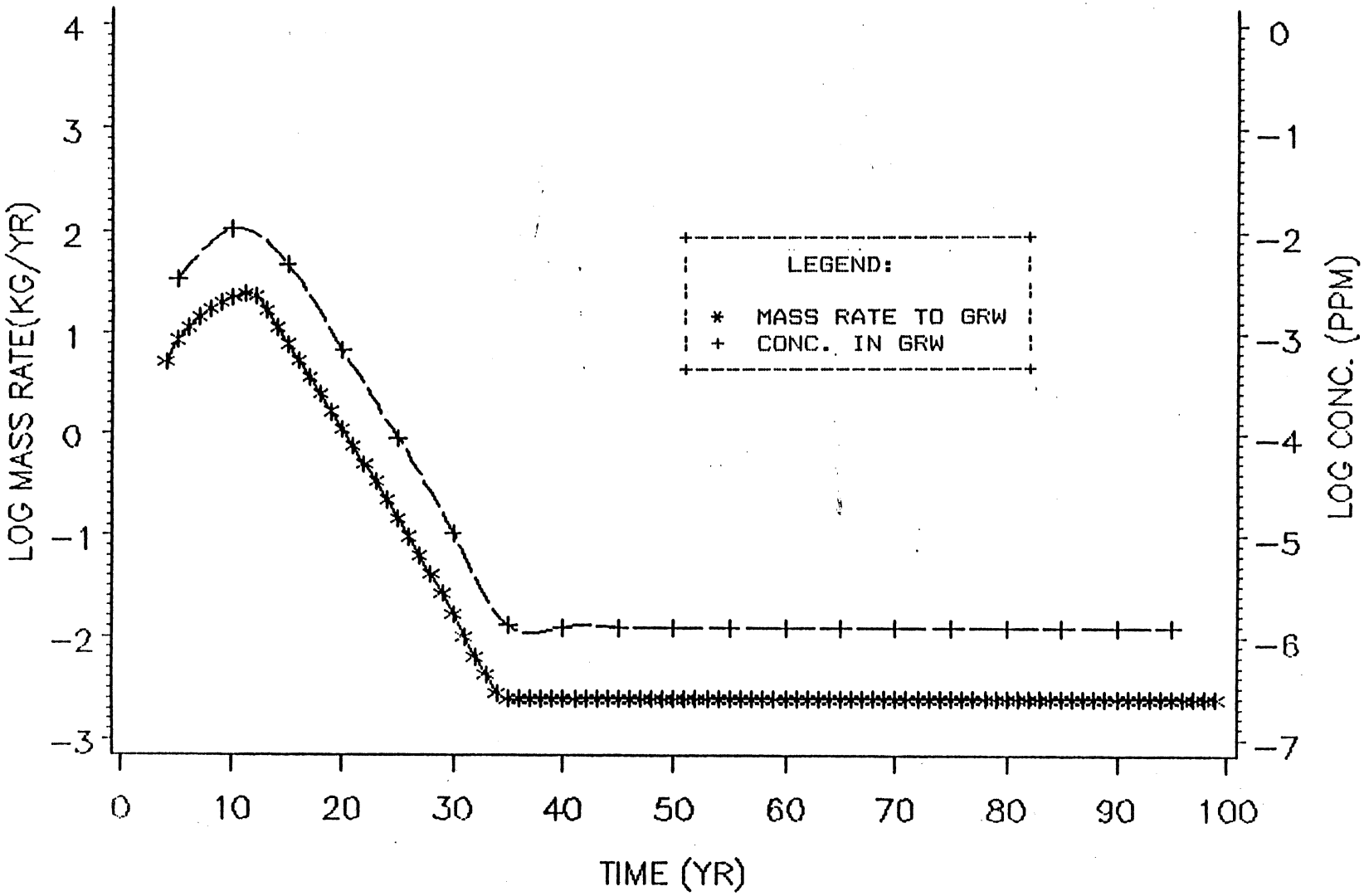


FIG. A-16: TIME DISTRIBUTIONS OF: (A) MASS INTO GROUNDWATER AND (B) DISSOLVED CONCENTRATION IN GROUNDWATER AT WELL LOCATION (X=200 M, Y=PLUME CENTERLINE, Z=20 M BELOW WATER TABLE) FOR CHEMICAL #7 AT WICHITA SITE

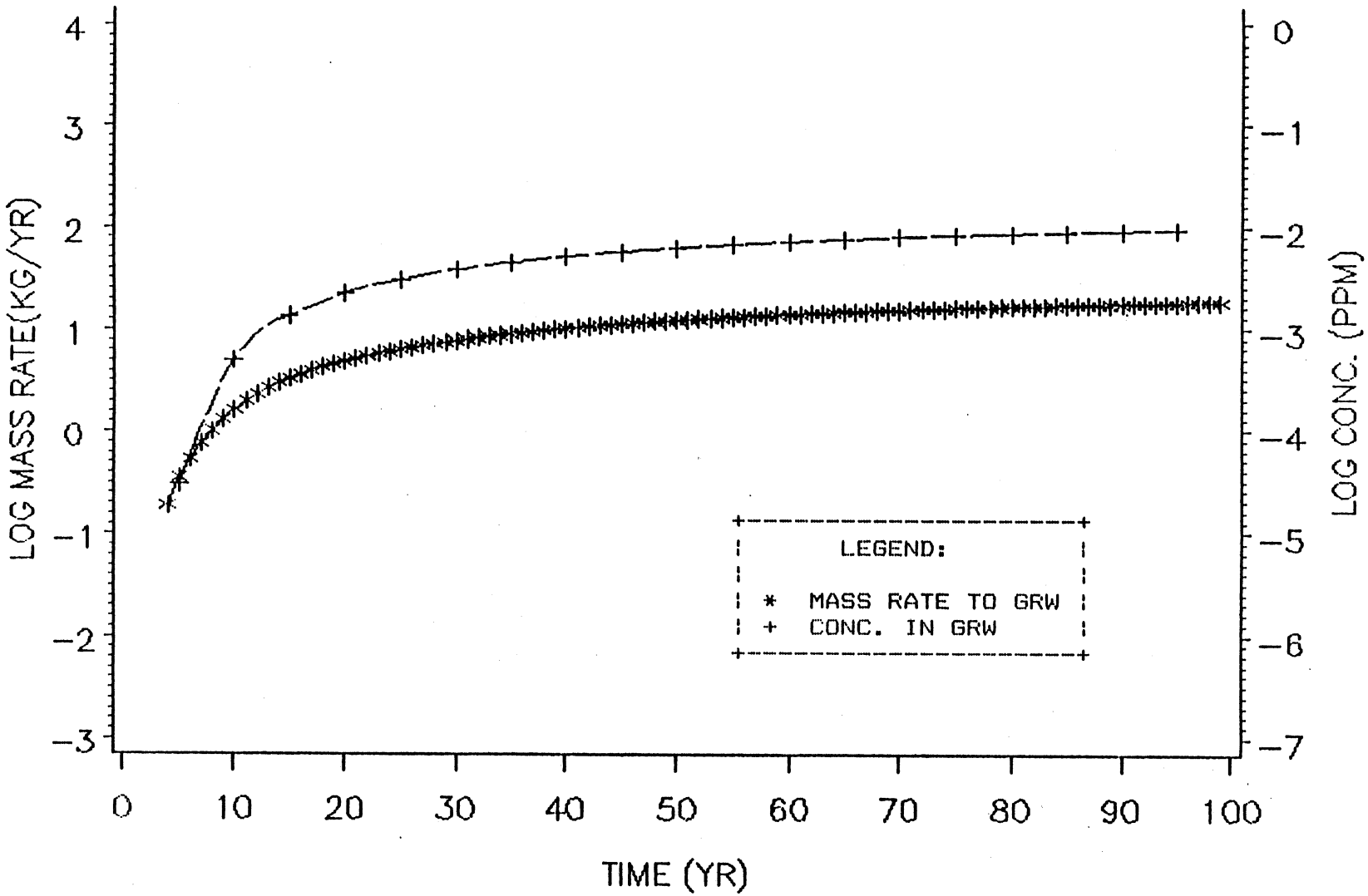


FIG. A-17: TIME DISTRIBUTIONS OF: (A) MASS INTO GROUNDWATER AND (B) DISSOLVED CONCENTRATION IN GROUNDWATER AT WELL LOCATION (X=200 M, Y=PLUME CENTERLINE, Z=20 M BELOW WATER TABLE) FOR CHEMICAL #8 AT WICHITA SITE

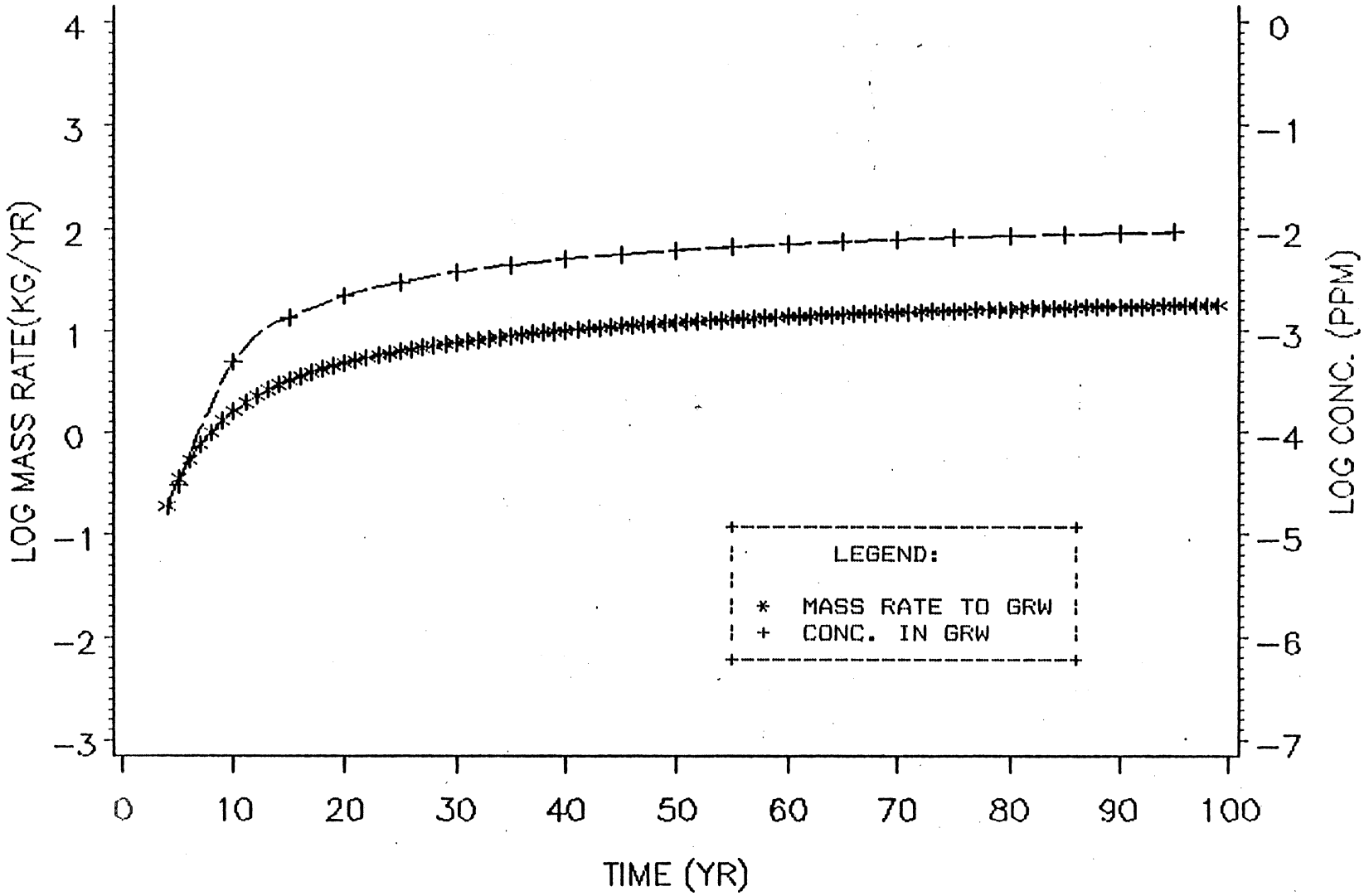
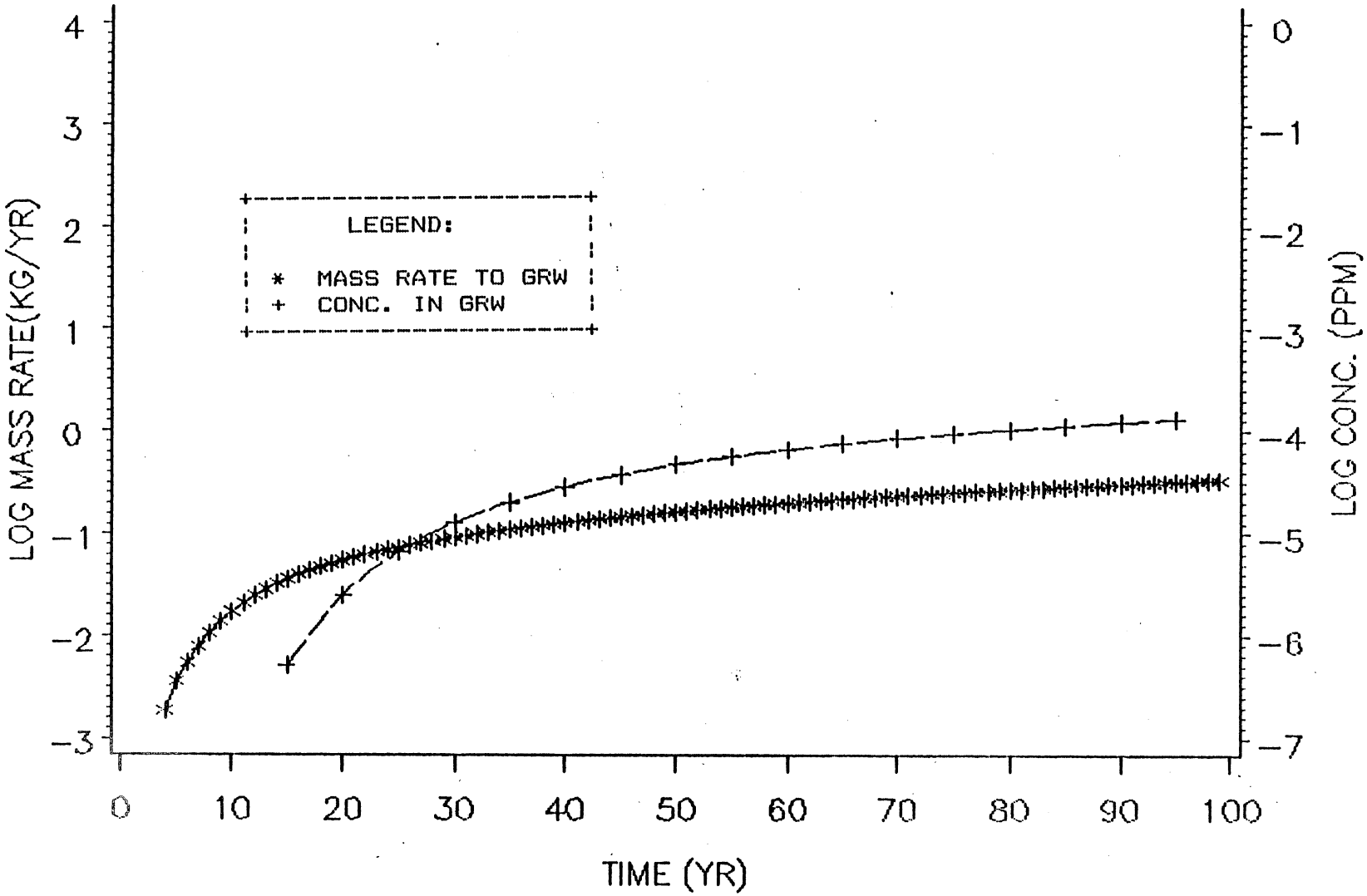


FIG. A-18: TIME DISTRIBUTIONS OF: (A) MASS INTO GROUNDWATER AND (B) DISSOLVED CONCENTRATION IN GROUNDWATER AT WELL LOCATION (X=200 M, Y=PLUME CENTERLINE, Z=20 M BELOW WATER TABLE) FOR CHEMICAL #9 AT WICHITA SITE



APPENDIX B

DISTANCE PROFILES OF GROUNDWATER CONCENTRATIONS

FIG. B-1 : DISSOLVED CONCENTRATION - DISTANCE DISTRIBUTION IN GROUNDWATER ALONG PLUME CENTERLINE AT Z=20 M BELOW WATER TABLE AT TIME=5 YEARS FOR CHEMICAL #1 AT BOSTON SITE

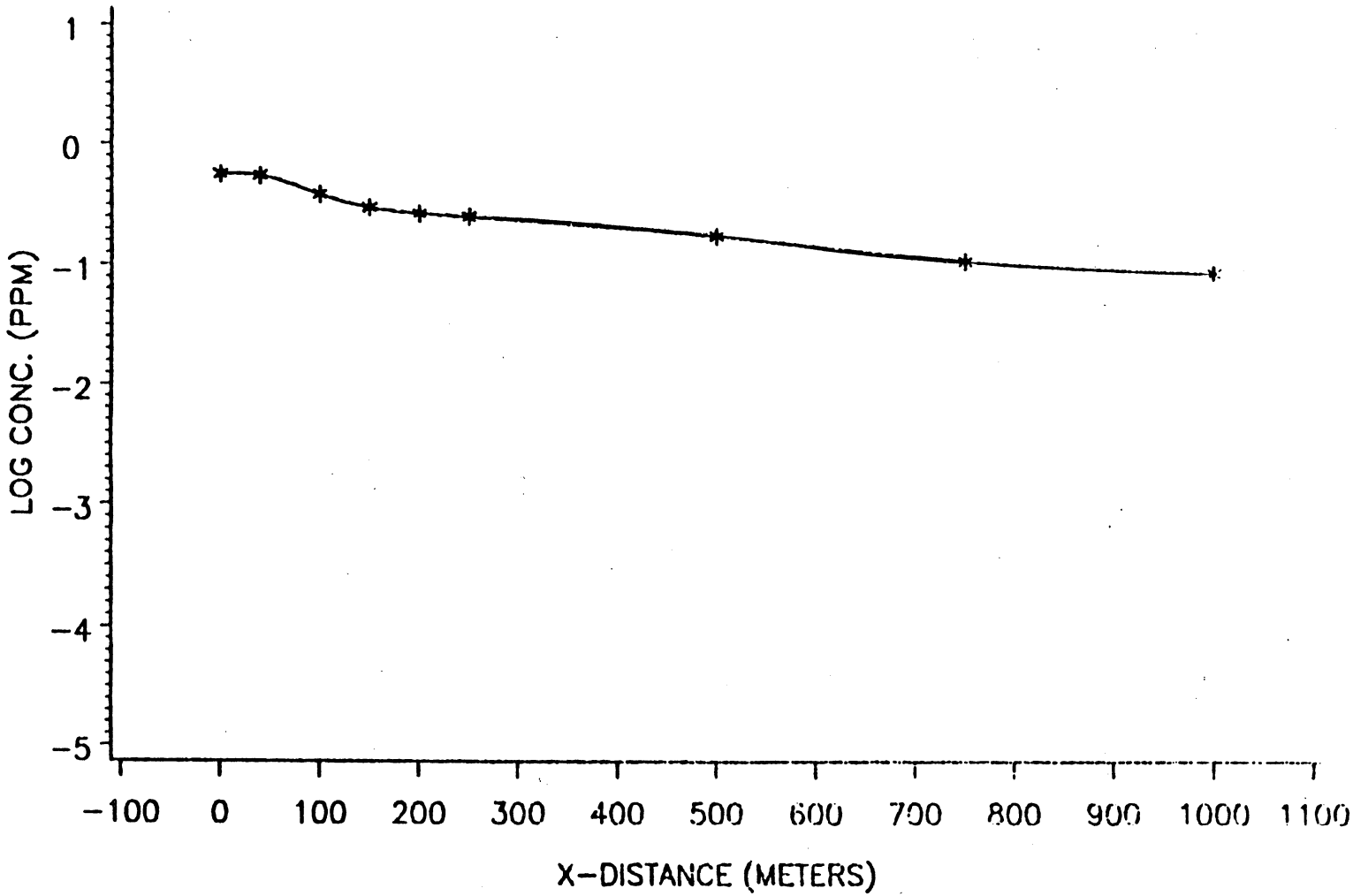


FIG. B-2 : DISSOLVED CONCENTRATION - DISTANCE DISTRIBUTION IN GROUNDWATER ALONG PLUME CENTERLINE AT Z=20 M BELOW WATER TABLE AT TIME=10 YEARS FOR CHEMICAL #2 AT BOSTON SITE

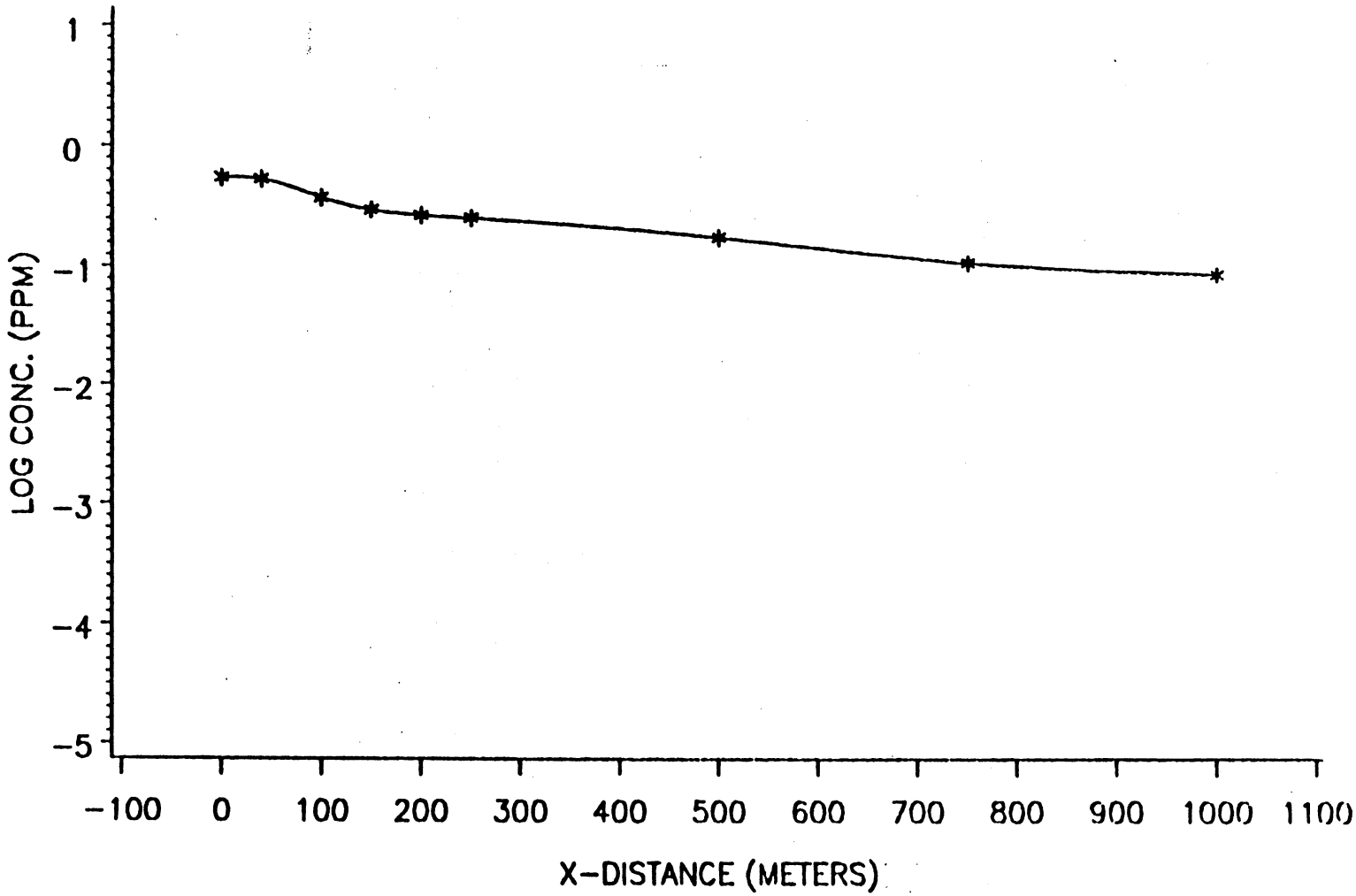


FIG. B-3 : DISSOLVED CONCENTRATION - DISTANCE DISTRIBUTION IN GROUNDWATER ALONG PLUME CENTERLINE AT Z=20 M BELOW WATER TABLE AT TIME=10 YEARS FOR CHEMICAL #3 AT BOSTON SITE

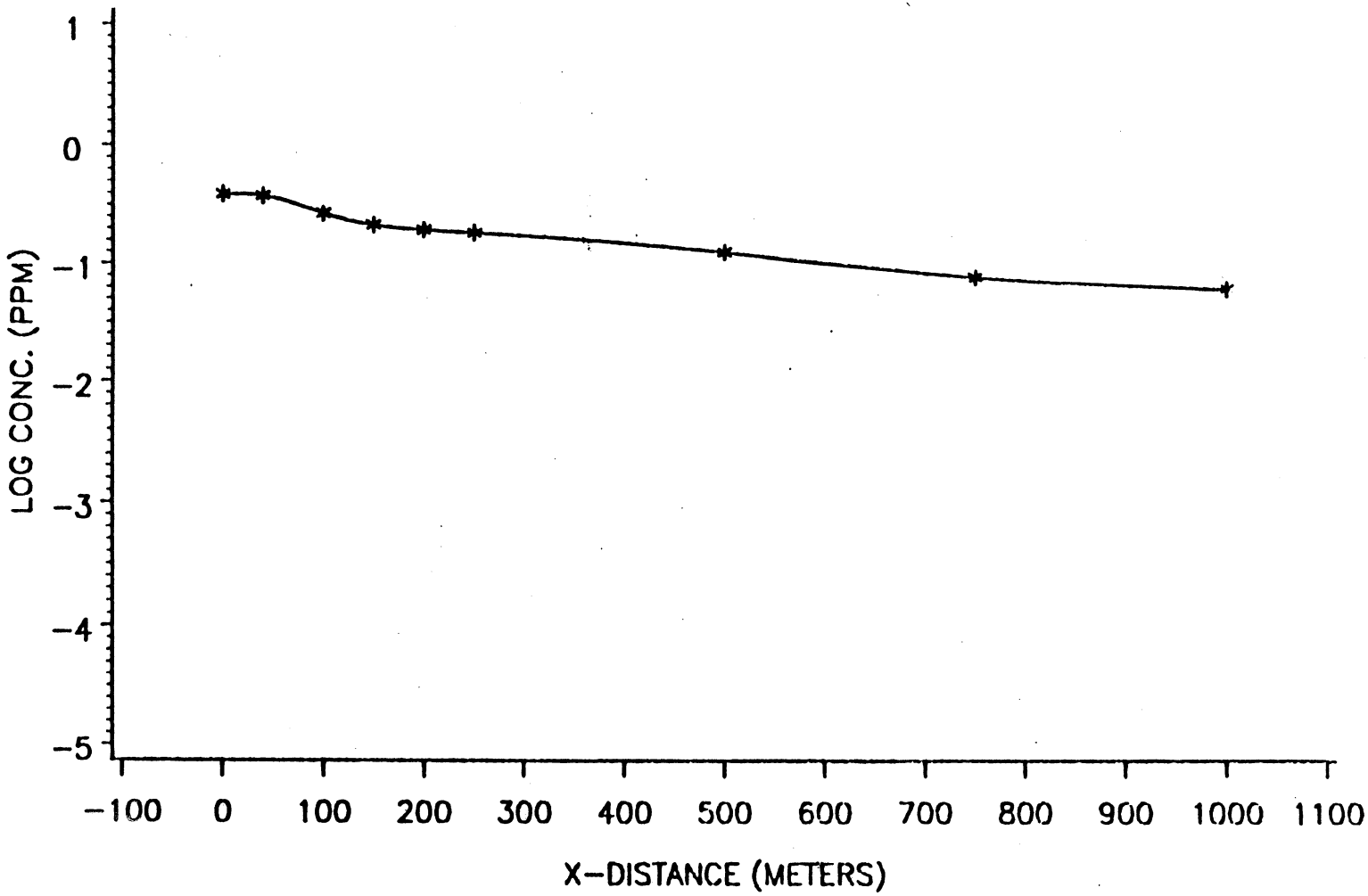


FIG. B-4 : DISSOLVED CONCENTRATION - DISTANCE DISTRIBUTION IN GROUNDWATER ALONG PLUME CENTERLINE AT Z=20 M BELOW WATER TABLE AT TIME=10 YEARS FOR CHEMICAL #4 AT BOSTON SITE

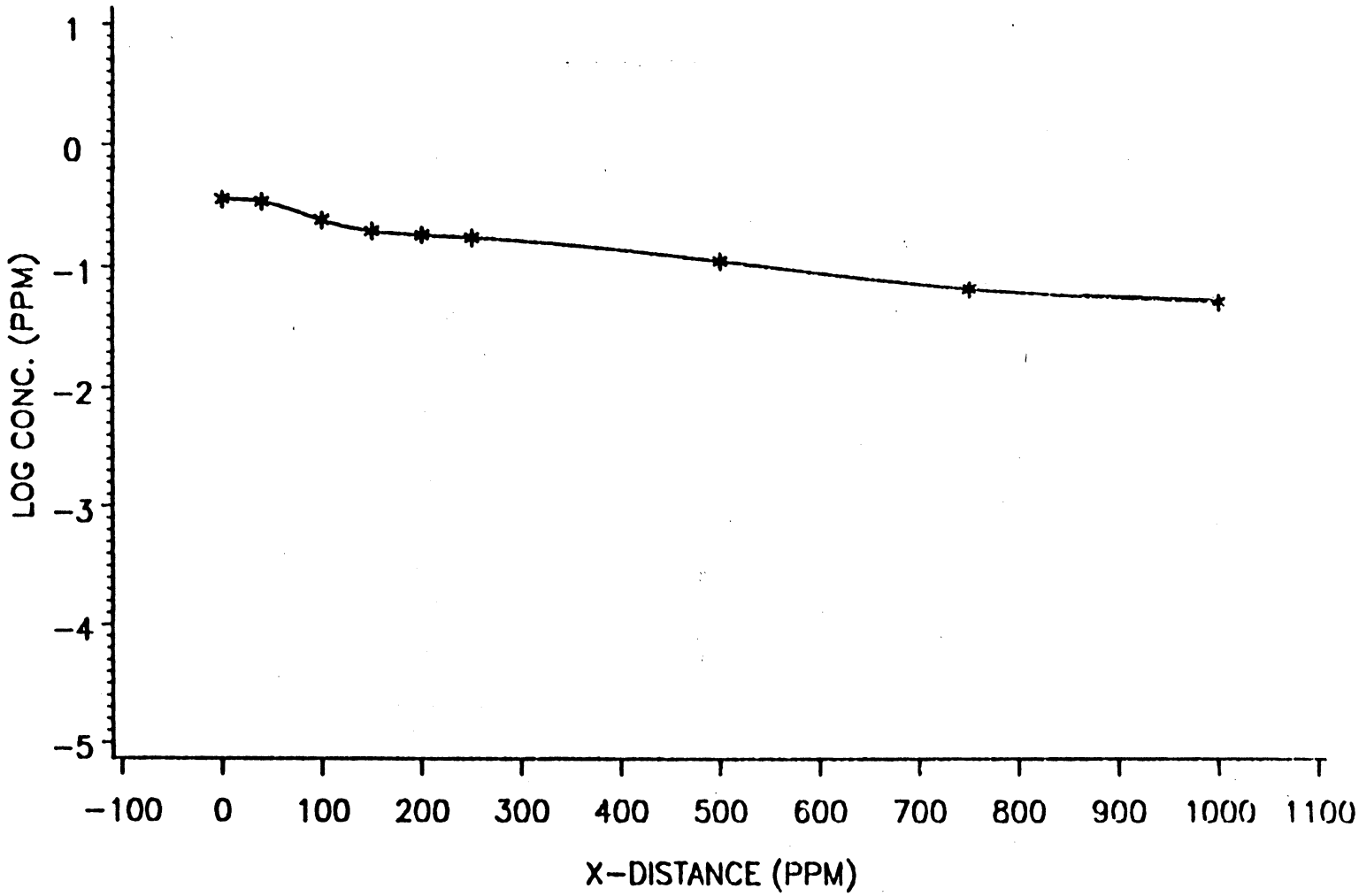


FIG. B-5 : DISSOLVED CONCENTRATION - DISTANCE DISTRIBUTION IN GROUNDWATER ALONG PLUME CENTERLINE AT Z=20 M BELOW WATER TABLE AT TIME=10 YEARS FOR CHEMICAL #5 AT BOSTON SITE

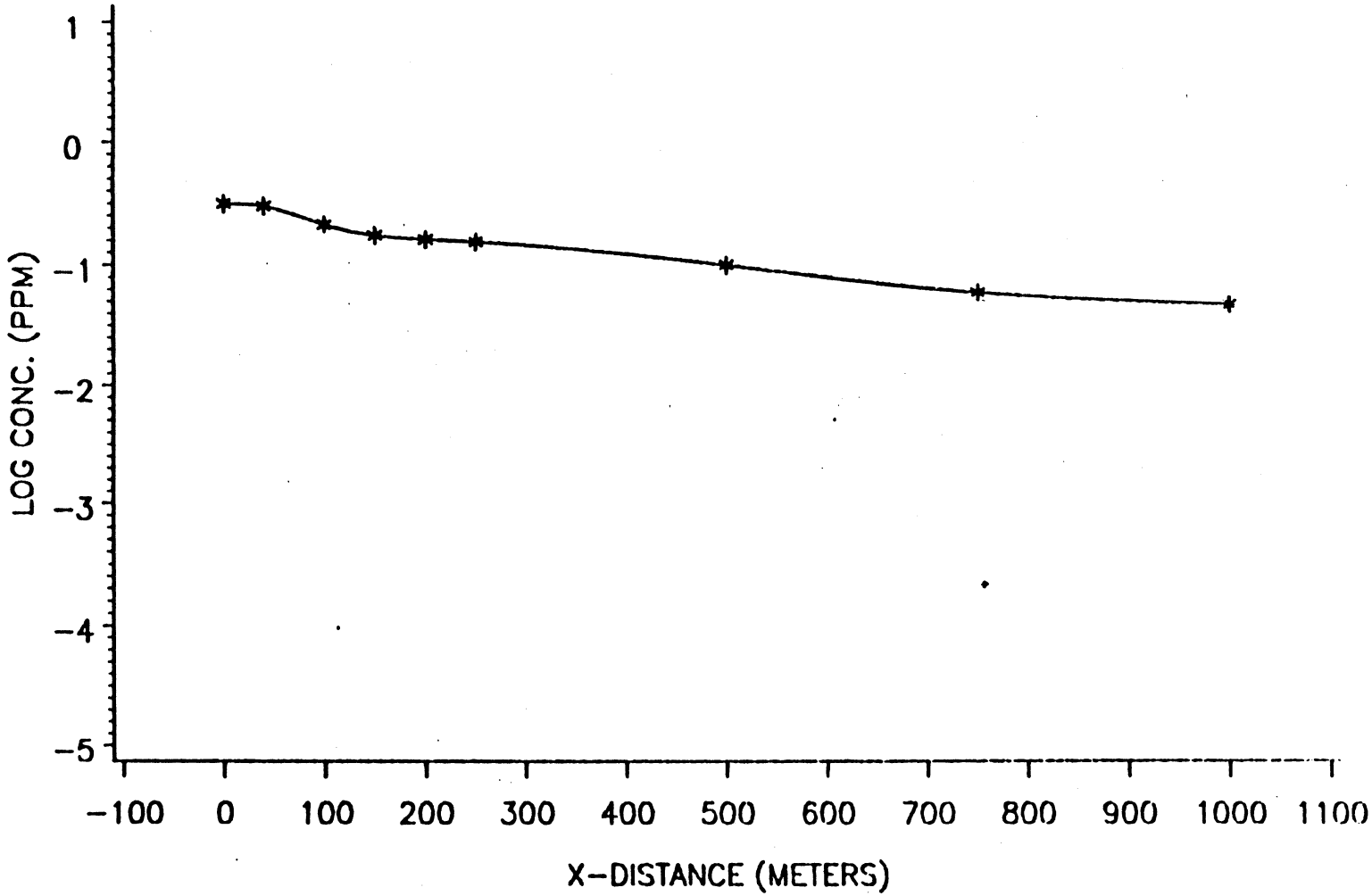


FIG. B-6 : DISSOLVED CONCENTRATION - DISTANCE DISTRIBUTION IN GROUNDWATER ALONG PLUME CENTERLINE AT Z=20 M BELOW WATER TABLE AT TIME=10 YEARS FOR CHEMICAL #6 AT BOSTON SITE

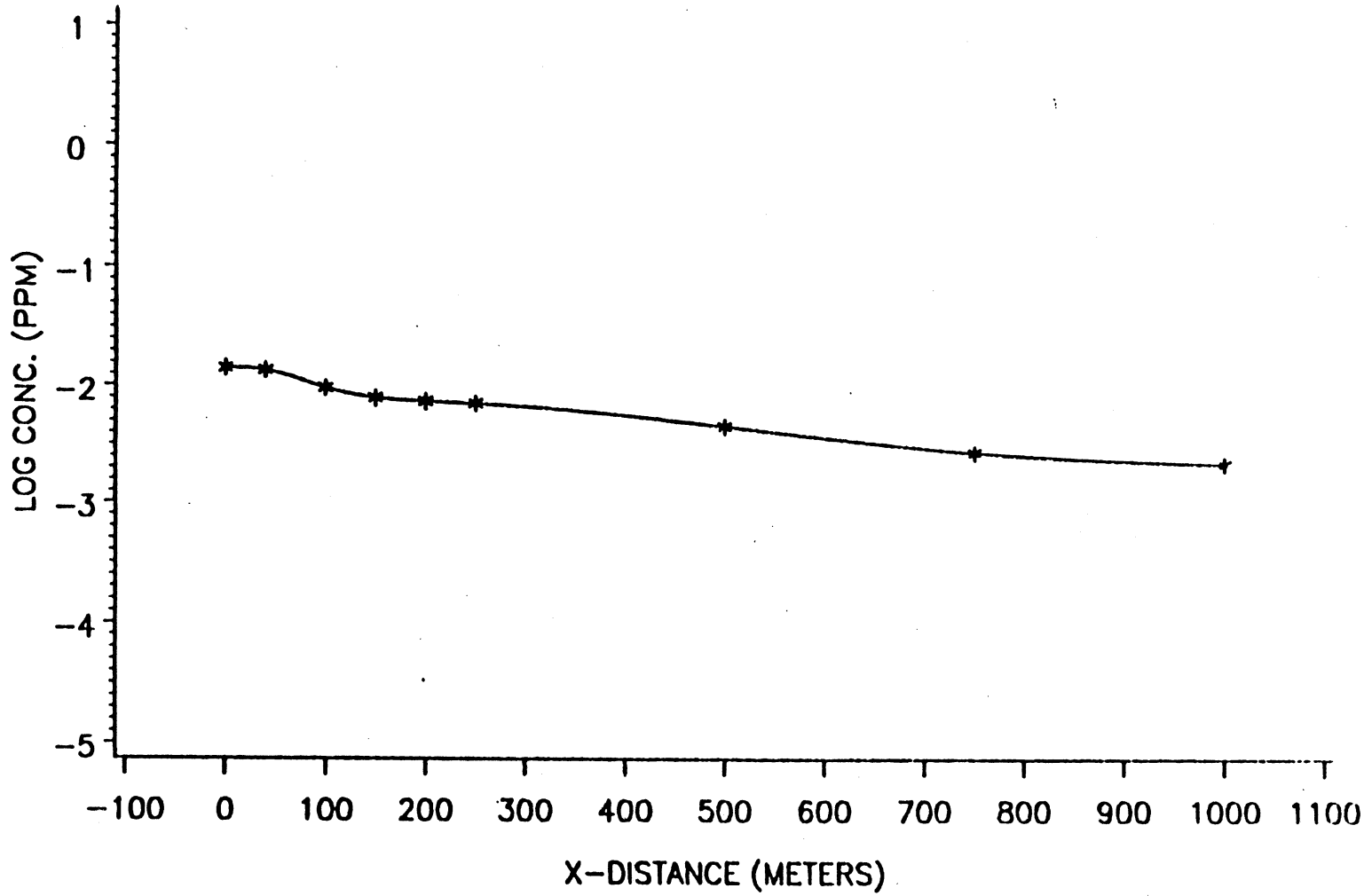


FIG. B-7 : DISSOLVED CONCENTRATION - DISTANCE DISTRIBUTION IN GROUNDWATER ALONG PLUME CENTERLINE AT Z=20 M BELOW WATER TABLE AT TIME=35 YEARS FOR CHEMICAL #7 AT BOSTON SITE

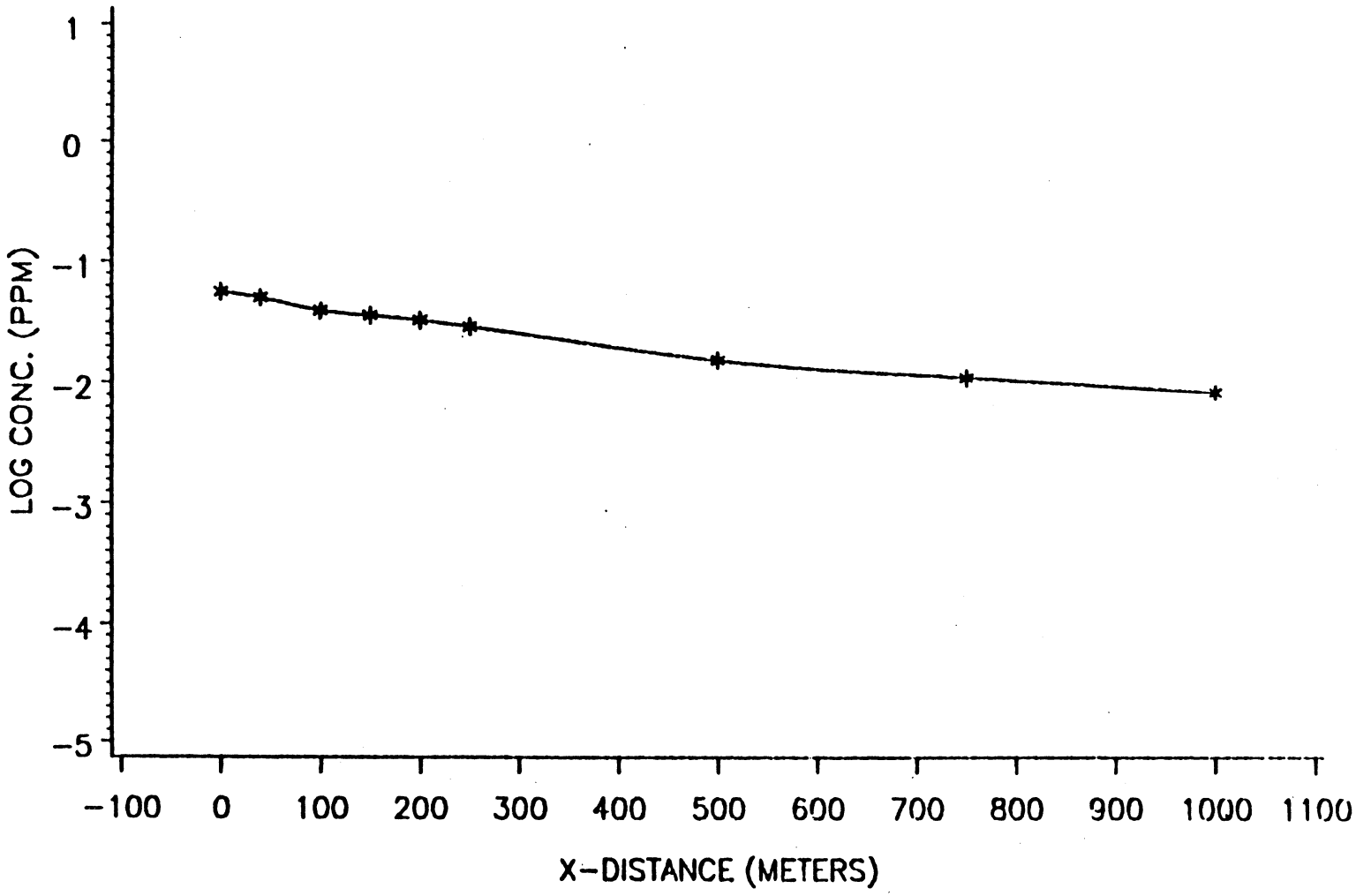


FIG. B-8 : DISSOLVED CONCENTRATION - DISTANCE DISTRIBUTION IN GROUNDWATER ALONG PLUME CENTERLINE AT Z=20 M BELOW WATER TABLE AT TIME=30 YEARS FOR CHEMICAL #8 AT BOSTON SITE

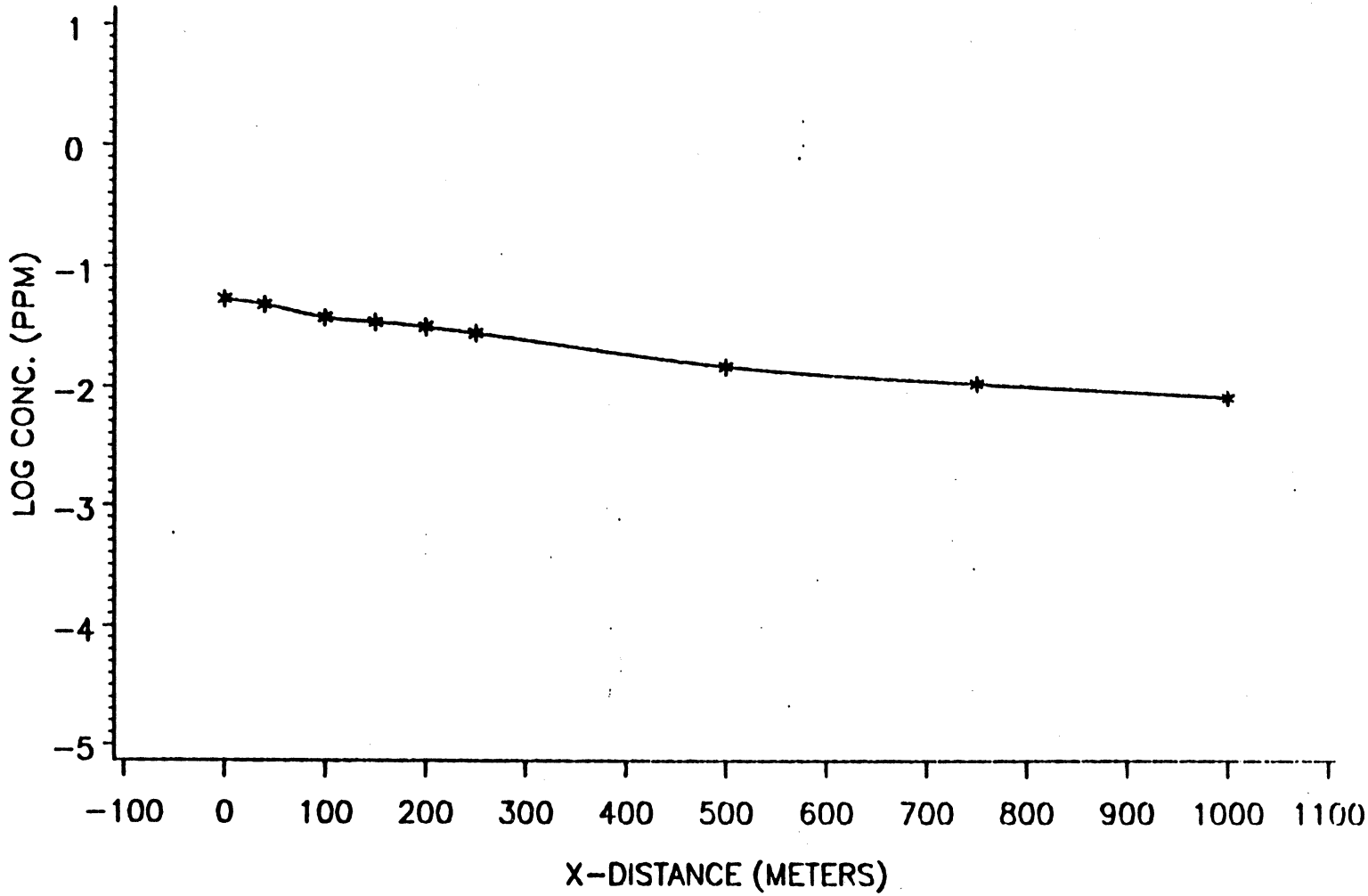


FIG. B-9 : DISSOLVED CONCENTRATION - DISTANCE DISTRIBUTION IN GROUNDWATER ALONG PLUME CENTERLINE AT Z=20 M BELOW WATER TABLE AT TIME=95 YEARS FOR CHEMICAL #9 AT BOSTON SITE

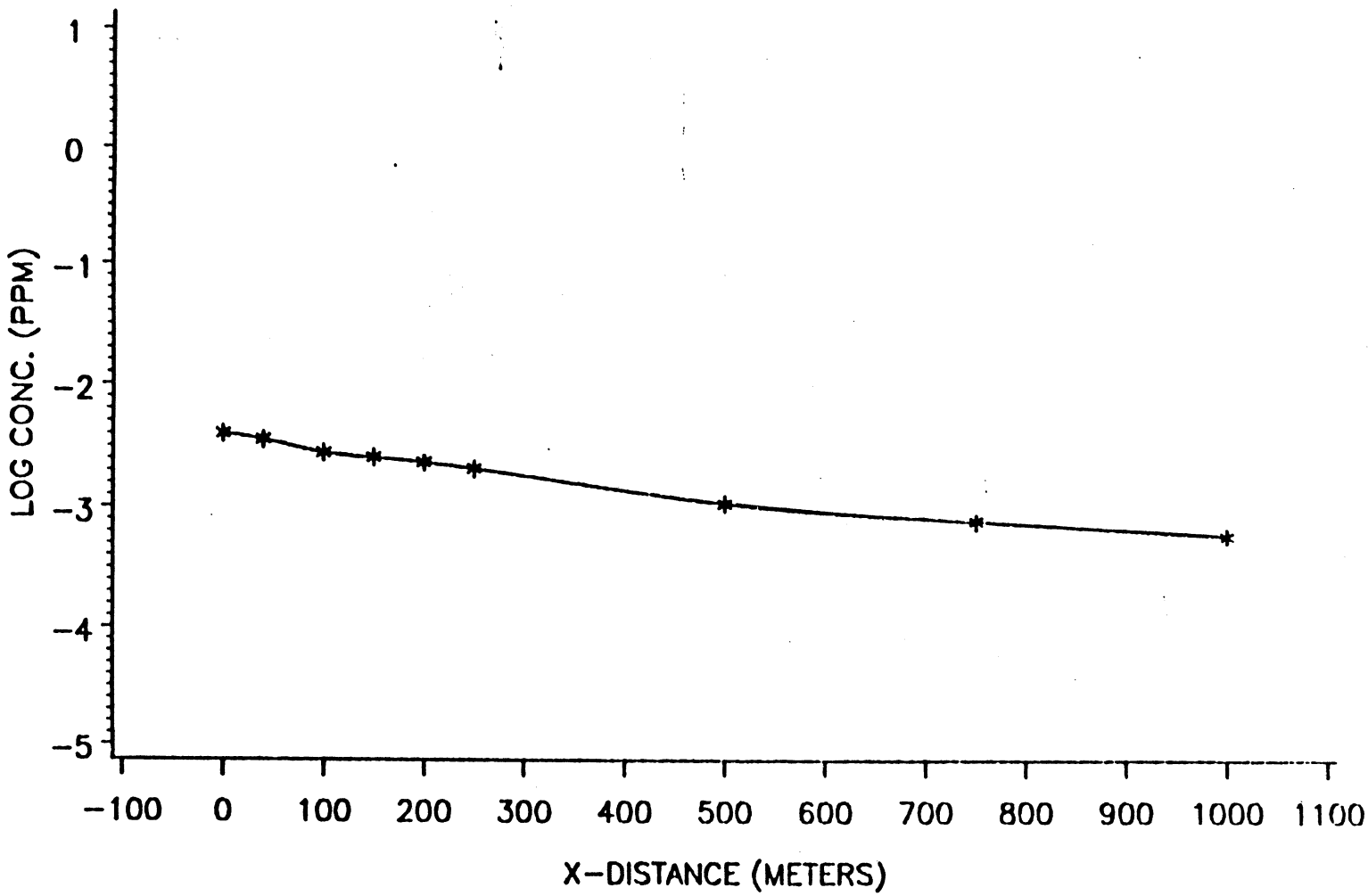


FIG. B-10: DISSOLVED CONCENTRATION - DISTANCE DISTRIBUTION IN GROUNDWATER ALONG PLUME CENTERLINE AT Z=20 M BELOW WATER TABLE AT TIME=5 YEARS FOR CHEMICAL #1 AT WICHITA SITE

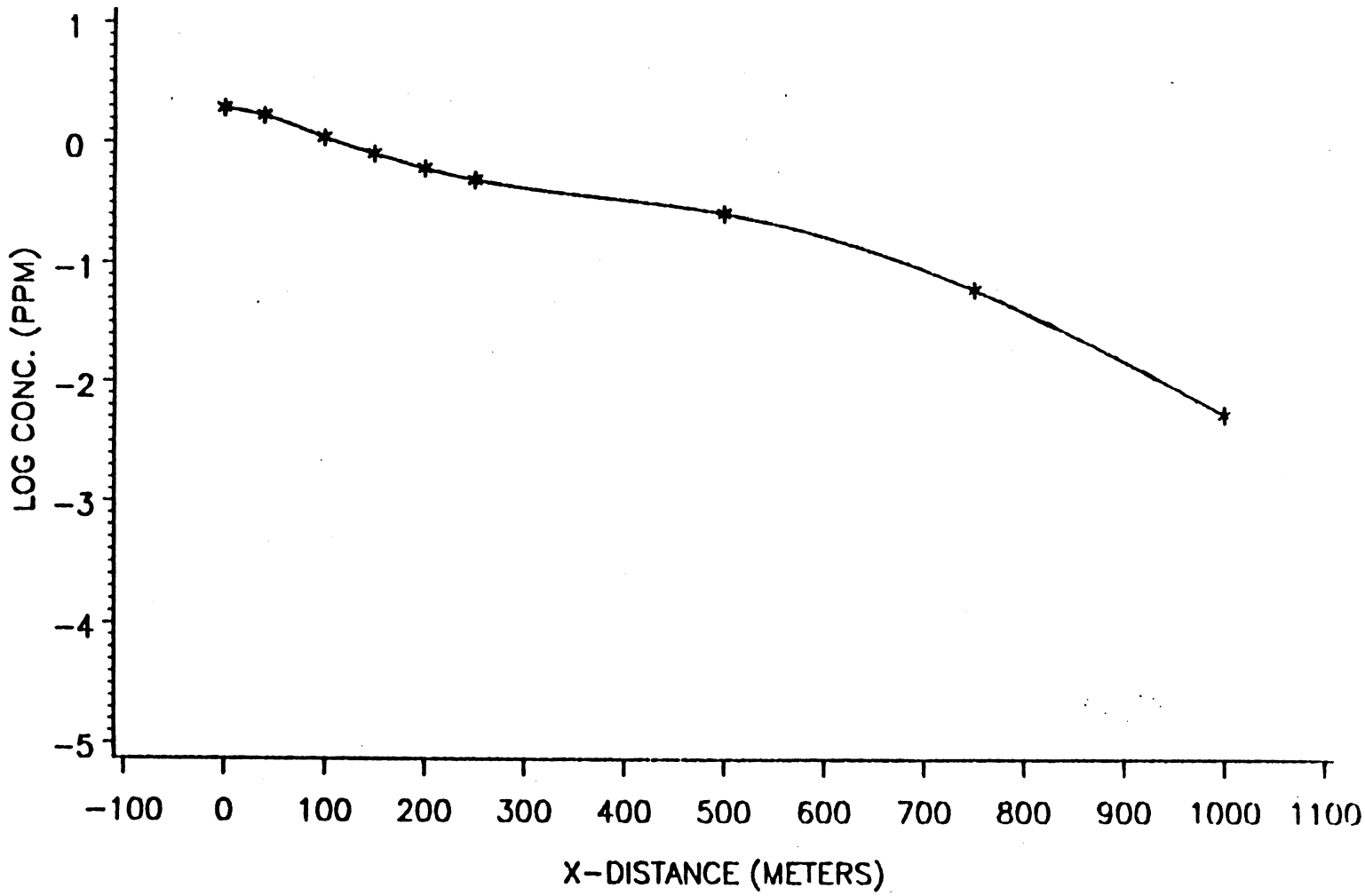


FIG. B-11: DISSOLVED CONCENTRATION - DISTANCE DISTRIBUTION IN GROUNDWATER ALONG PLUME CENTERLINE AT Z=20 M BELOW WATER TABLE AT TIME=10 YEARS FOR CHEMICAL #2 AT WICHITA SITE

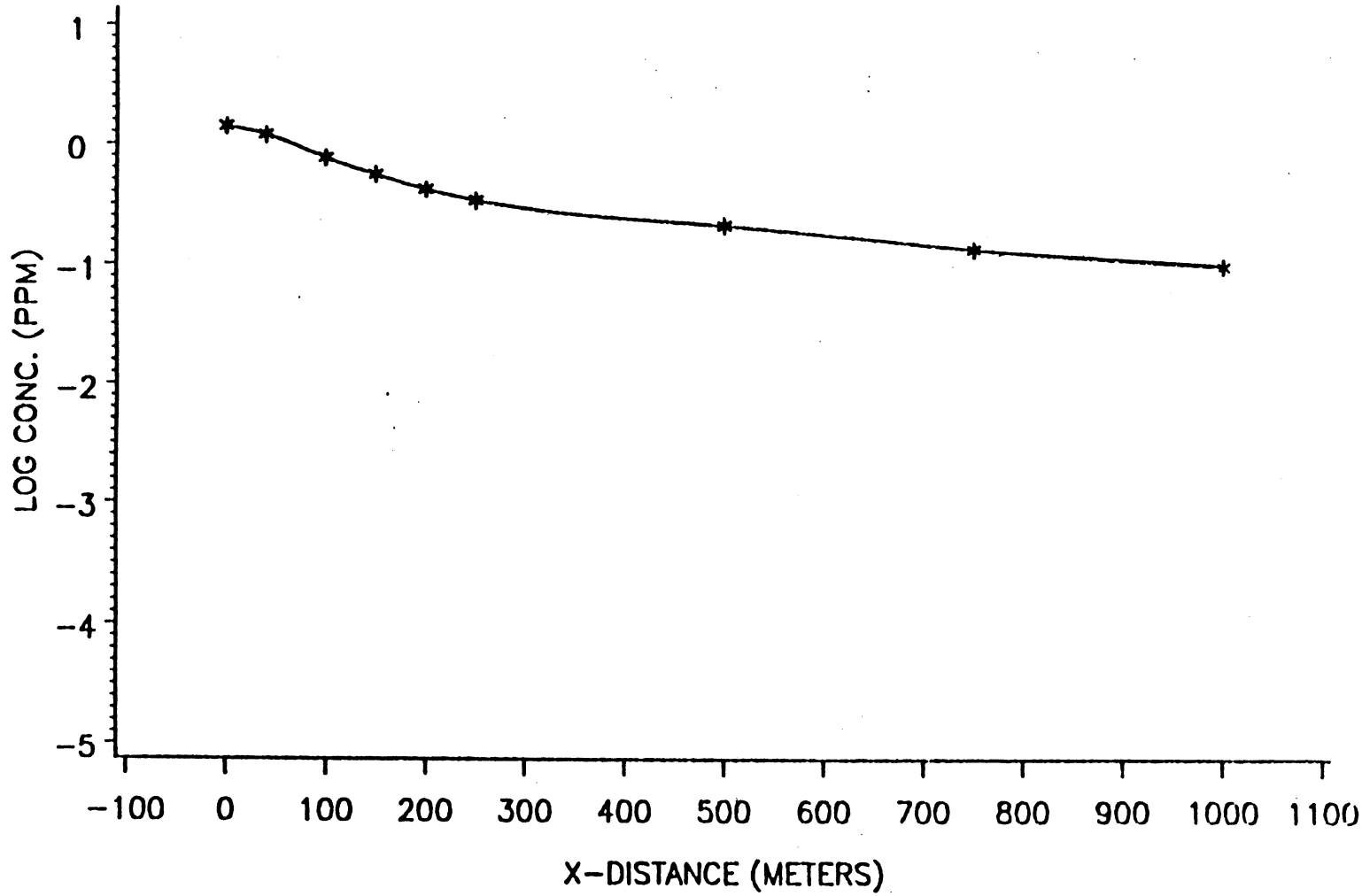


FIG. B-12: DISSOLVED CONCENTRATION - DISTANCE DISTRIBUTION IN GROUNDWATER ALONG PLUME CENTERLINE AT Z=20 M BELOW WATER TABLE AT TIME=10 YEARS FOR CHEMICAL #3 AT WICHITA SITE

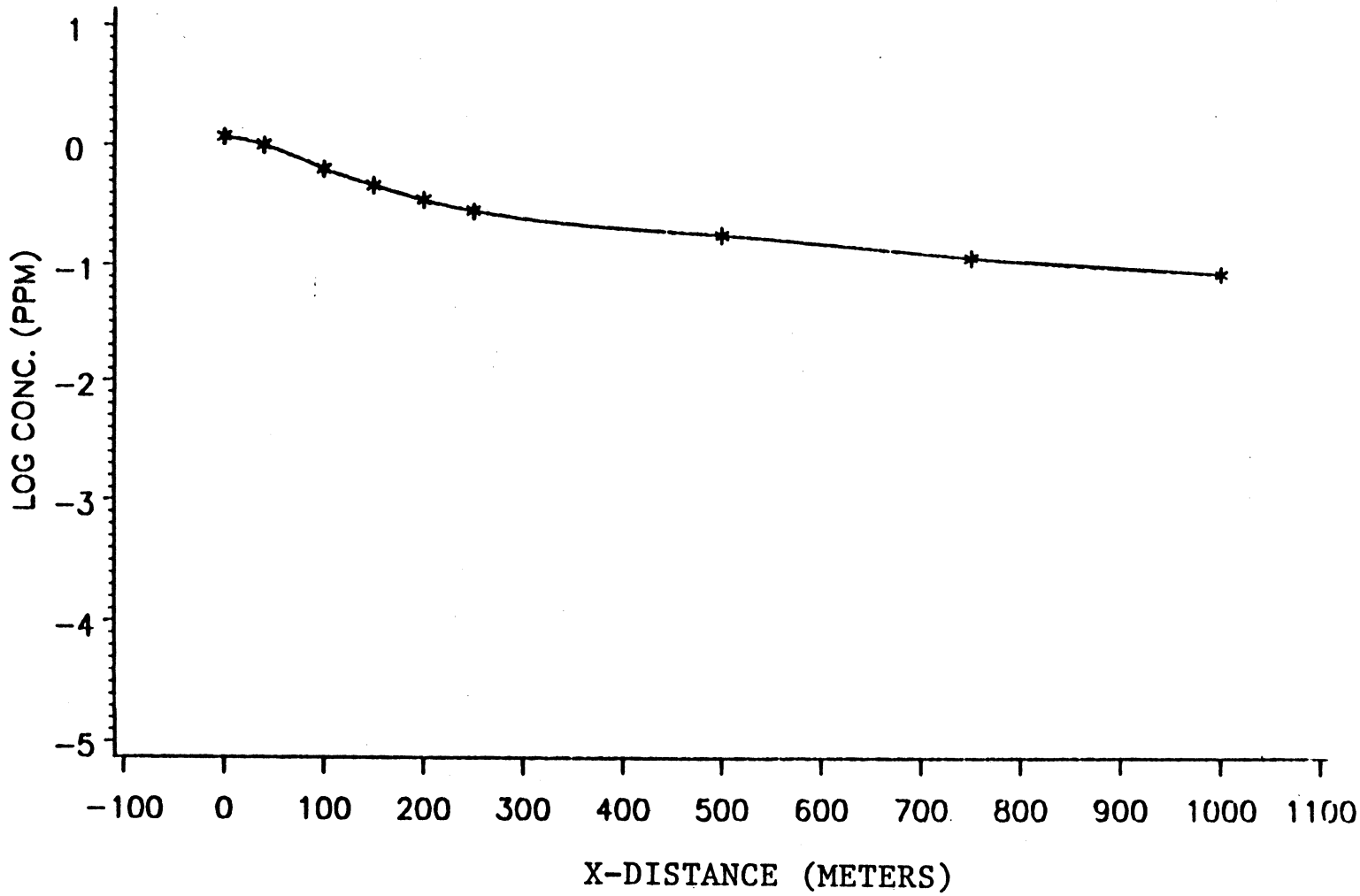


FIG. B-13: DISSOLVED CONCENTRATION - DISTANCE DISTRIBUTION IN GROUNDWATER ALONG PLUME CENTERLINE AT Z=20 M BELOW WATER TABLE AT TIME=25 YEARS FOR CHEMICAL #4 AT WICHITA SITE

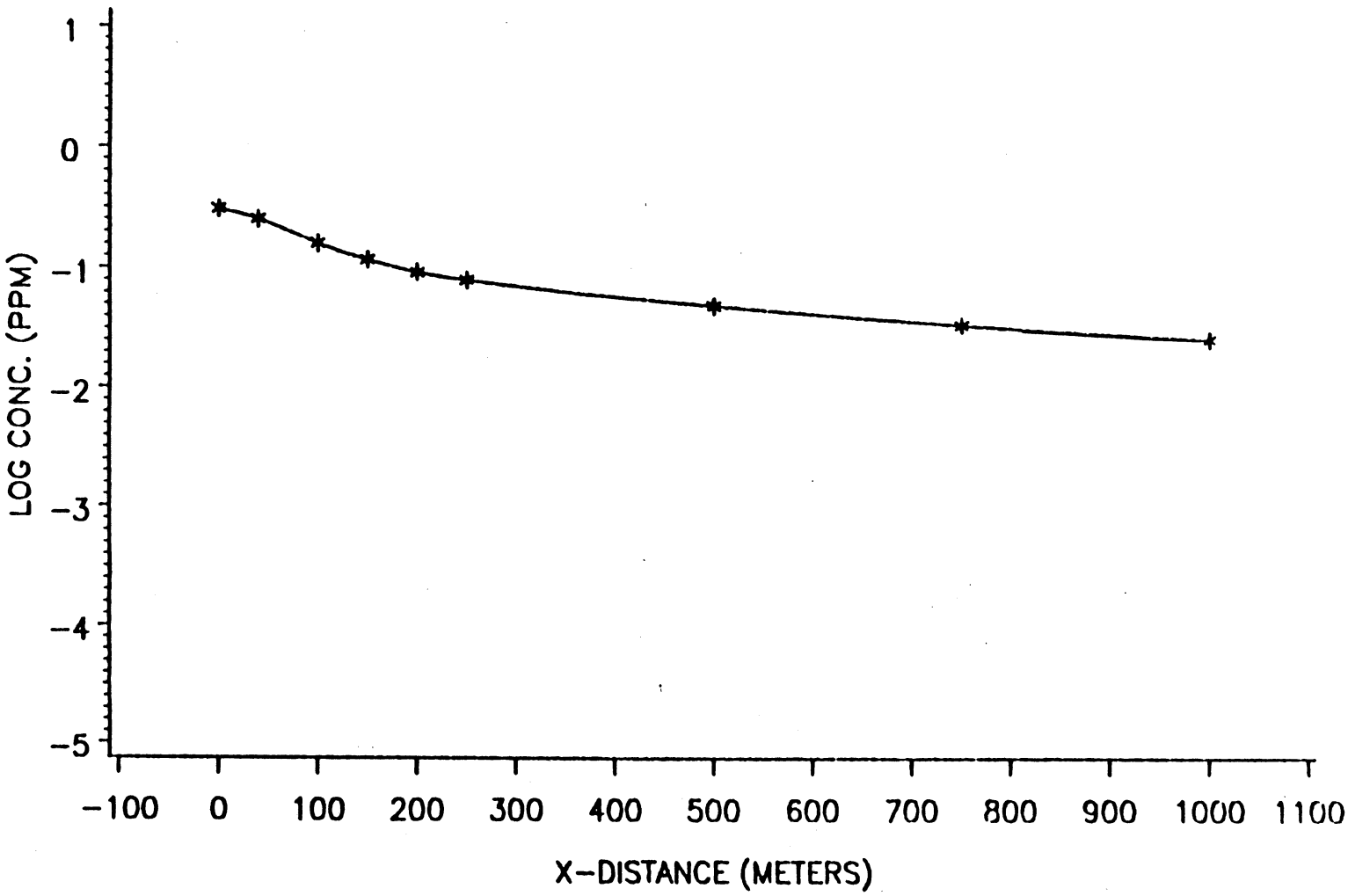


FIG. B-14: DISSOLVED CONCENTRATION - DISTANCE DISTRIBUTION IN GROUNDWATER ALONG PLUME CENTERLINE AT Z=20 M BELOW WATER TABLE AT TIME=20 YEARS FOR CHEMICAL #5 AT WICHITA SITE

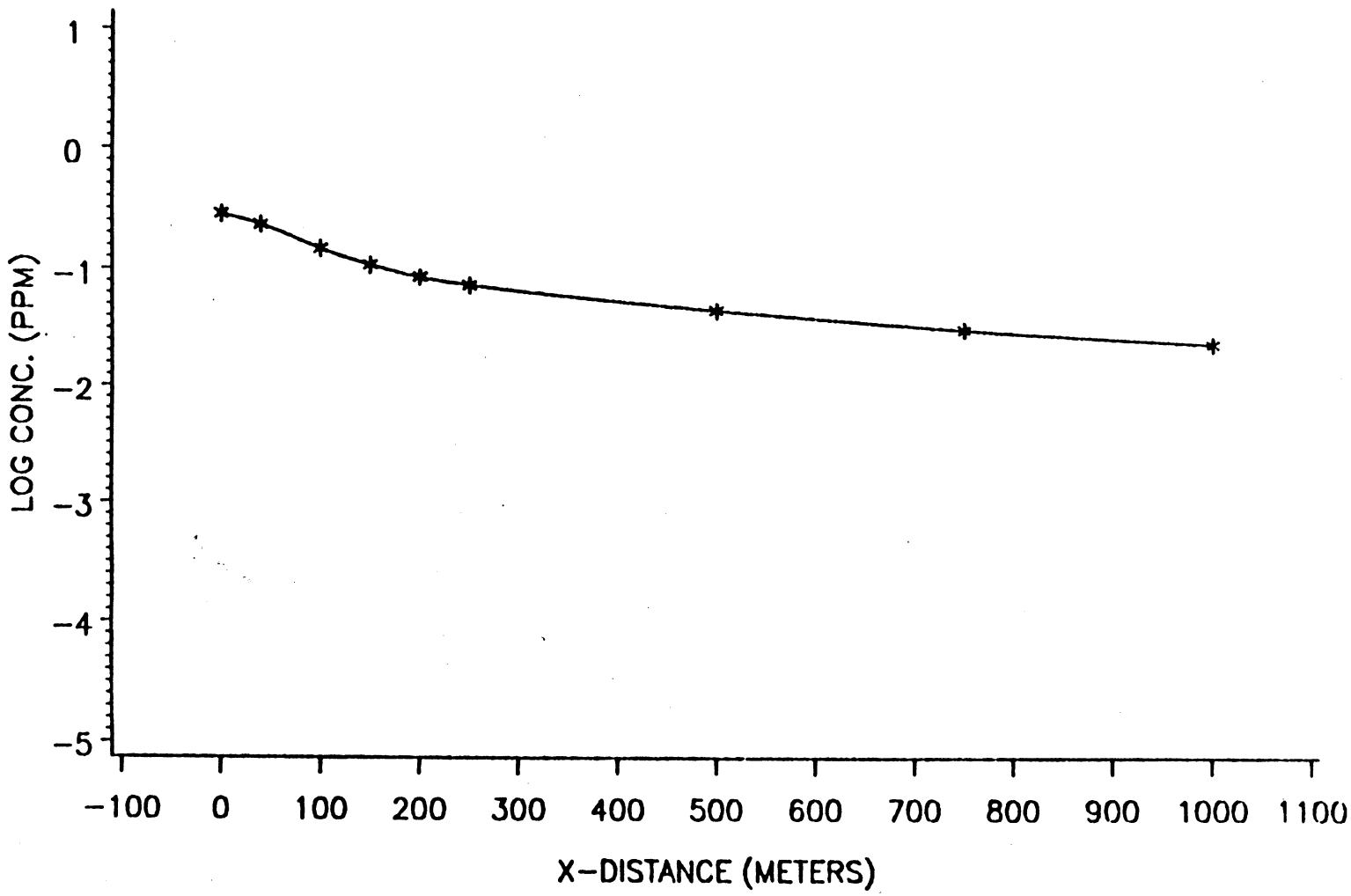


FIG. B-15: DISSOLVED CONCENTRATION - DISTANCE DISTRIBUTION IN GROUNDWATER ALONG PLUME CENTERLINE AT Z=20 M BELOW WATER TABLE AT TIME=10 YEARS FOR CHEMICAL #6 AT WICHITA SITE

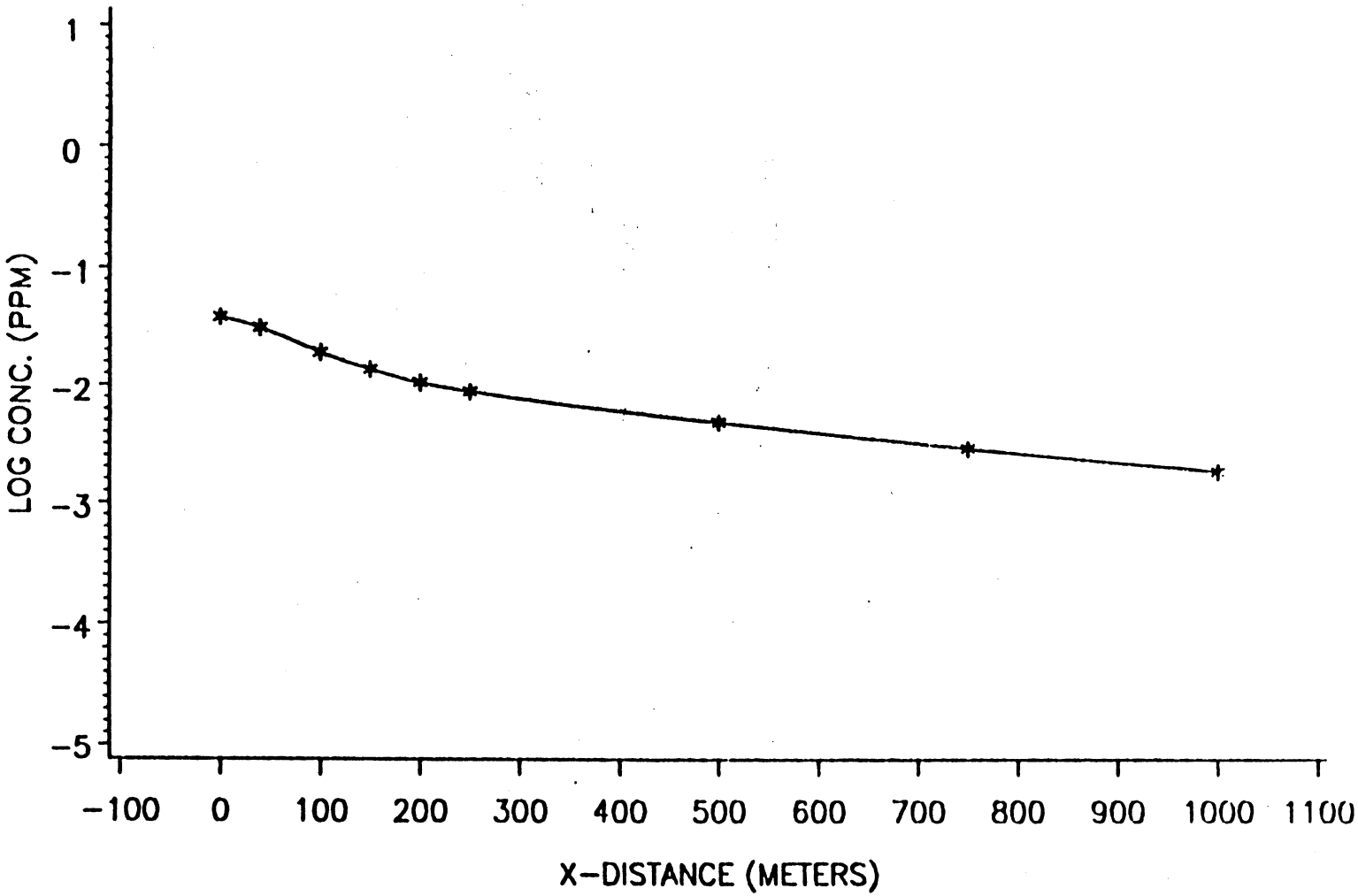


FIG. B-16: DISSOLVED CONCENTRATION - DISTANCE DISTRIBUTION IN GROUNDWATER ALONG PLUME CENTERLINE AT Z=20 M BELOW WATER TABLE AT TIME=95 YEARS FOR CHEMICAL #7 AT WICHITA SITE

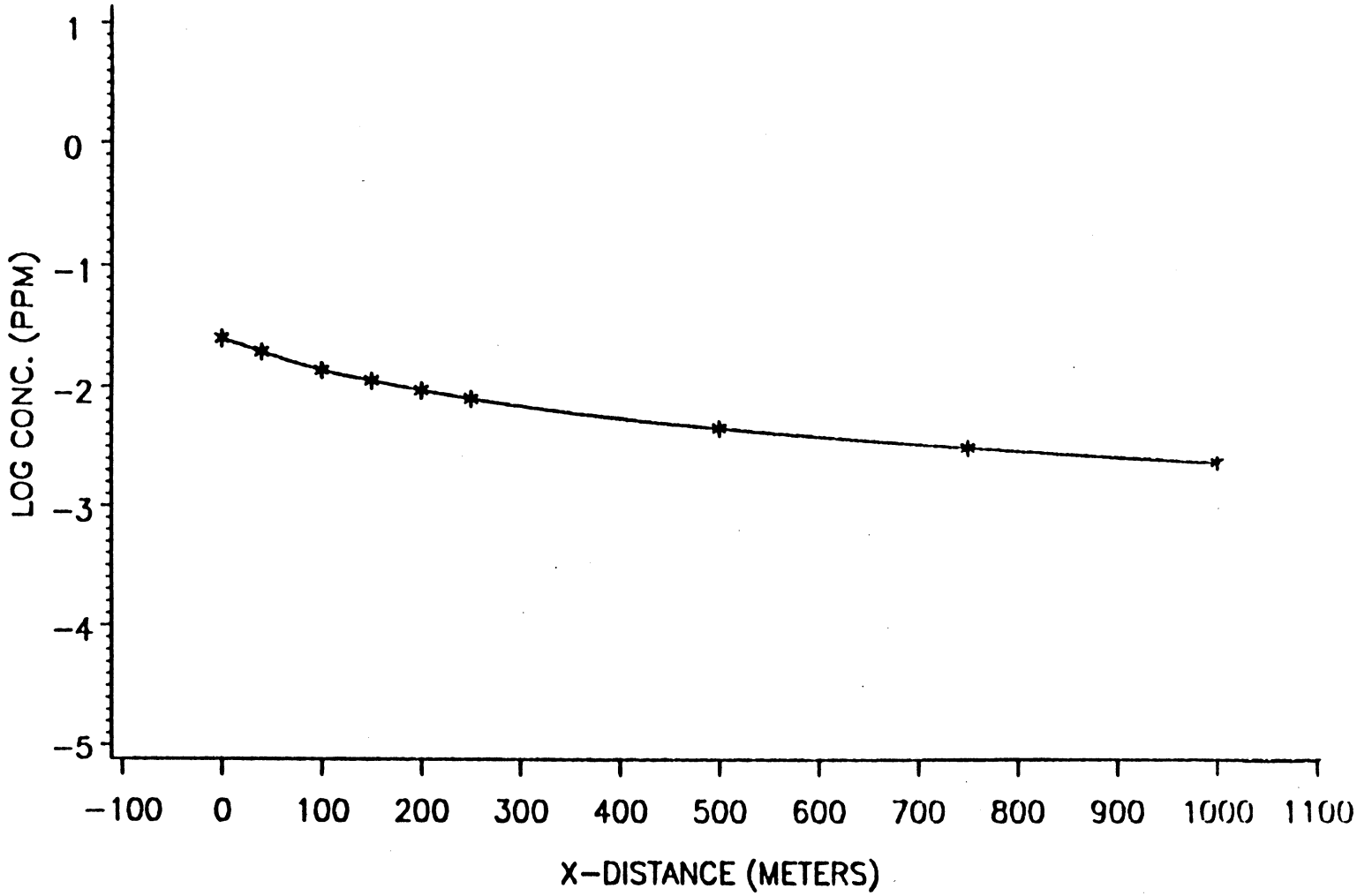


FIG. B-17: DISSOLVED CONCENTRATION - DISTANCE DISTRIBUTION IN GROUNDWATER ALONG PLUME CENTERLINE AT Z=20 M BELOW WATER TABLE AT TIME=95 YEARS FOR CHEMICAL #8 AT WICHITA SITE

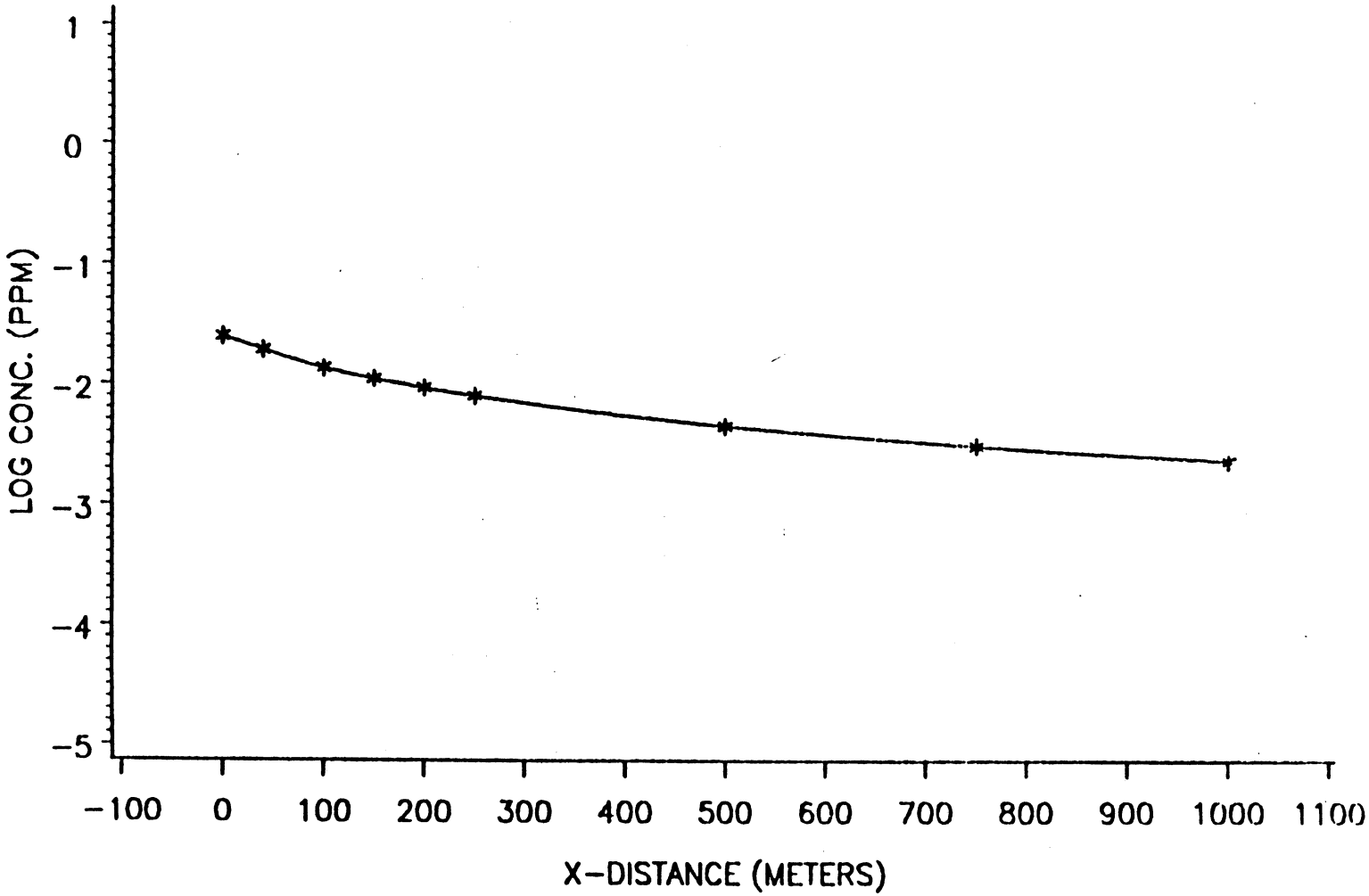


FIG. B-18: DISSOLVED CONCENTRATION - DISTANCE DISTRIBUTION IN GROUNDWATER ALONG PLUME CENTERLINE AT Z=20 M BELOW WATER TABLE AT TIME=95 YEARS FOR CHEMICAL #9 AT WICHITA SITE