1D-00593

TECHNICAL MEMORANDUM

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Jim Morrison, TDEC
Tonya Barker/Rob Williamson, NSA Memphis
Jack Carmichael, USGS

From: John Stedman, EnSafe Inc.

Date: January 21, 1998

Re: NSA Memphis AOC A Corrective Measures Study — Modeling Approach

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INTRODUCTION

This technical memorandum describes an approach for using modeling as a tool to evaluate natural attenuation as a remedy (alone or combined with other remedies) for Naval Support Activity (NSA) Memphis Northside fluvial groundwater (AOC A). Modeling will be used in the AOC A Corrective Measures Study (CMS) to help:

- Demonstrate the feasibility of natural attenuation
- Predict maximum steady-state plume lengths to identify natural attenuation and sentinel well locations, as well as, locations for additional monitoring wells to further define the extent of contamination
- Estimate time required to achieve cleanup goals using natural attenuation as a remedy

APPROACH

Modeling is one of the tools that will be used to provide a reasonable estimate of the feasibility of natural attenuation as a remedy at AOC A. Simulations can be performed using input parameters such as average groundwater velocity, retardation, contaminant concentrations, and dispersion to estimate the nature and extent of current groundwater plumes over time. These parameters are derived from data collected during the RCRA Facility Investigation (RFI); therefore, they are reasonably representative of the site.

In addition to modeling, geochemical screening and long-term monitoring are to be used to evaluate natural attenuation. If geochemical evidence and modeling supports natural attenuation as a suitable remedial alternative within a reasonable time frame, and natural attenuation is protective of human health and the environment (i.e., it appears that potential receptors will not be impacted), long-term contaminant monitoring will be performed. Long-term monitoring is the demonstrative step in the implementation of natural attenuation and supports the selection of this remedial alternative. Modeling will also be used to locate monitoring and sentinel wells that will be part of the long-term monitoring. Modeling will also be used to identify well locations where contaminant concentrations are required to fill in data needs that will complete the contaminant plumes' downgradient extent.

Modeling scenarios for TCE contamination at AOC A are currently being evaluated using the computer code MYGRT, an analytical model based on an advection-dispersion-retardation-decay equation. The U.S. Geological Survey has performed simulations for three locations within the AOC: the northern edge of the plume, the "grassy" area plume, and the N-6 plume. The decay rate obtained from the simulation is at the conservative end of ranges for TCE as reported in technical publications. Simulated dimensions of the TCE plume in the grassy area and the N-6 area agree with the observed data from site investigations and the RFI. Furthermore, simulations projected the three plumes over time. Simulated results show that the plumes would reach steady state in 45 to 60 years, and once the source was depleted, decayed to <5 ug/L in 15 to 36 years. Attachment 1 includes assumptions and input parameters that were used in the simulations. Attachment 2 describes simulations and model outputs. These simulations represent a preliminary evaluation of natural attenuation using modeling. Additional simulations will be performed during the CMS and final results will be presented in the CMS report

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Attachment 1

Assumptions and Input Parameters

Solute transport simulation at NSAM Northside AOC using a 2-D analytical solution

Transport scenarios for TCE from the NSAM Northside AOC were evaluated using the computer code MYGRT. MYGRT is a analytical model based on the advection-dispersion-retardation-decay equation (Cleary and Ungs, 1978 and van Genuchten and Alves, 1982). One and 2-D simulations are possible.

MYGRT model assumptions:

- The groundwater seepage velocity remains constant over the area of the simulation.
- The aquifer properties remain constant over the area of the simulation.
- Dispersion is represented by Fick's Law. The coefficients remain constant for a given simulation.
- Sorption is treated as linear, equilibrium partitioning between aqueous and solid phases.
- Transport of a single solute species for a given simulation is adequate. (i.e. interactions between species are not considered.)
- First order kinetics adequately simulate solute transformation or decay. In first order kinetics, the solute transformation is modeled by exponential decay with a single rate constant. It does not consider geochemical environment, microbiological community present, or effects from other solutes present. [$C(t) = C_o e^{-\lambda t}$; the decay constant is related to half-life by $\lambda = 0.693/t_{1/2}$]

Site background and assumptions;

Site - NSAM Northside AOC
Period of operation ~1945-95
Transport of solute away from the site occurs in the fluvial deposits.

Input parameters summary:

Solute simulated: TCE
Size of disposal area: determined based on individual site data; source width perpendicular to flow varied from 20 to 40 meters
Duration of source term: 1945 to present (1998), duration into the future is unknown, simulations run assuming 100 year persistence of source term.

average ground-water velocity (V_x): = $\frac{K \times \left(\frac{dh}{dl}\right)}{n}$ = 7.3m/yr

where;

horizontal hydraulic conductivity (K): 1.5 m/day (5 ft/day)
horizontal hydraulic gradient(dh/dl): 0.0033
porosity (n): 0.25

longitudinal dispersion coefficient (D_x): determined based on site scale; varied from 58 to 73 m^2/yr
transverse dispersion coefficient (D_y): determined based on site scale: varied from 5.8 to 7.3 m^2/yr
retardation coefficient (R): 1.4
decay coefficient (k): 0.13 yr^{-1}($T_{1/2}$ = 5.33 years)
concentration of TCE in ground water at the downgradient edge of source (C_o): determined based on individual site data; ranged from 127 to 3,580 ug/L.

Input parameters with explanation:

Solute simulated: TCE

Size of disposal area: determined based on individual site data, values listed in individual simulations.

Duration of source term: 1945 to 2045; the source term persists due to continued leaching from the disposal area and continued dissolution from possible residual DNAPL drops and globs in the fluvial deposits. Site evidence suggests the source has persisted to the present (1998); duration into the future is unknown. Simulations considered here assume a duration of 100 years. Laboratory experiments, mathematical models, and field observation suggest ground-water contamination problems will exist at most chlorinated solvent waste disposal facilities for decades to centuries (Cohen and Mercer, 1993; Pankow and Cherry, 1996).

average ground-water velocity (V_x): $= \frac{K \times \left(\frac{dh}{dl}\right)}{n} = 7.3\text{m/yr}$

where;

horizontal hydraulic conductivity (K): 1.5 m/day (5 ft/day), estimate of hydraulic conductivity of the fluvial deposits from USGS aquifer test (Carmichael and others, 1997)

horizontal hydraulic gradient (dh/dl): 0.0033, estimated from ground-water elevation contours of the lower fluvial deposits measured on 4/96 as show on BRAC Team Update figure (EnSafe, Dwg Name: 126.P01, Dwg Date 06-25-96)

porosity (n): 0.25, effective porosity value used in MODPATH simulations (Robinson and others, 1997)

longitudinal dispersion coefficient (D_x): $= \alpha_L * V_x$

where;

longitudinal dispersivity coefficient (α_L): estimated from regression data (Gelhar and others, 1985) based on scale of individual site.

transverse dispersion coefficient (D_y): estimated as $0.1 * D_x$, transverse dispersion typically is estimated as 0.1 to 0.3 times the longitudinal dispersion (EPRI report EN-6531, 1989).

retardation coefficient (R): 1.4, calculated from TOC and bulk density values measured from fluvial deposits samples from Northside AOC. Literature values show "the retardation factor for TCE at sandy sites are generally less than 10, often between 1 and 2.5" (Mackay, 1990; Mehran and others, 1987; Wilson and others, 1981) from Pankow and Cherry (1996).

decay coefficient (k): 0.13 yr^{-1}, This value was determined by modeling the change in observed concentration of TCE between wells 11LF (North edge of apron source area) and downgradient well 10LF. Degradation rates for TCE from several recent studies reported in the proceedings "Symposium on Natural Attenuation of Chlorinated Organics in Ground Water" (September, 1996) range from 7.3 to 0.16 yr^{-1} (EPA/540/R-96/509). Lucius and others (1993) report a range from 0.77 to 0.15 yr^{-1} as calculated from half-lifes in ground water of 0.89 to 4.5 years.

concentration of TCE in ground water at the downgradient edge of source (C_o): determined based on individual site data; values listed in individual simulations (data from sampling reports, EnSafe).

Attachment 2

Simulation Descriptions and Model Outputs

Solute transport simulation at NSAM Northside AOC using a 2-D analytical solution

Follow-up simulations from Oct BRAC meeting

1) TCE transport simulation from north edge of apron area. Assume well 11LF (127 ug/L) is representative of source area with well 10LF (16 ug/L) as an observation point downgradient along centerline of flow. If all input parameters except decay coefficient (k) are known, what k results in the observed concentrations at well 10LF?

Assuming:

$v = 7.3$ m/yr

$\alpha_L = 10$ m; based on scale of transport

$D_x = 10 \text{ m} * 7.3 \text{ m/yr} = 73 \text{ m}^2/\text{yr}$

$D_y = 0.1 * D_x = 7.3 \text{ m}^2/\text{yr}$

$R = 1.4$; calculated from f_{oc} (TOC) and bulk density values measured from fluvial deposits samples from Northside AOC

Width of source zone is 40 m.

Results:

A decay coefficient (k) of 0.13 yr^{-1} simulates the observed concentration of 16 ug/L at well 10LF.

2) Assuming R and k from the north edge of apron area (11LF to 10LF) scenario is representative of entire Northside AOC:

- What source concentration at the "grassy" area is needed to result in a TCE concentration of 550 ug/L at well 4LF, assuming well 4LF is along the centerline of flow?

Assuming:

$v = 7.3$ m/yr

$\alpha_L = 8$ m; based on scale of transport

$D_x = 8 \text{ m} * 7.3 \text{ m/yr} = 58 \text{m}^2/\text{yr}$

$D_y = 0.1 * D_x = 5.8 \text{ m}^2/\text{yr}$

$R = 1.4$

$k = 0.13 \text{ yr}^{-1}$

Width of source zone is 30 m (from width of "grassy" area).

Results:

A starting concentration in the grassy area of 3,580 ug/L is needed to simulate 550 ug/L at well 4LF

3) If N-6 is simulated as source area, what does expected TCE plume look like?

Assuming:

$v = 7.3$ m/yr

$\alpha_L = 10$ m; based on scale of transport

$D_x = 10 \text{ m} * 7.3 \text{ m/yr} = 73 \text{ m}^2/\text{yr}$

$D_y = 0.1 * D_x = 7.3 \text{ m}^2/\text{yr}$

$R = 1.4$

$k = 0.13 \text{ yr}^{-1}$

Width of source zone is 20 m (from L. Hughes map in AOC A report).

Concentration at source zone is 820 ug/L (from table in AOC A report).

Results:

The 5 ug/L contour extends approximately 205 meters from the source area.

4) Examine migration of plumes through time; project until all concentrations are below MCL.

Assuming sources began at 1945 and will last as subsurface sources until 2045 (100 years duration).

- Apron area.
- "Grassy" area.
- N-6 hanger.

Results:

- Source mass and concentrations effect the time for a plume to reach steady-state and the time for plume to decay.

- Depending on when releases occurred and the duration of subsurface sources, current plumes at the Northside AOC may or may not presently be at steady state.

- Duration of subsurface source will be a major factor in determining duration of the plume.

- Maximum plume extents ranged from about 190 to 340 meters.

Summary:

- All input parameters used are within expected ranges.

- Retardation and decay coefficients used are towards the conservative end of expected ranges.

- Simulated plumes agree with existing work and data.

Solute transport
Follow-up simulations

At NSAM Northside AOC
Using a 2-D analytical model

Site background

- Northside AOC
- Primary contaminant is TCE
- Period of operation - 1945 to 1995
- Transport away from the site is assumed to occur in the fluvial deposits

Simulations were run using MYGRT, a 2-D analytical model developed by the Electric Power Research Institute

MYGRT model assumptions

- Ground water velocity is constant
- Aquifer properties are constant
- Dispersion can be described by Fick's Law
- Linear equilibrium sorption
- Interactions with other solutes are not modeled
- First order kinetics describe solute transformation or decay

Follow-up simulations

- 1. North edge of apron area as source
- 2. Grassy area source concentration estimate
- 3. N-6 area plume simulation
- 4. Evolution of plumes through time

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Input parameters

- Groundwater hydraulic data (conductivity, gradient, porosity, and velocity) are reasonably well defined.
- Dispersion parameters estimated based on scale of transport.

Input parameters - continued

- Retardation factor of 1.4 is estimated based on measured TOC and bulk density value.
- Decay coefficient (λ) is not known, however, typically lab values range from 0.15 to 0.77 yr^{-1} ($T_{1/2}$ = 4.6 to 1 years); field values have been reported to range from 0.16 to 7.3 yr^{-1} ($T_{1/2}$ = 4.3 to 0.09 years).

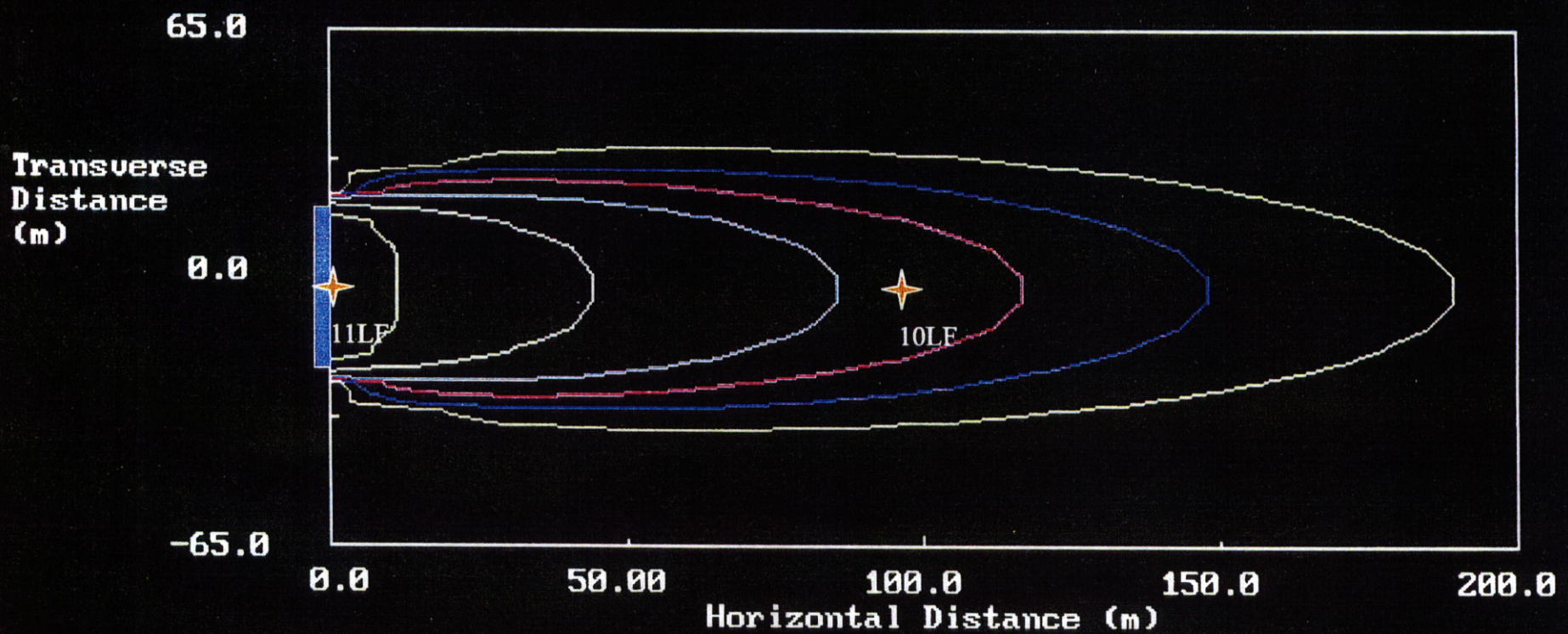
1. North edge of apron area

- Assume well 11LF (127 ug/L) is source area
- Well 10LF (16 ug/L) is observation point
- Assume all parameters except λ are known reasonably well
- Estimate λ to match observation well

$$\lambda = 0.13\ yr^{-1}\ (T_{1/2} = 5.3\ yr)$$

- Simulates TCE concentration at well 10LF of 16 ug/L which matches observed concentrations.
- Rate is at the low end of the range of decay rates from laboratory and field sites and therefore is towards the conservative side.

#1: North edge of apron area



Time = 1997.00 years
Solute = TCE
Press <enter> to continue.

–	500.00 (ug/L)	*	20.00 (ug/L)
–	200.00 (ug/L)	*	10.00 (ug/L)
*	100.00 (ug/L)	*	5.00 (ug/L)
*	50.00 (ug/L)	*	2.00 (ug/L)

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#2. Grassy area source concentration

- Assuming R and λ from the north edge of apron area is representative of entire Northside AOC.

- What source area concentration at the "grassy area" will result in concentration of 550 ug/L at well 4LF?

#2: Input parameters

Co = ??

Dx = 58 m^2/yr

Dy = 5.8 m^2/yr

V = 7.34 m/yr

Rd = 1.4

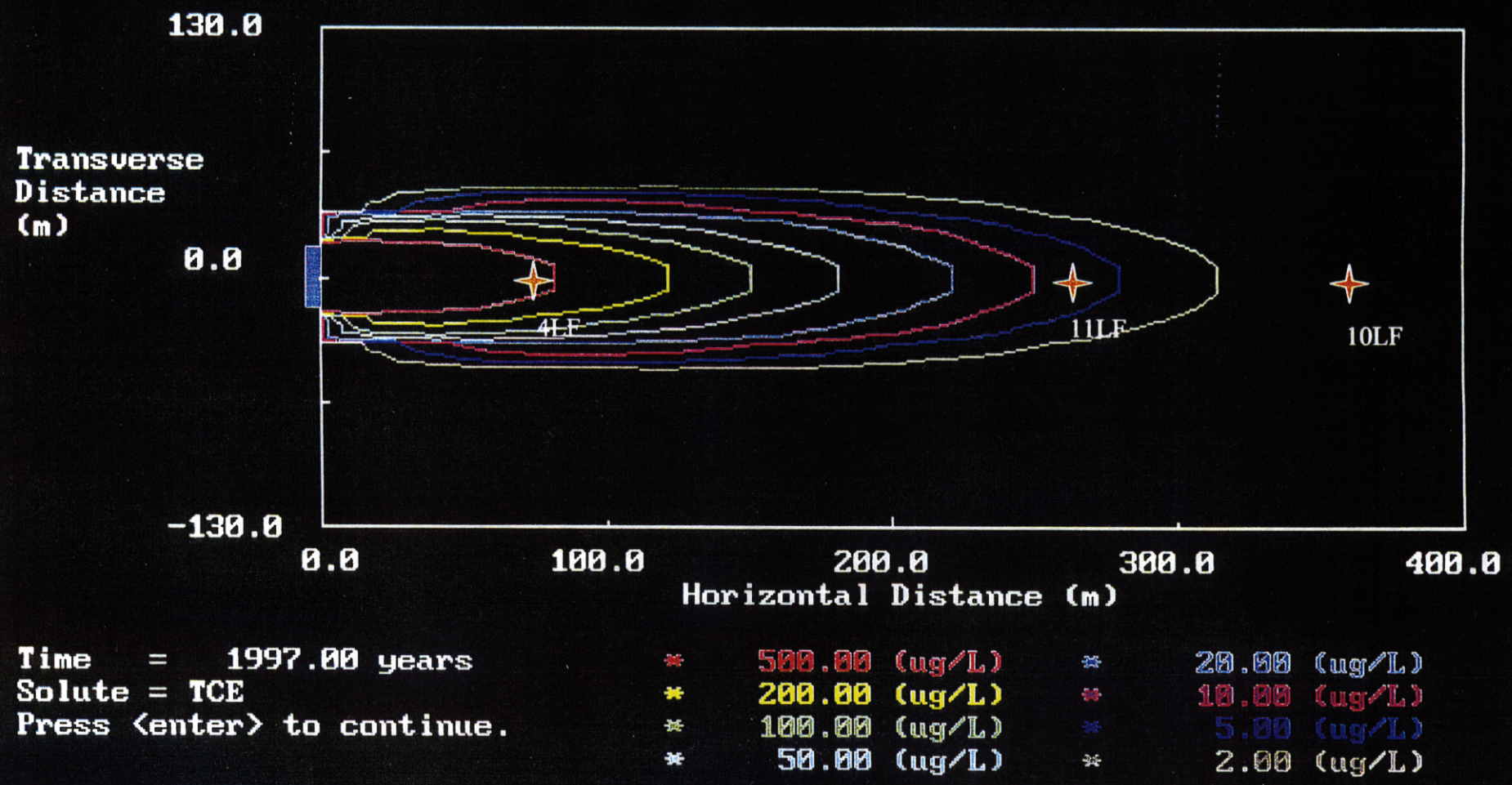
λ = 0.13 yr^{-1} ($T_{1/2}$ = 5.3 yr)

Ton = 1945

Co = 3,580 ug/L

- Simulates TCE concentration at well 4LF of 550 ug/L which matches observed concentration.
- Concentrations observed at wells 11LF and 10LF are higher than simulated from this "grassy area" source concentration supporting the concept of the north edge of apron area as additional source area.

#2: "Grassy area" source



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#3. N-6 source area

- Assume concentration at source area is 820 ug/L
- What is expected extent of plume?

#3: Input parameters

Co = 820 ug/L

Dx = 73 m^2/yr

Dy = 7.3 m^2/yr

V = 7.34 m/yr

Rd = 1.4

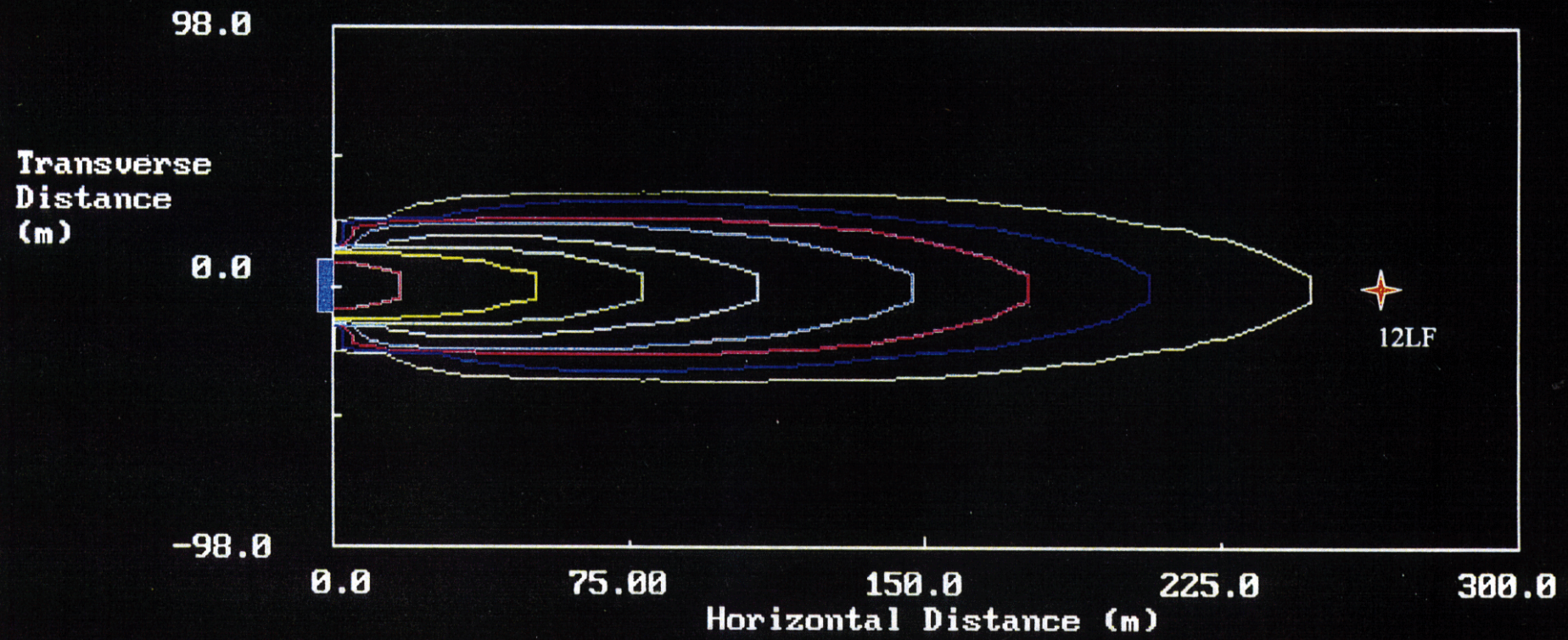
λ = 0.13 yr^{-1}

Ton = 1945

- The 5 ug/L contour extends approximately 205 meters from the source area.

- This closely matches conceptual plume length for middle part of fluvial deposits.

#3: N-6 Source area



Time = 1997.00 years
Solute = TCE
Press <enter> to continue.

*	500.00 (ug/L)	*	20.00 (ug/L)
*	200.00 (ug/L)	*	10.00 (ug/L)
*	100.00 (ug/L)	*	5.00 (ug/L)
*	50.00 (ug/L)	*	2.00 (ug/L)

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#4a-c: Plume evolution with time

- Assume all sources began in 1945
- Assume all sources persist in the subsurface until 2045 (100 years duration)

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#4a: North edge of apron area

Co = 127ug/L

Dx = 73 m2/yr

Dy = 7.3 m2/yr

V = 7.34 m/yr

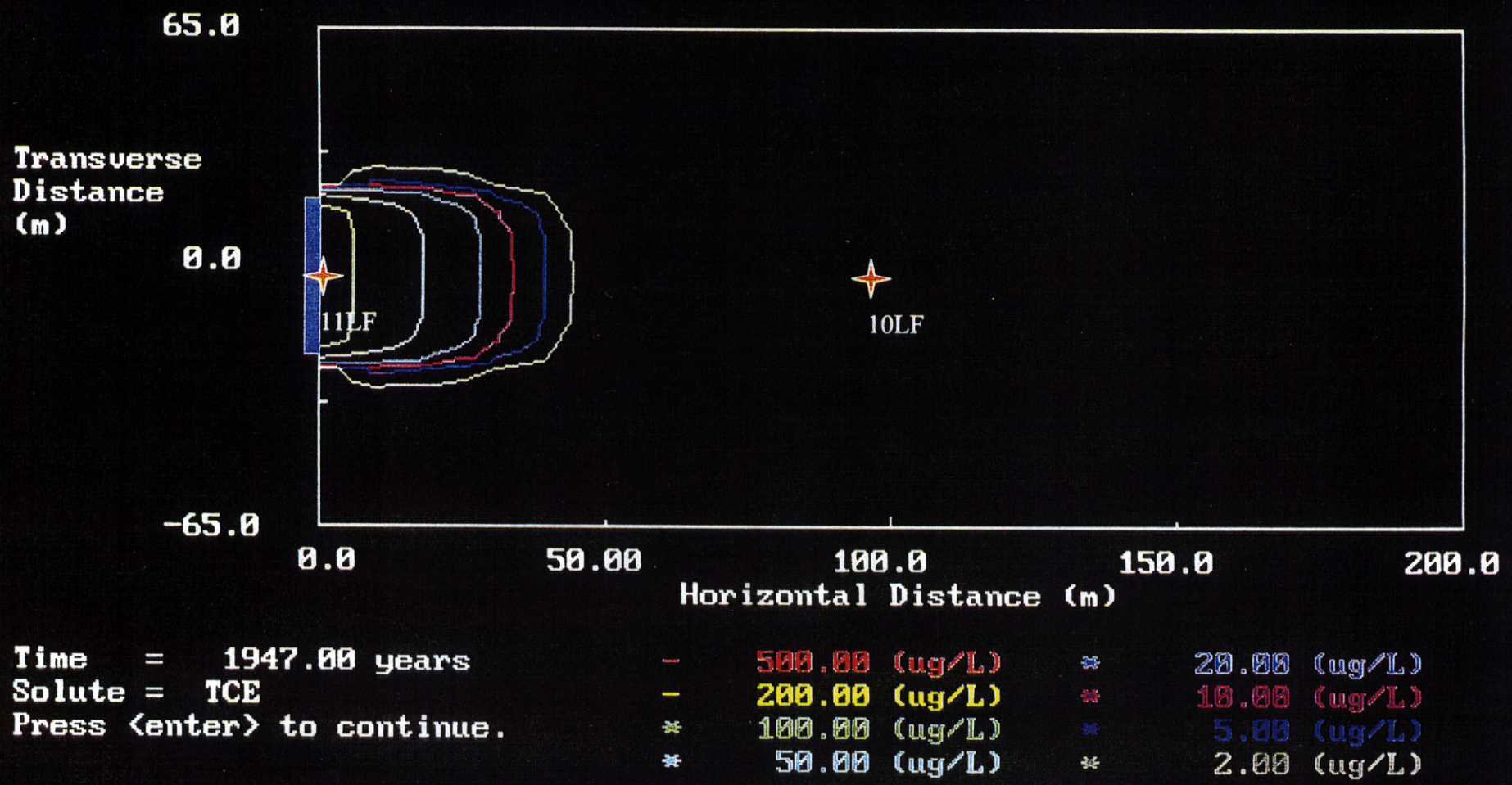
Rd = 1.4

λ = 0.13 yr^{-1} ($T_{1/2}$ = 5.3 yr)

Ton = 1945

Toff = 2045

Run 4a: North edge of apron area, 1947



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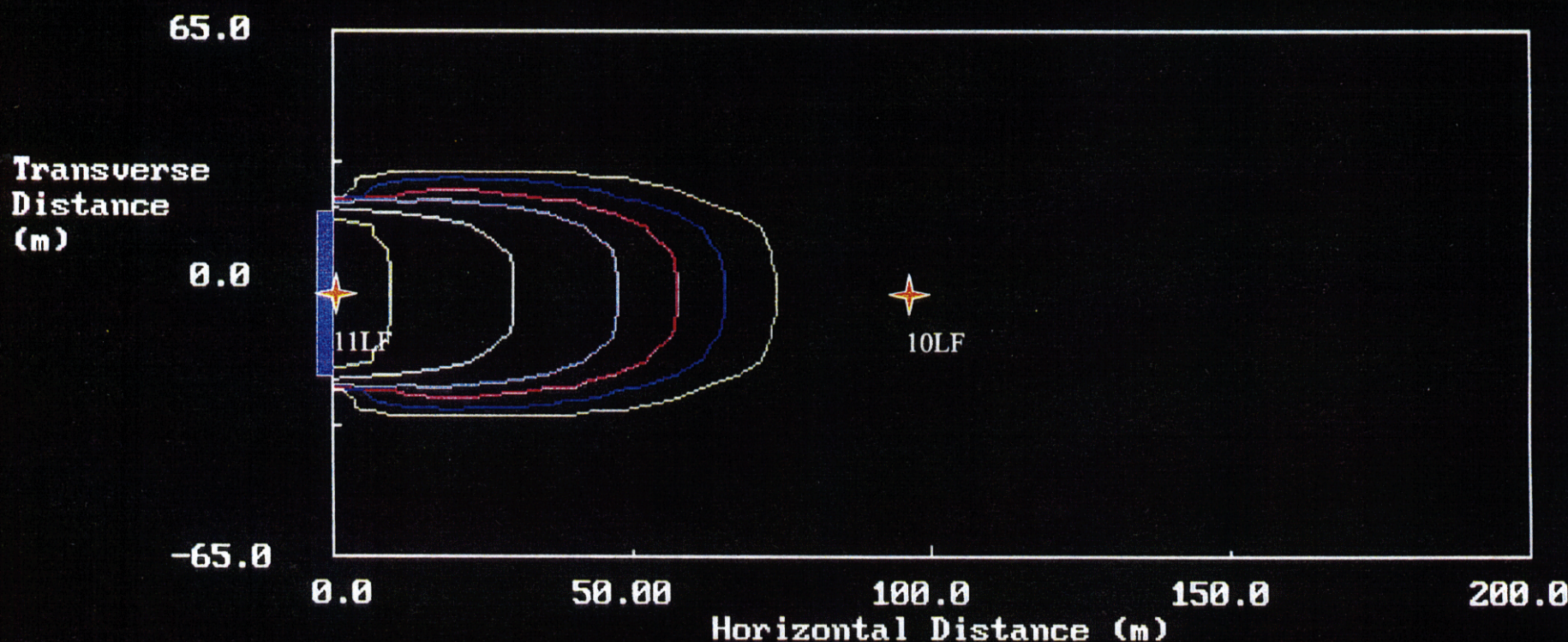
Run 4a: North edge of apron area, 1950



Time = 1950.00 years
Solute = TCE
Press <enter> to continue.

–	500.00 (ug/L)	*	20.00 (ug/L)
–	200.00 (ug/L)	*	10.00 (ug/L)
*	100.00 (ug/L)	*	5.00 (ug/L)
*	50.00 (ug/L)	*	2.00 (ug/L)

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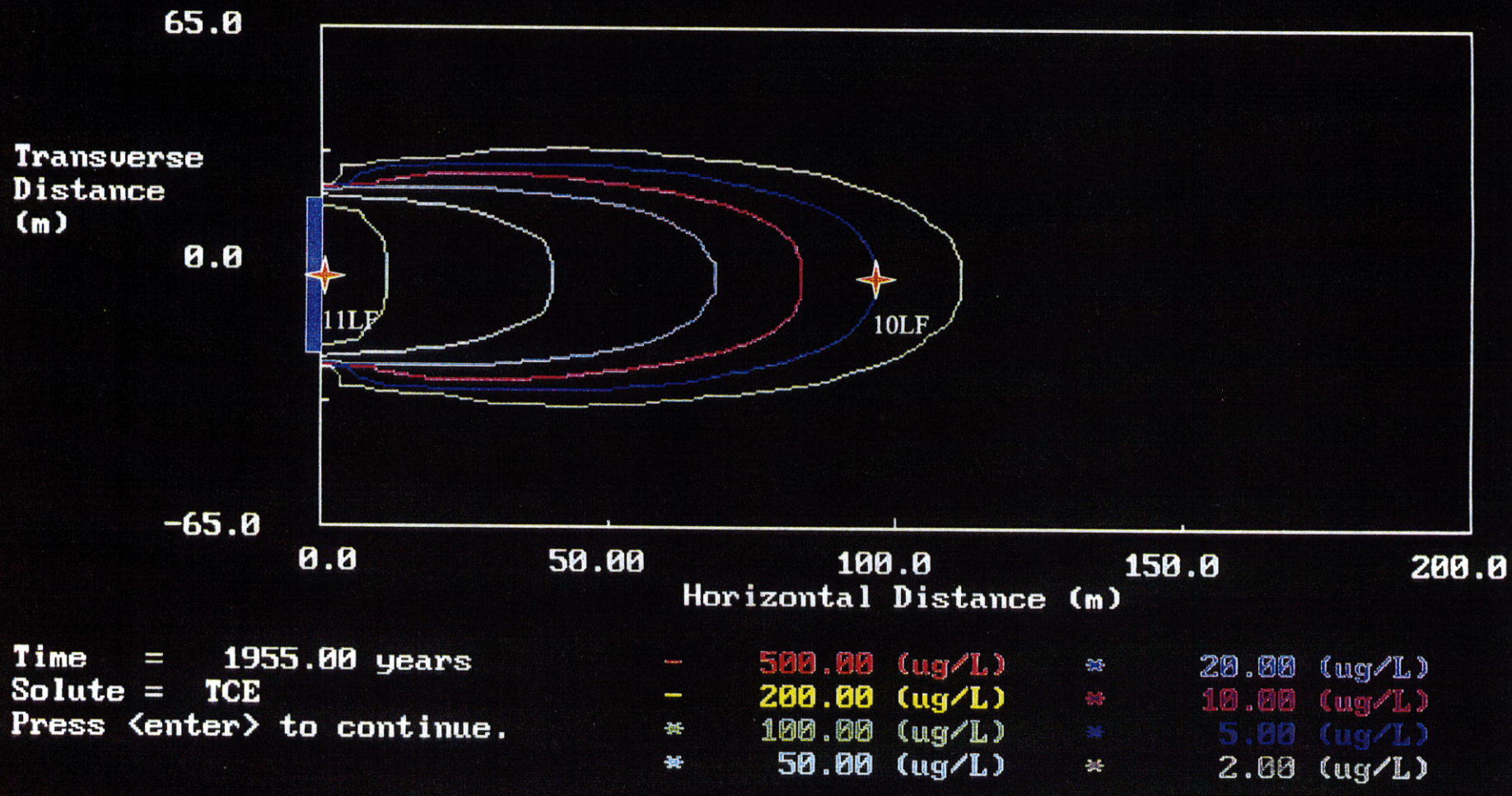
Run 4a: North edge of apron area, 1955



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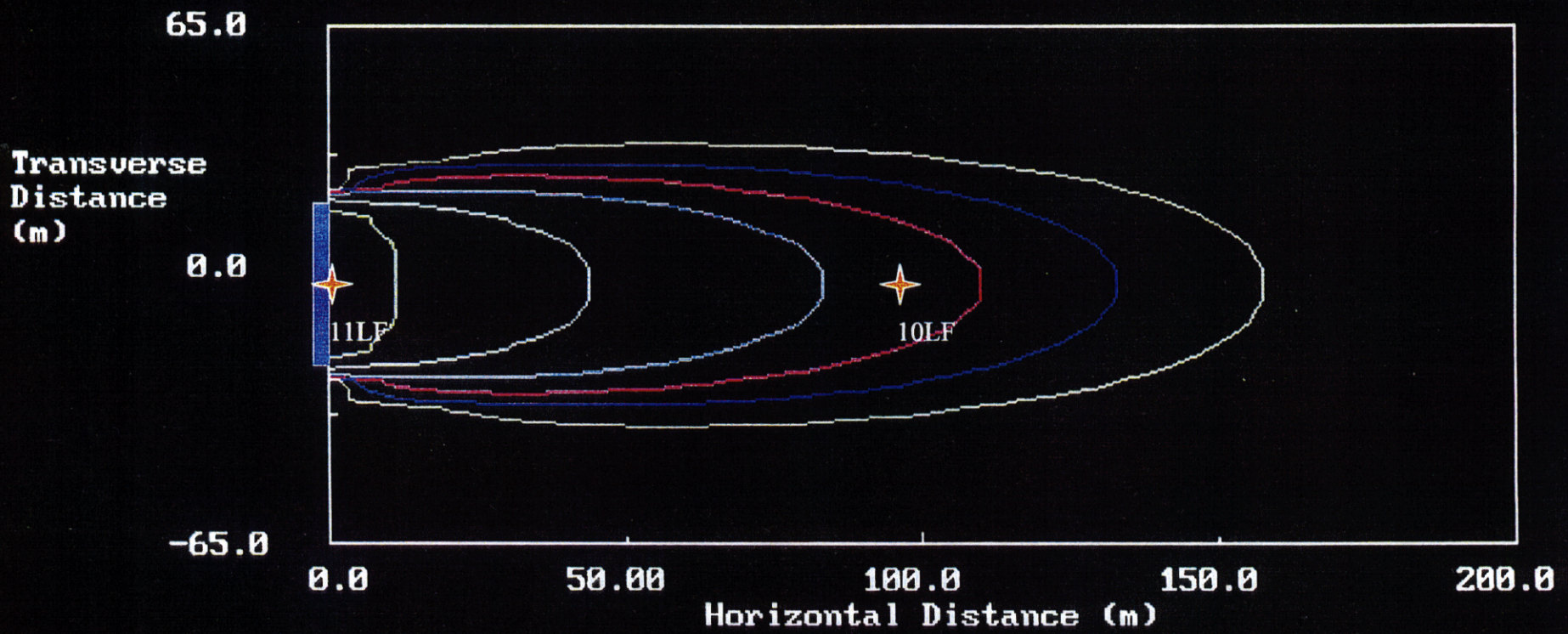
Run 4a: North edge of apron area, 1965



Time = 1965.00 years
Solute = TCE
Press <enter> to continue.

–	500.00 (ug/L)	*	20.00 (ug/L)
–	200.00 (ug/L)	*	10.00 (ug/L)
*	100.00 (ug/L)	*	5.00 (ug/L)
*	50.00 (ug/L)	*	2.00 (ug/L)

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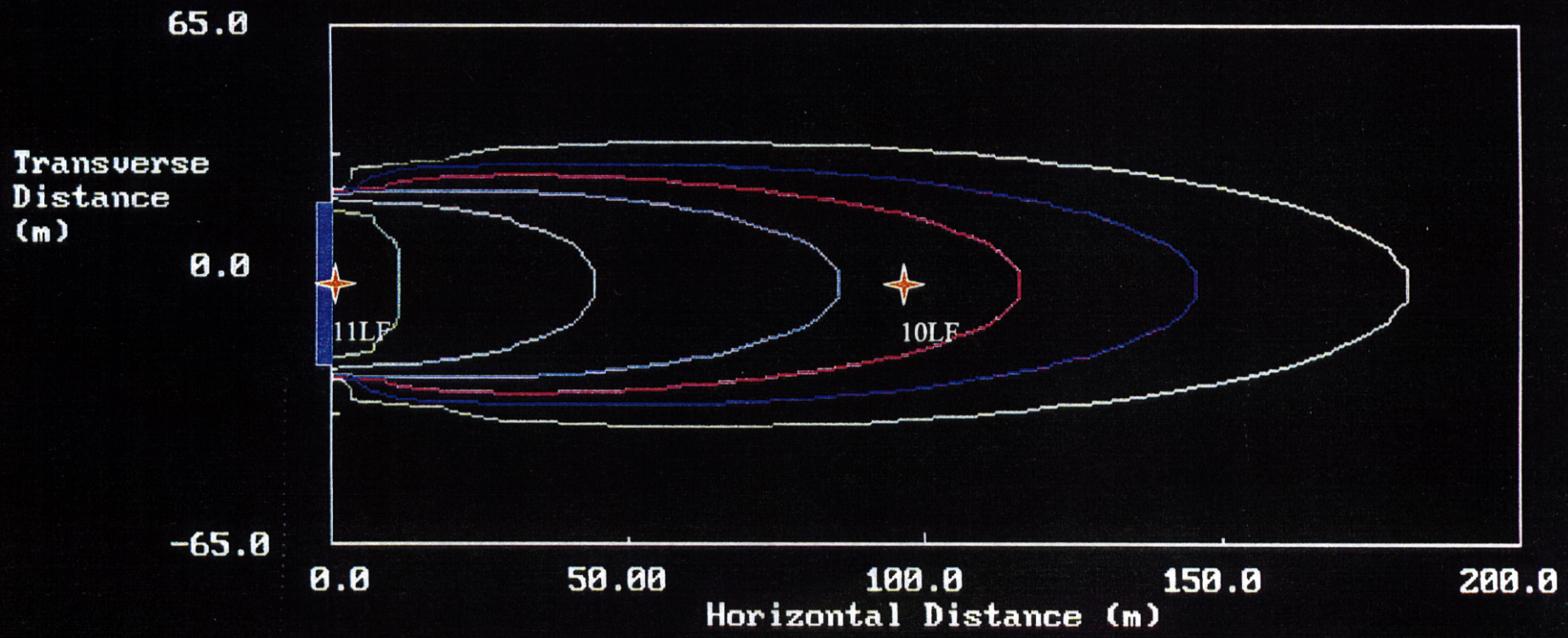
Run 4a: North edge of apron area, 1975



Time = 1975.00 years
Solute = TCE
Press <enter> to continue.

–	500.00 (ug/L)	*	20.00 (ug/L)
–	200.00 (ug/L)	*	10.00 (ug/L)
*	100.00 (ug/L)	*	5.00 (ug/L)
*	50.00 (ug/L)	*	2.00 (ug/L)

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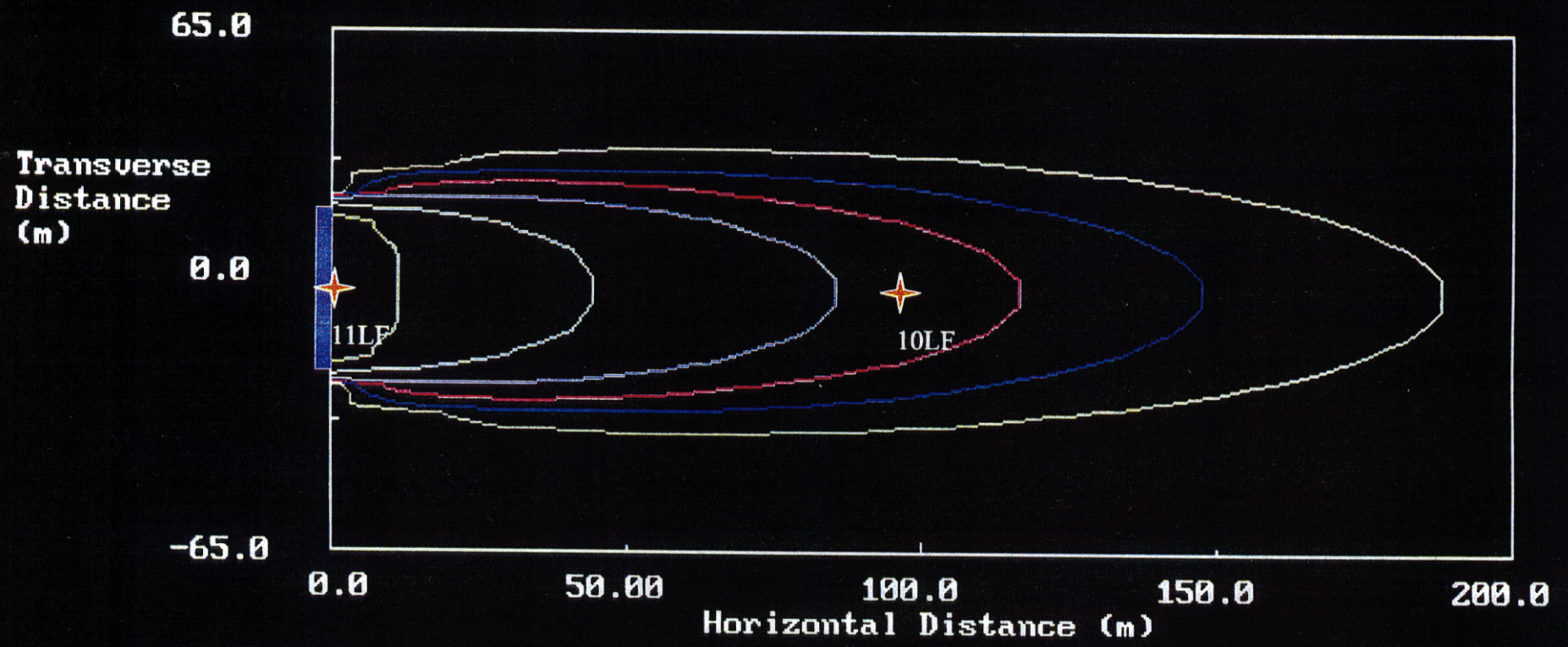
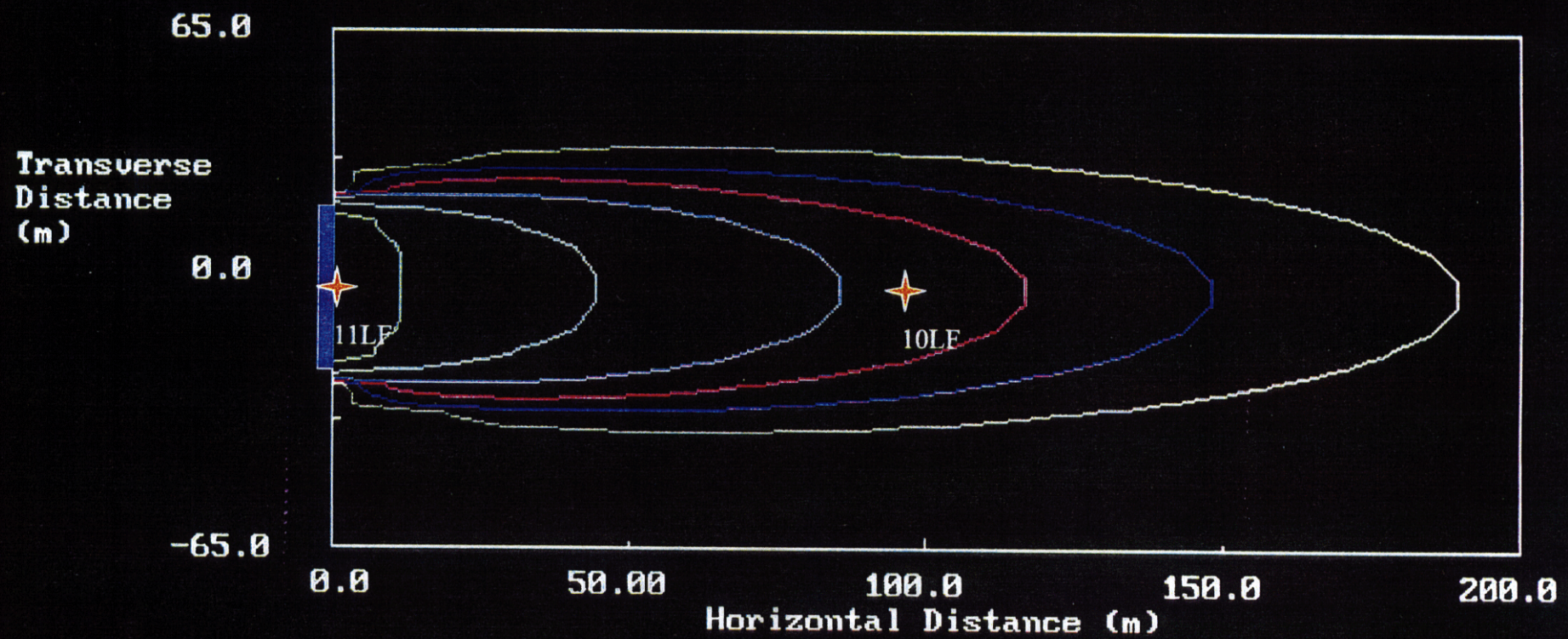
Run 4a: North edge of apron area, 1985



Time = 1985.00 years
Solute = TCE
Press <enter> to continue.

–	500.00 (ug/L)	*	20.00 (ug/L)
–	200.00 (ug/L)	*	10.00 (ug/L)
*	100.00 (ug/L)	*	5.00 (ug/L)
*	50.00 (ug/L)	*	2.00 (ug/L)

Run 4a: North edge of apron area, 1995



Time = 1995.00 years
Solute = TCE
Press <enter> to continue.

–	500.00 (ug/L)	*	20.00 (ug/L)
–	200.00 (ug/L)	*	10.00 (ug/L)
*	100.00 (ug/L)	*	5.00 (ug/L)
*	50.00 (ug/L)	*	2.00 (ug/L)

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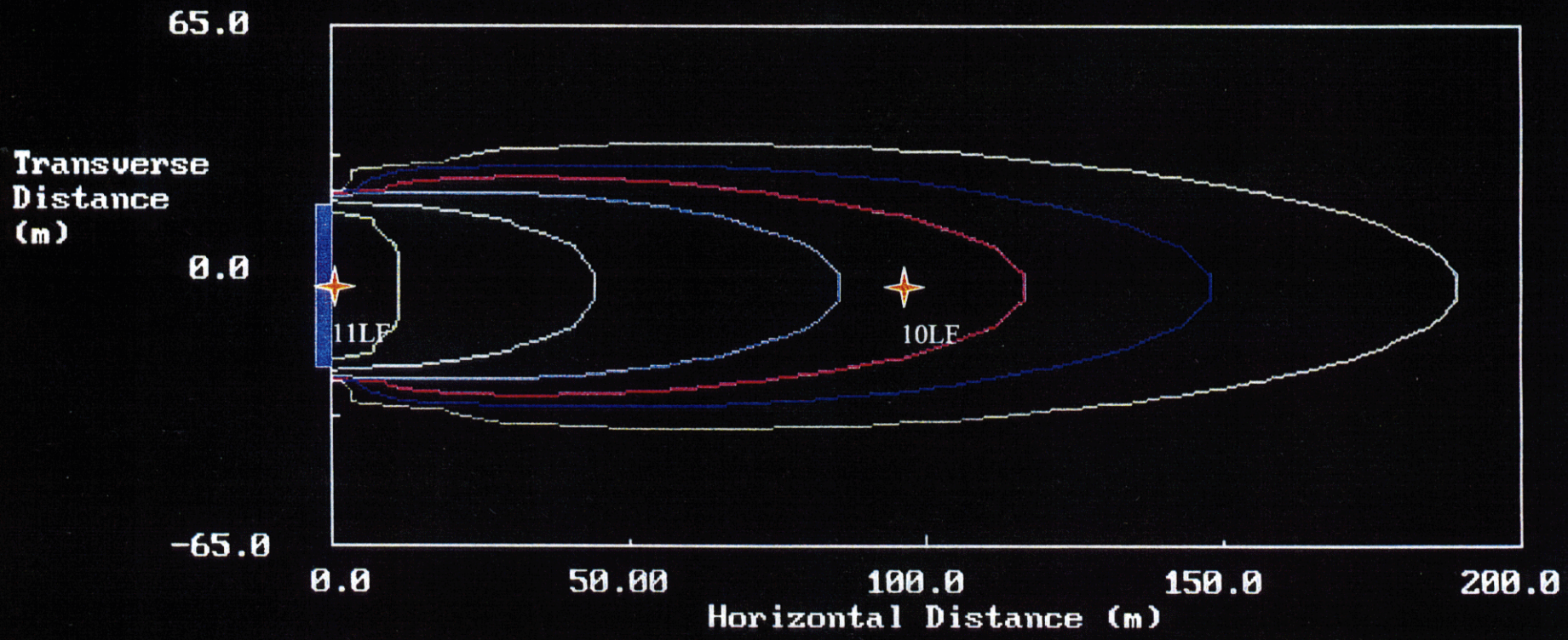
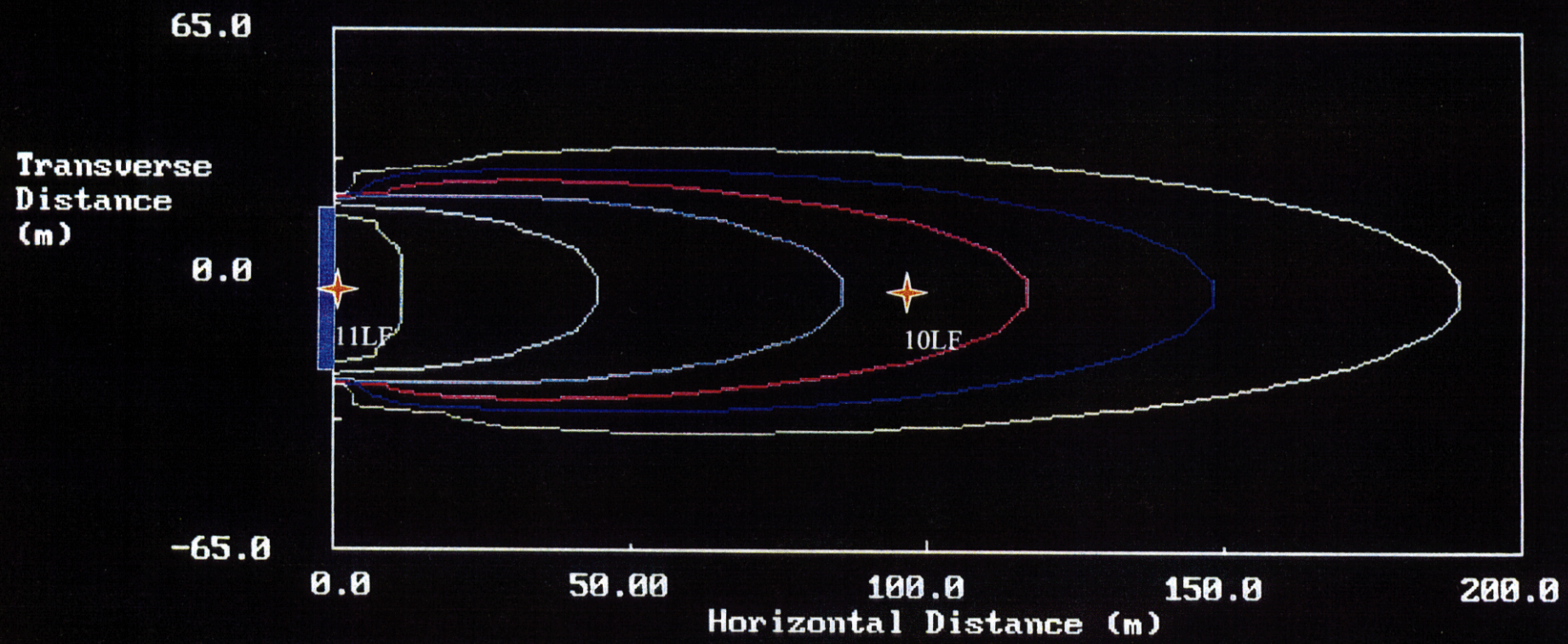
Run 4a: North edge of apron area, 2005



Time = 2005.00 years
Solute = TCE
Press <enter> to continue.

–	500.00 (ug/L)	*	20.00 (ug/L)
–	200.00 (ug/L)	*	10.00 (ug/L)
*	100.00 (ug/L)	*	5.00 (ug/L)
*	50.00 (ug/L)	*	2.00 (ug/L)

Run 4a: North edge of apron area, 2015



Time = 2015.00 years
Solute = TCE
Press <enter> to continue.

–	500.00 (ug/L)	*	20.00 (ug/L)
–	200.00 (ug/L)	*	10.00 (ug/L)
*	100.00 (ug/L)	*	5.00 (ug/L)
*	50.00 (ug/L)	*	2.00 (ug/L)

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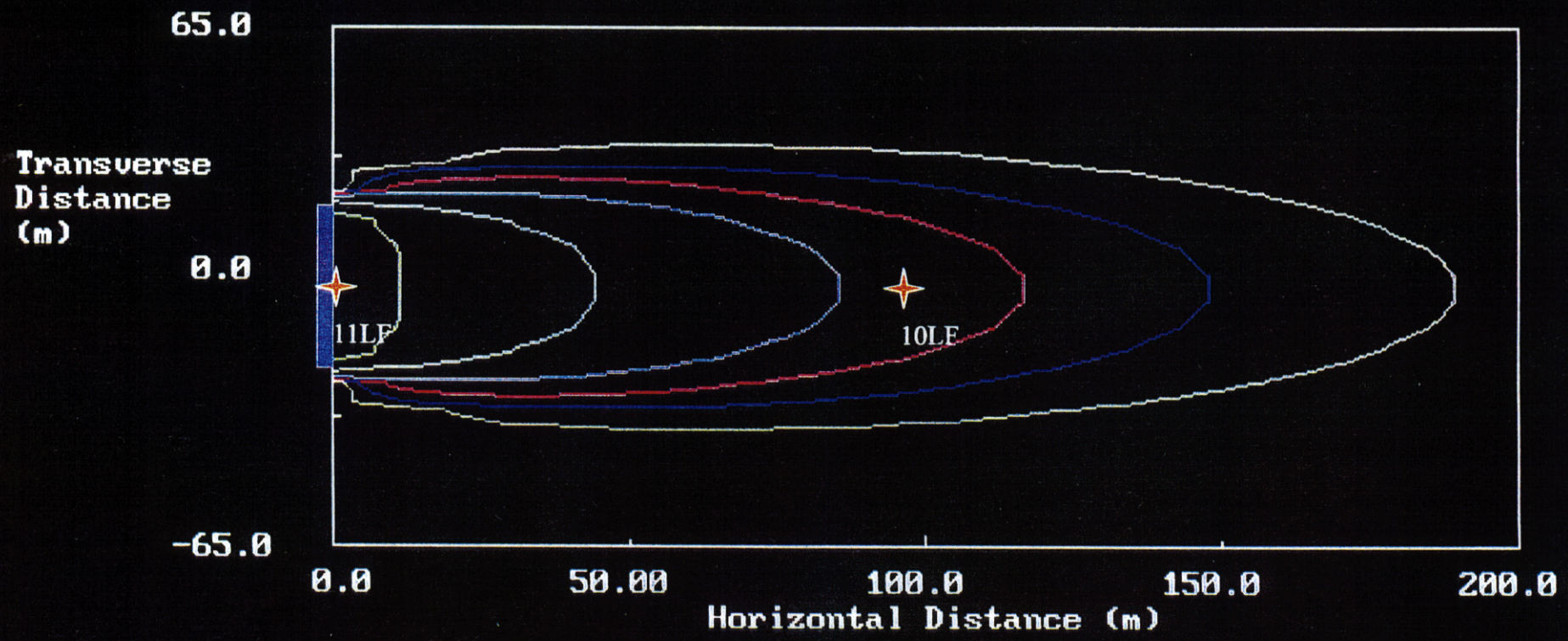
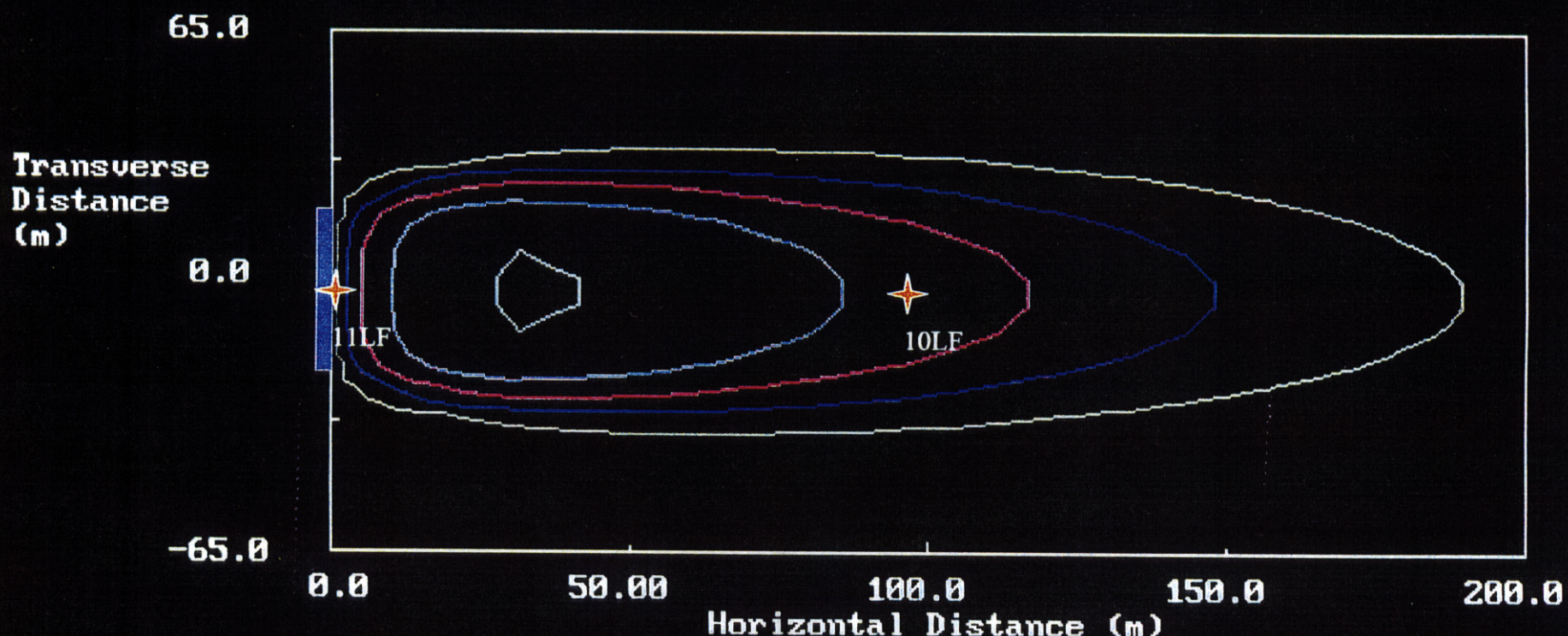
Run 4a: North edge of apron area, 2045



Time = 2045.00 years
Solute = TCE
Press <enter> to continue.

–	500.00 (ug/L)	*	20.00 (ug/L)
–	200.00 (ug/L)	*	10.00 (ug/L)
*	100.00 (ug/L)	*	5.00 (ug/L)
*	50.00 (ug/L)	*	2.00 (ug/L)

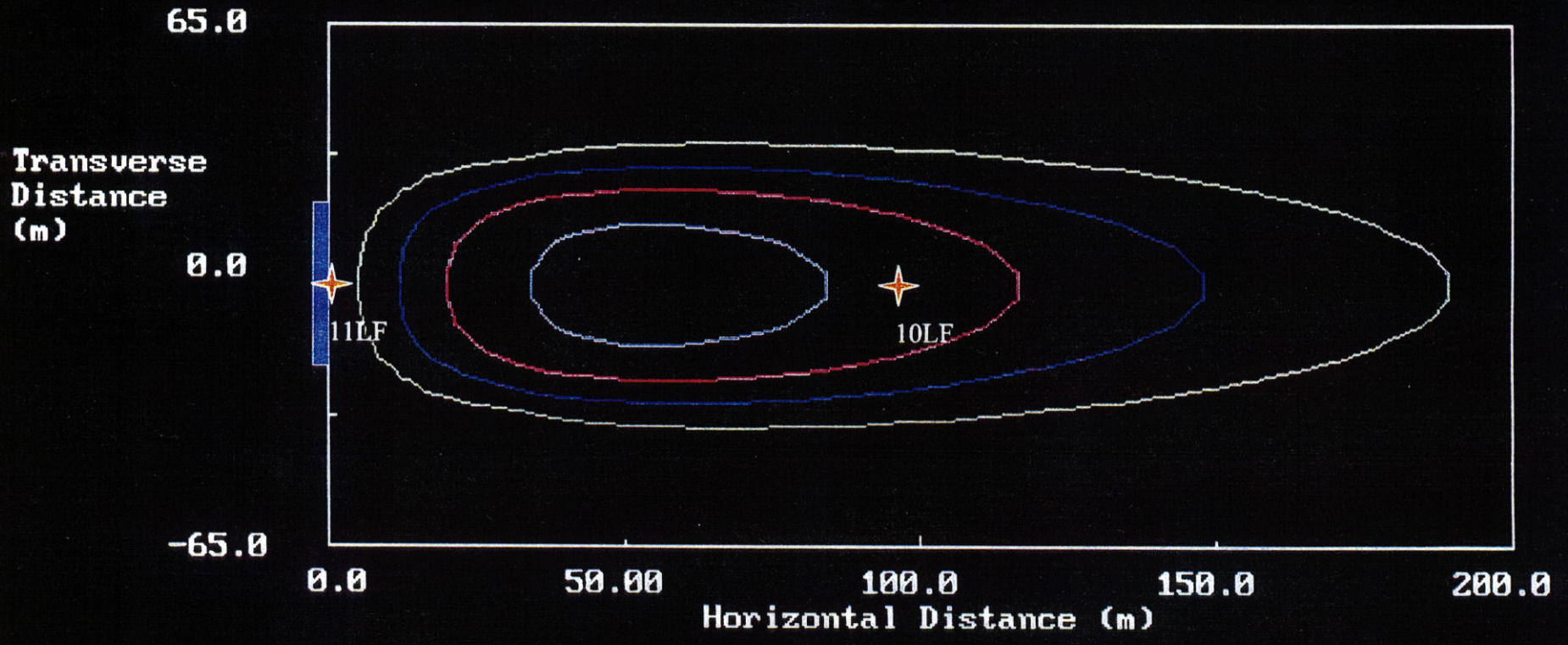
Run 4a: North edge of apron area, 2047



Time = 2047.00 years
Solute = TCE
Press <enter> to continue.

–	500.00 (ug/L)	*	20.00 (ug/L)
–	200.00 (ug/L)	*	10.00 (ug/L)
–	100.00 (ug/L)	*	5.00 (ug/L)
*	50.00 (ug/L)	*	2.00 (ug/L)

Run 4a: North edge of apron area, 2050



Time = 2050.00 years
Solute = TCE
Press <enter> to continue.

- 500.00 (ug/L)
- 200.00 (ug/L)
- 100.00 (ug/L)
- 50.00 (ug/L)
- 20.00 (ug/L)
- 10.00 (ug/L)
- 5.00 (ug/L)
- 2.00 (ug/L)

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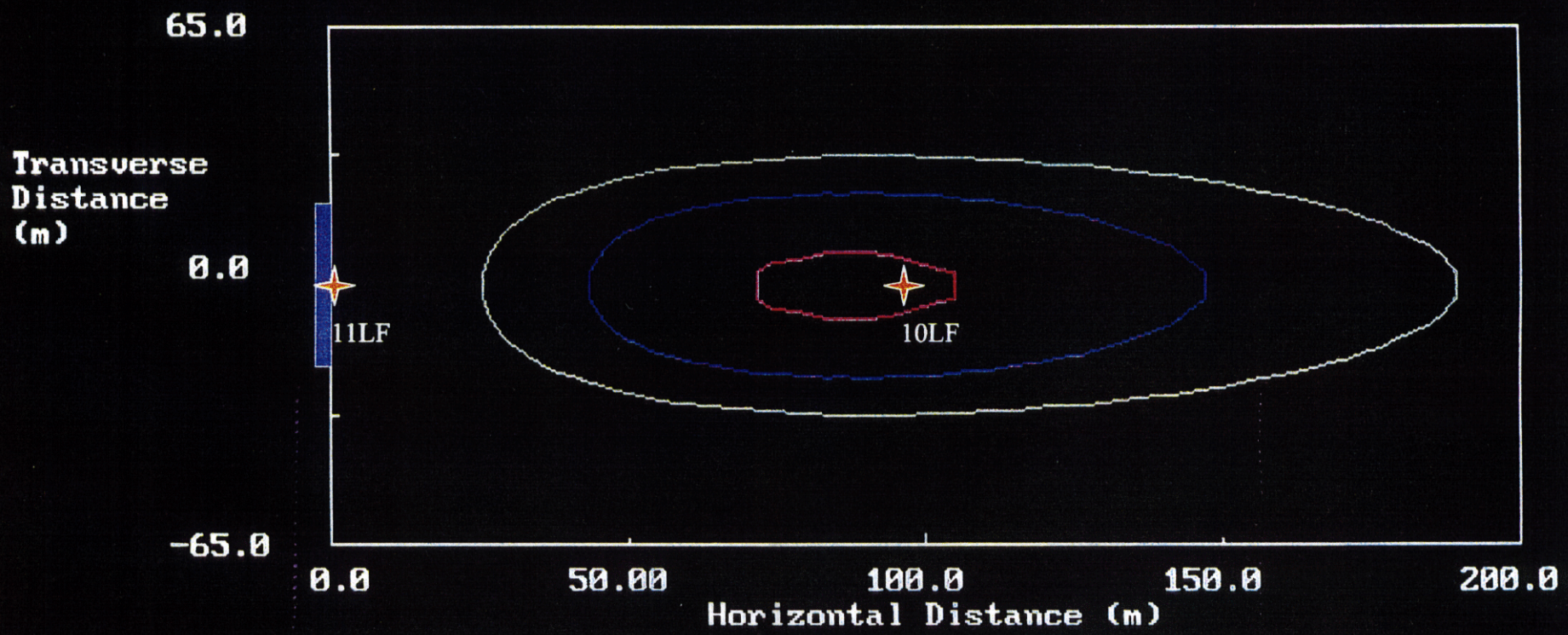
Run 4a: North edge of apron area, 2055

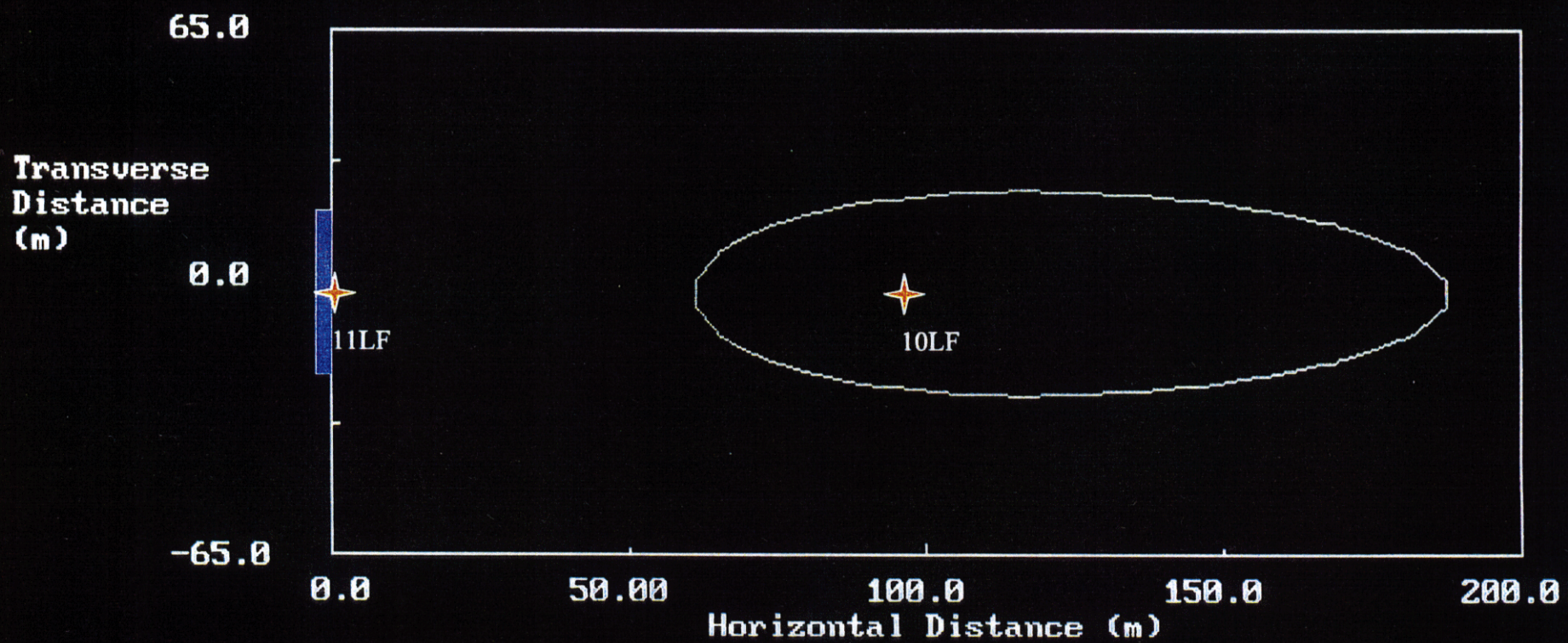


Time = 2055.00 years
Solute = TCE
Press <enter> to continue.

–	500.00 (ug/L)	–	20.00 (ug/L)
–	200.00 (ug/L)	*	10.00 (ug/L)
–	100.00 (ug/L)	*	5.00 (ug/L)
–	50.00 (ug/L)	*	2.00 (ug/L)

170000

Run 4a: North edge of apron area, 2060

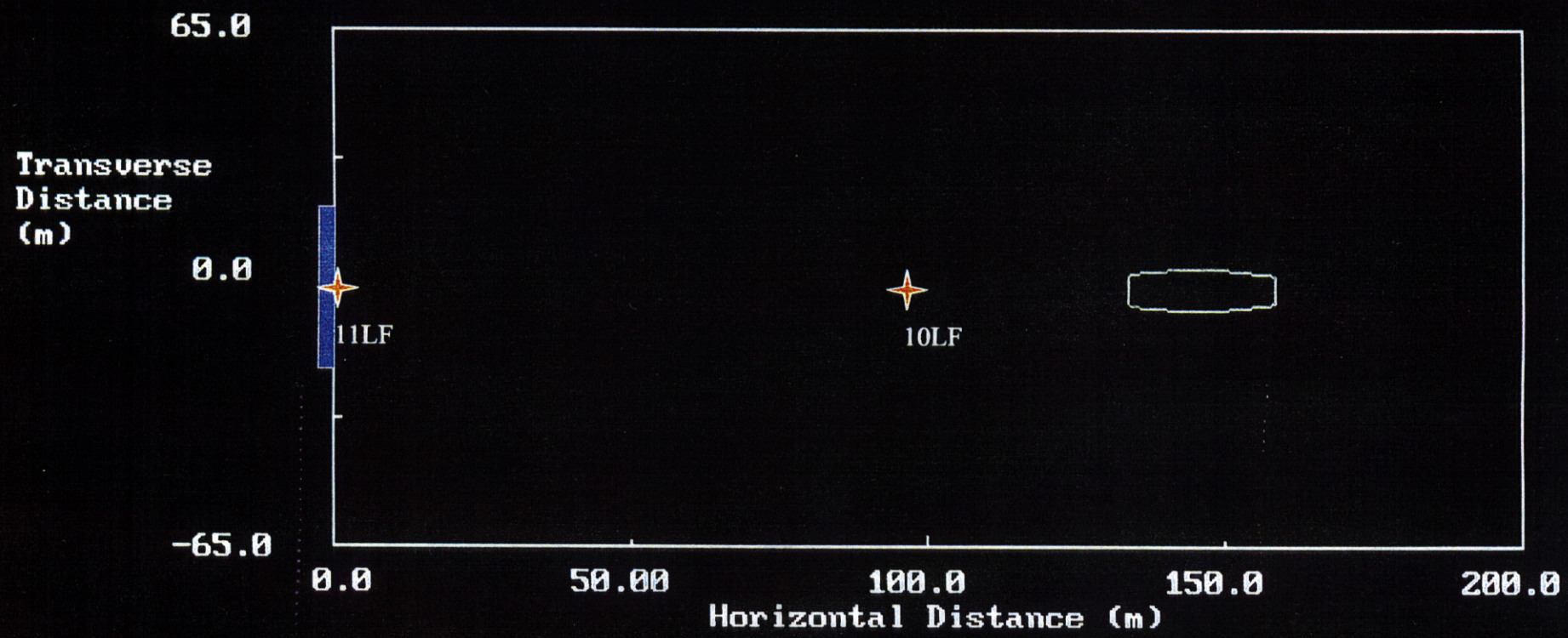


Time = 2060.00 years
Solute = TCE
Press <enter> to continue.

–	500.00 (ug/L)	–	20.00 (ug/L)
–	200.00 (ug/L)	–	10.00 (ug/L)
–	100.00 (ug/L)	–	5.00 (ug/L)
–	50.00 (ug/L)	*	2.00 (ug/L)

000042

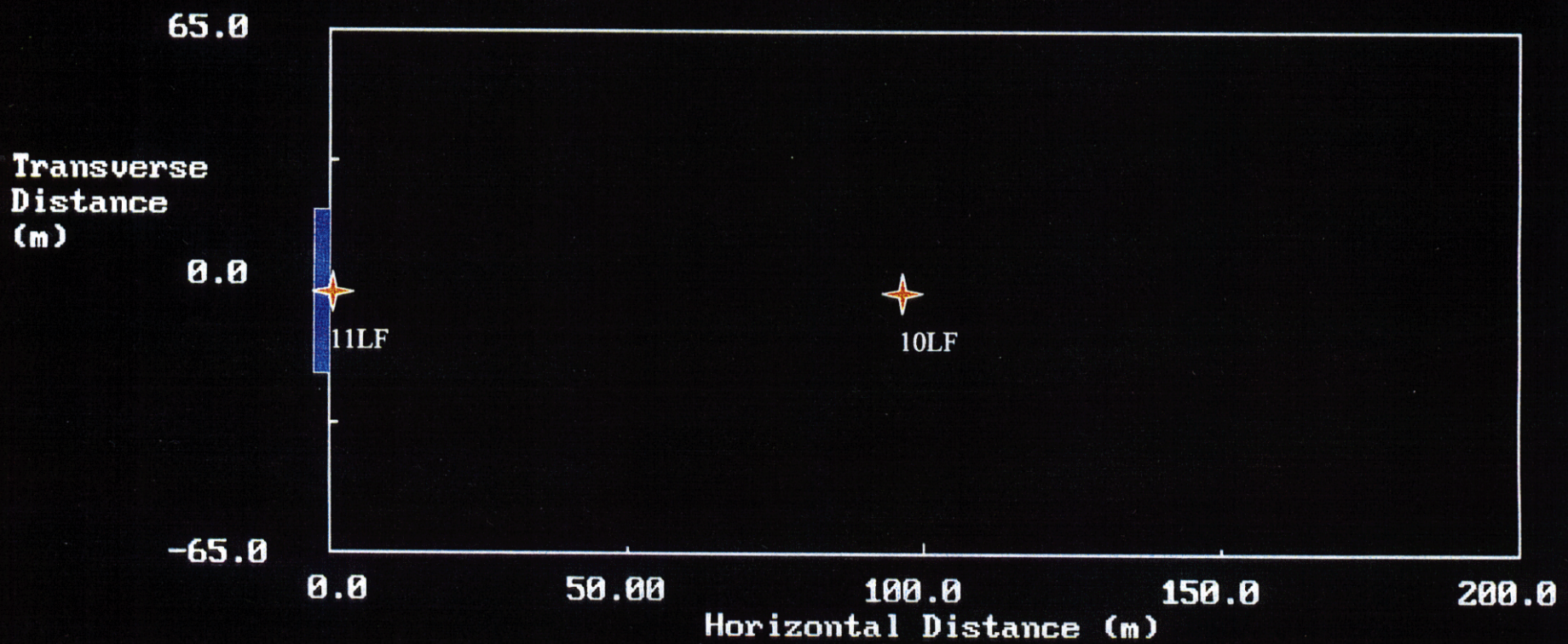
Run 4a: North edge of apron area, 2065



Time = 2065.00 years
Solute = TCE
Press <enter> to continue.

–	500.00 (ug/L)	–	20.00 (ug/L)
–	200.00 (ug/L)	–	10.00 (ug/L)
–	100.00 (ug/L)	–	5.00 (ug/L)
–	50.00 (ug/L)	*	2.00 (ug/L)

Run 4a: North edge of apron area, 2070



Time = 2070.00 years
Solute = TCE
Press <enter> to continue.

- 500.00 (ug/L)
- 200.00 (ug/L)
- 100.00 (ug/L)
- 50.00 (ug/L)
- 20.00 (ug/L)
- 10.00 (ug/L)
- 5.00 (ug/L)
- 2.00 (ug/L)

000244

Results: North edge of apron area

- 5 ug/L contour reaches steady-state in about 45 years.
- Once source is depleted, concentrations decay to below 5 ug/L in about 15 years.

EP6000

#4b: "Grassy area" source

Co = 3580 ug/L

Dx = 58 m2/yr

Dy = 5.8 m2/yr

V = 7.34 m/yr

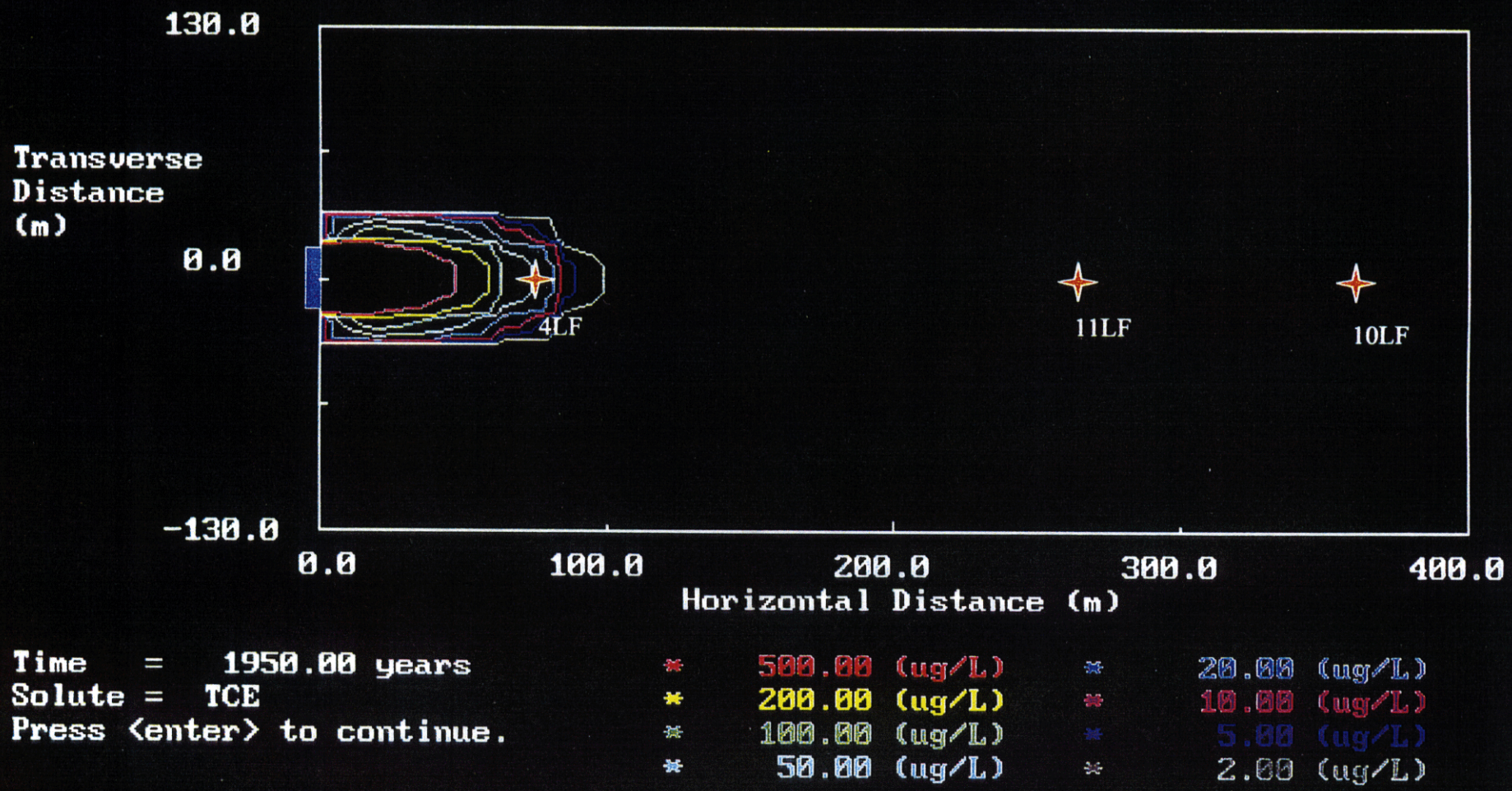
Rd = 1.4

λ = 0.13 yr^{-1} ($T_{1/2}$ = 5.3 yr)

Ton = 1945

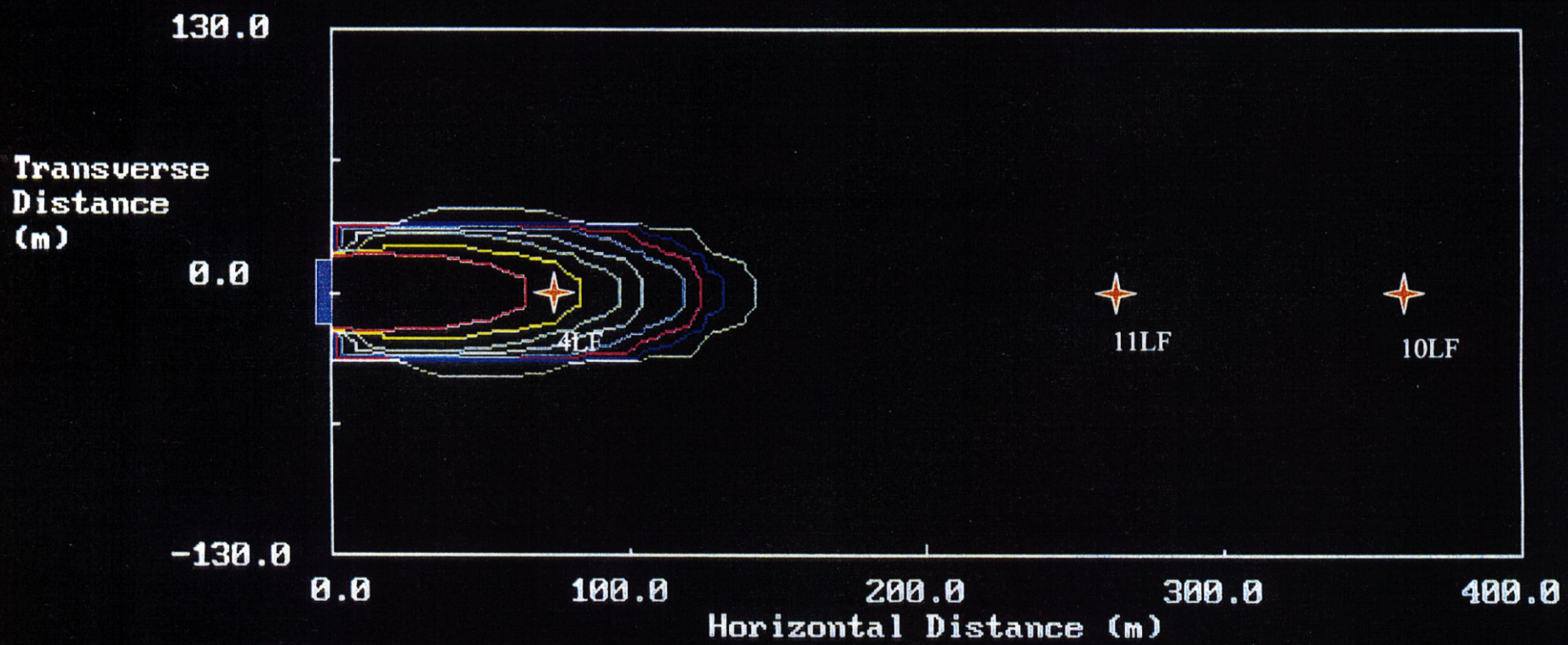
Toff = 2045

Run 4b: "Grassy area" source, 1950



00593CB2Y

Run 4b: "Grassy area" source, 1955

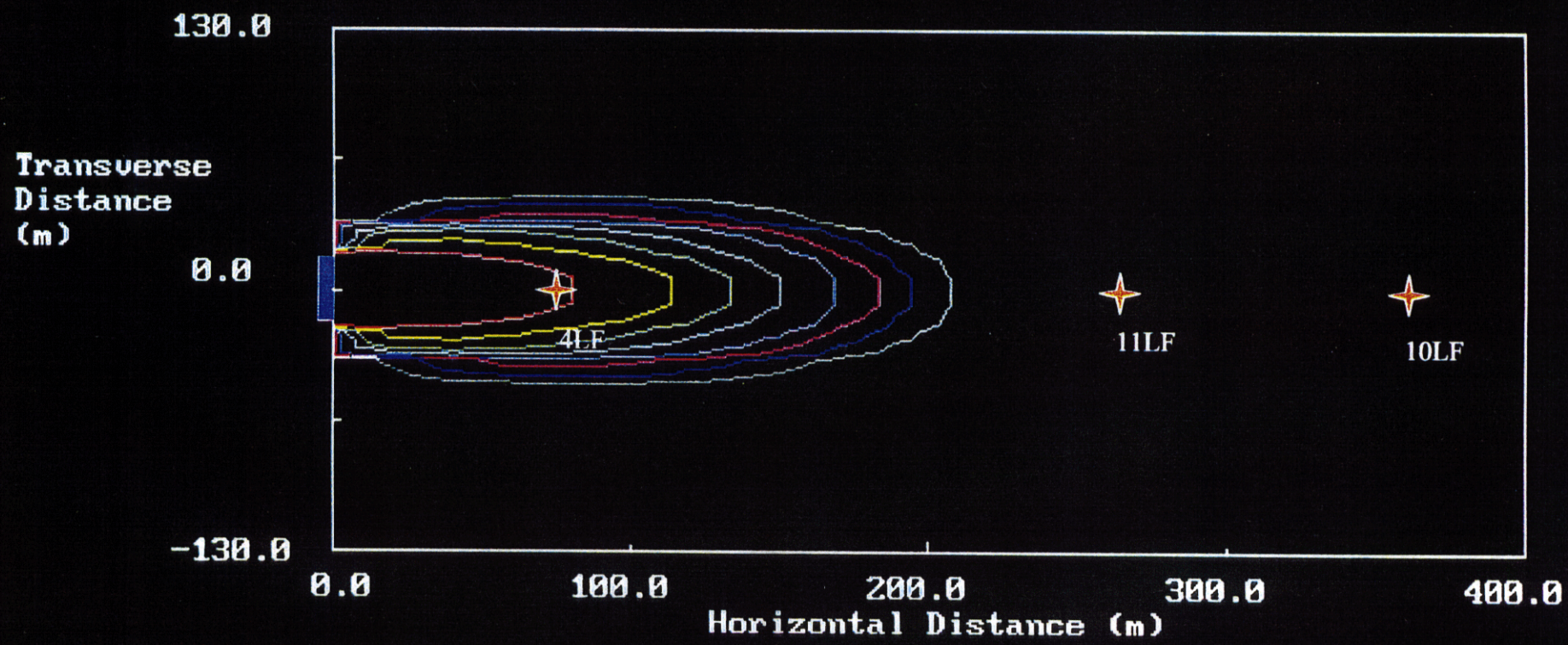


Time = 1955.00 years
Solute = TCE
Press <enter> to continue.

*	500.00 (ug/L)	*	20.00 (ug/L)
*	200.00 (ug/L)	*	10.00 (ug/L)
*	100.00 (ug/L)	*	5.00 (ug/L)
*	50.00 (ug/L)	*	2.00 (ug/L)

870006

Run 4b: "Grassy area" source, 1965

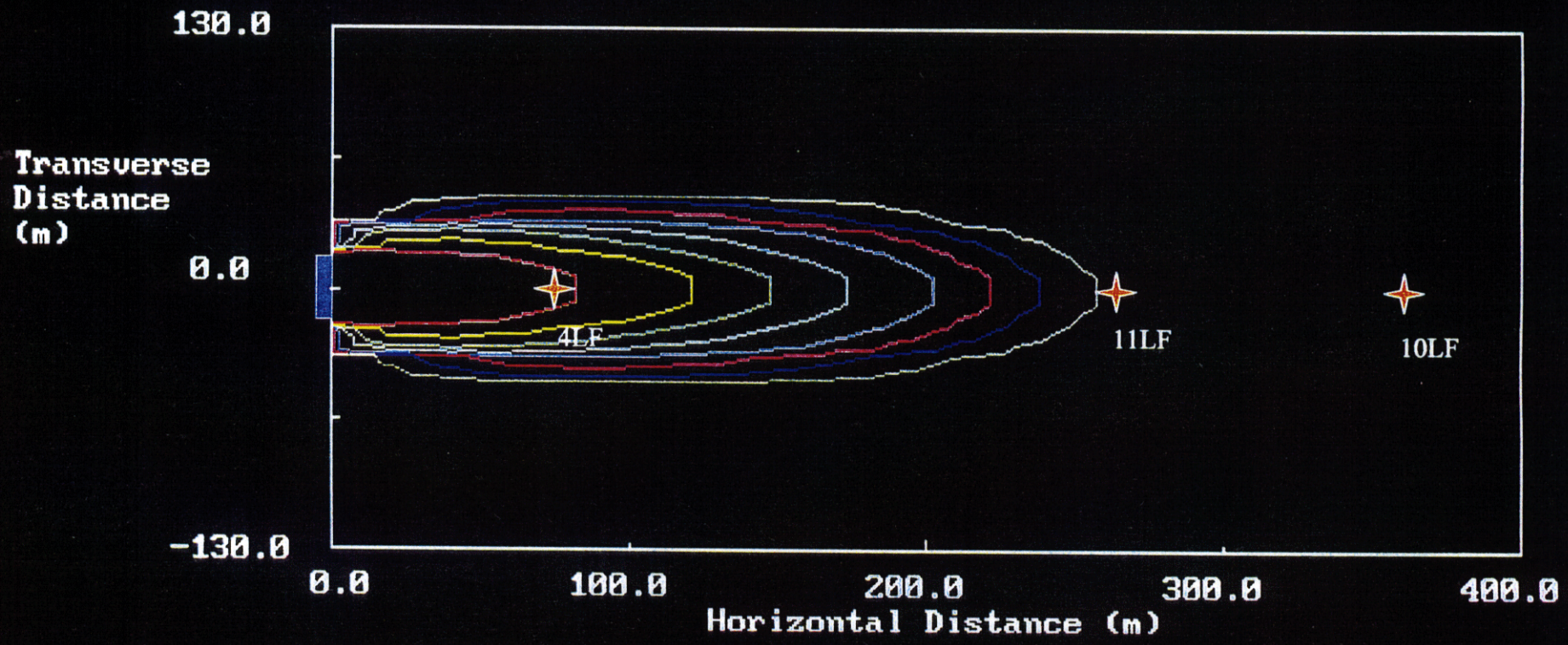


Time = 1965.00 years
Solute = TCE
Press <enter> to continue.

*	500.00 (ug/L)	*	20.00 (ug/L)
*	200.00 (ug/L)	*	10.00 (ug/L)
*	100.00 (ug/L)	*	5.00 (ug/L)
*	50.00 (ug/L)	*	2.00 (ug/L)

670000

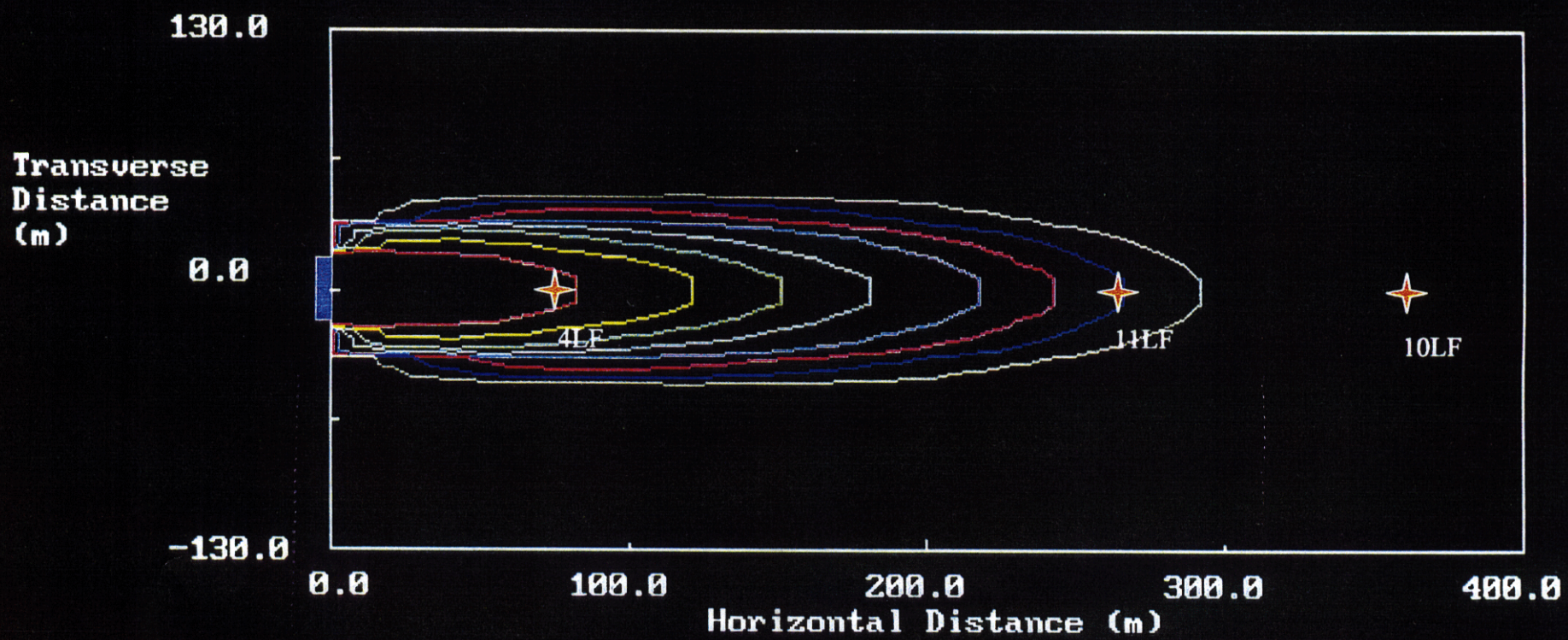
Run 4b: "Grassy area" source, 1975



Time = 1975.00 years
Solute = TCE
Press <enter> to continue.

*	500.00 (ug/L)	*	20.00 (ug/L)
*	200.00 (ug/L)	*	10.00 (ug/L)
*	100.00 (ug/L)	*	5.00 (ug/L)
*	50.00 (ug/L)	*	2.00 (ug/L)

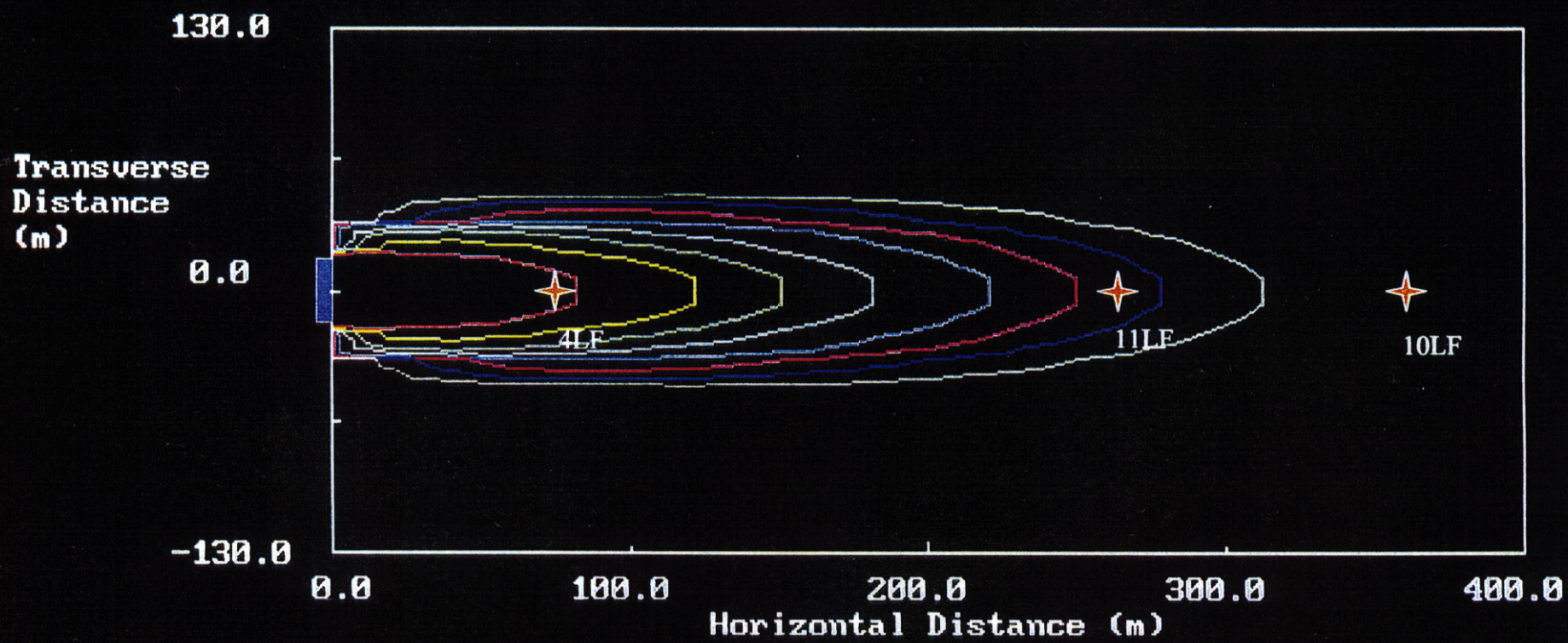
Run 4b: "Grassy area" source, 1985



Time = 1985.00 years
Solute = TCE
Press <enter> to continue.

*	500.00 (ug/L)	*	20.00 (ug/L)
*	200.00 (ug/L)	*	10.00 (ug/L)
*	100.00 (ug/L)	*	5.00 (ug/L)
*	50.00 (ug/L)	*	2.00 (ug/L)

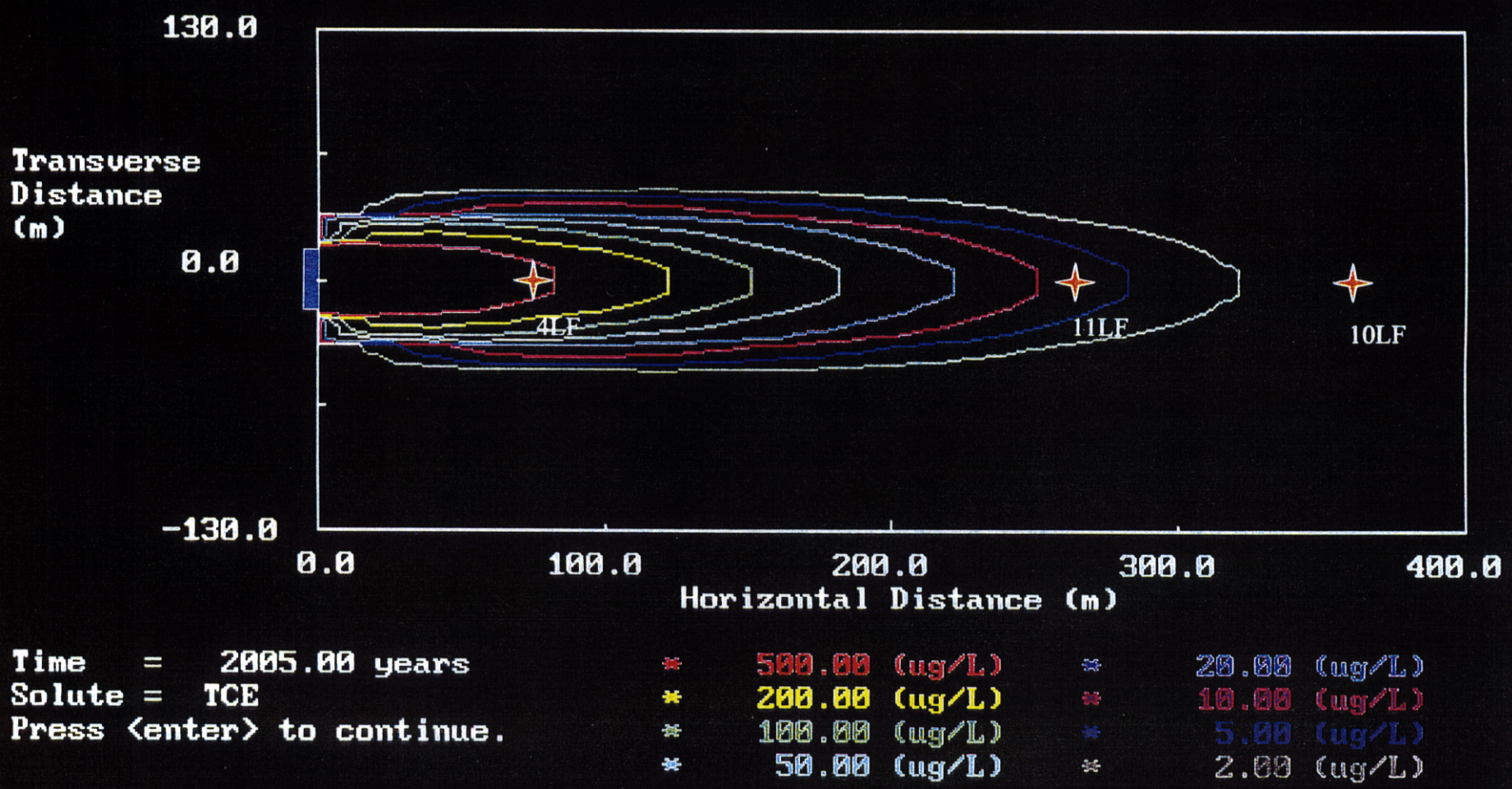
Run 4b: "Grassy area" source, 1995



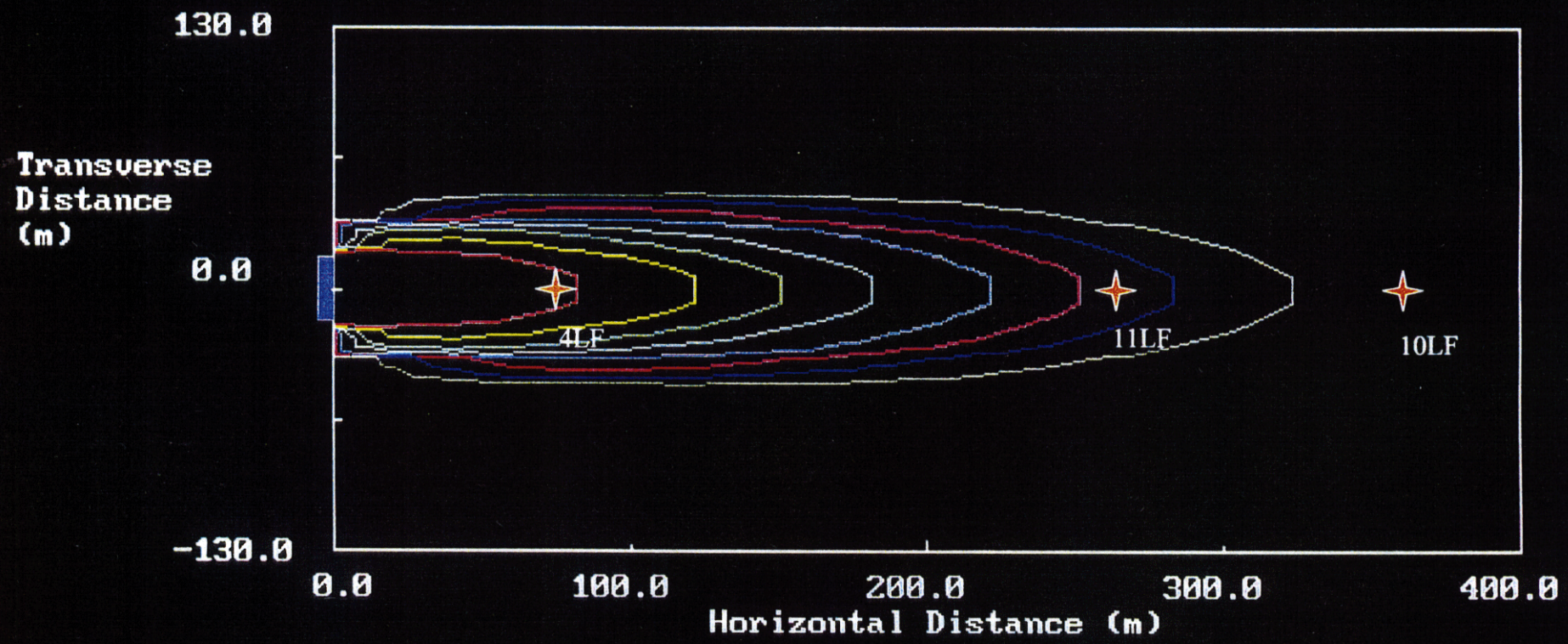
Time = 1995.00 years
Solute = TCE
Press <enter> to continue.

*	500.00 (ug/L)	*	20.00 (ug/L)
*	200.00 (ug/L)	*	10.00 (ug/L)
*	100.00 (ug/L)	*	5.00 (ug/L)
*	50.00 (ug/L)	*	2.00 (ug/L)

Run 4b: "Grassy area" source, 2005



Run 4b: "Grassy area" source, 2015

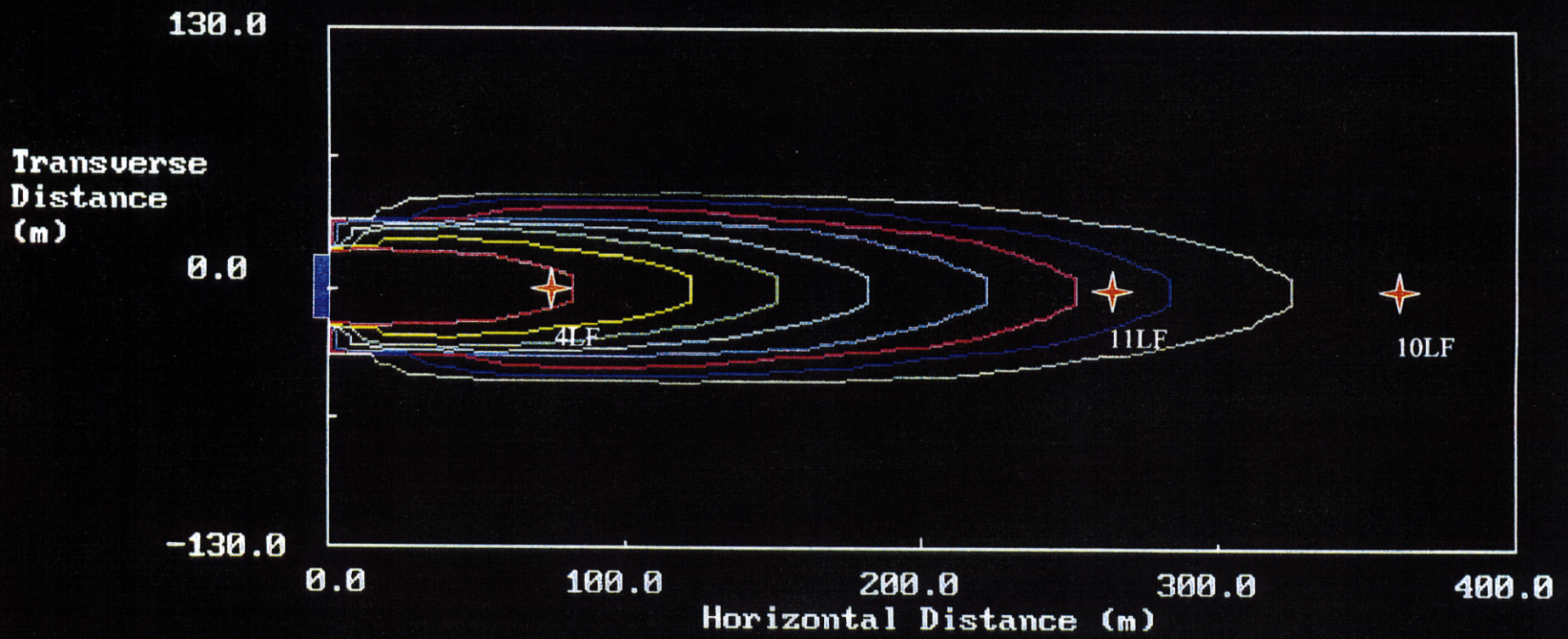


Time = 2015.00 years
Solute = TCE
Press <enter> to continue.

*	500.00 (ug/L)	*	20.00 (ug/L)
*	200.00 (ug/L)	*	10.00 (ug/L)
*	100.00 (ug/L)	*	5.00 (ug/L)
*	50.00 (ug/L)	*	2.00 (ug/L)

000054

Run 4b: "Grassy area" source, 2025

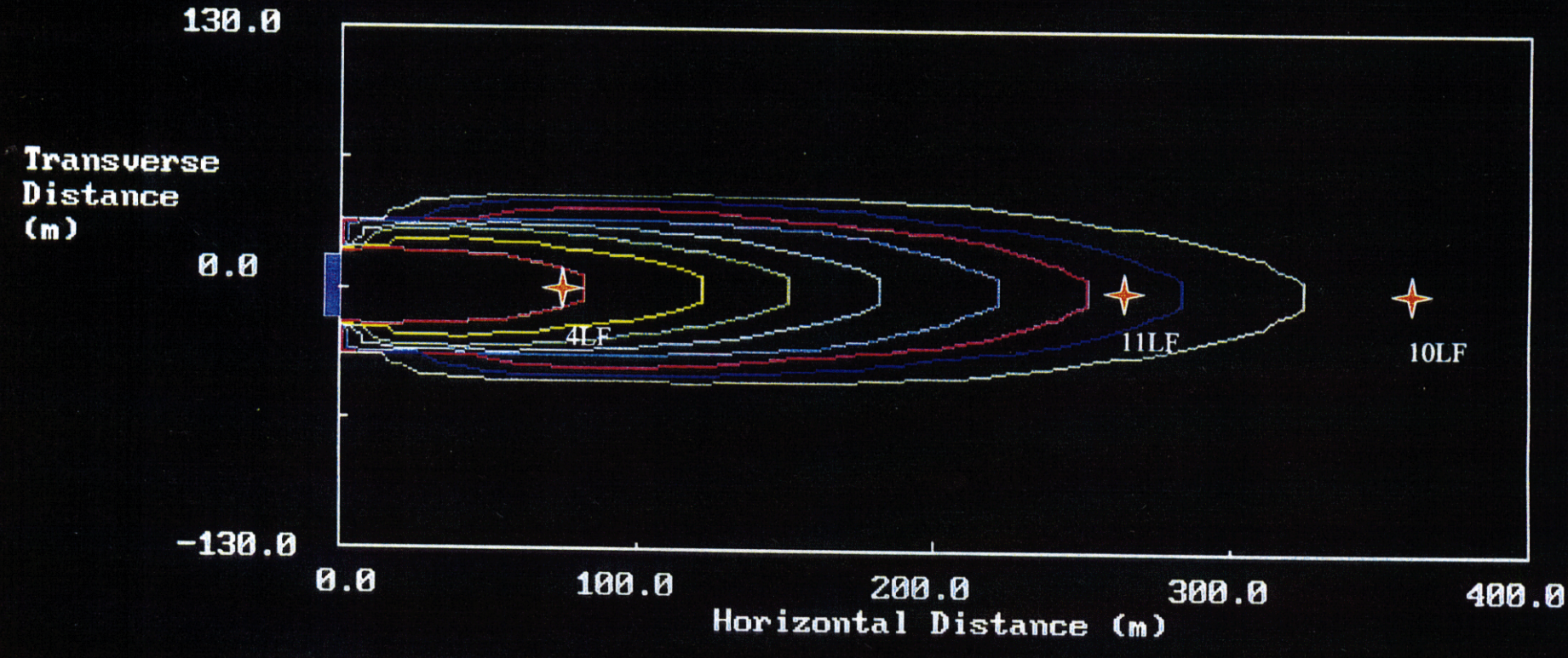


Time = 2025.00 years
Solute = TCE
Press <enter> to continue.

*	500.00 (ug/L)	*	20.00 (ug/L)
*	200.00 (ug/L)	*	10.00 (ug/L)
*	100.00 (ug/L)	*	5.00 (ug/L)
*	50.00 (ug/L)	*	2.00 (ug/L)

000755

Run 4b: "Grassy area" source, 2035

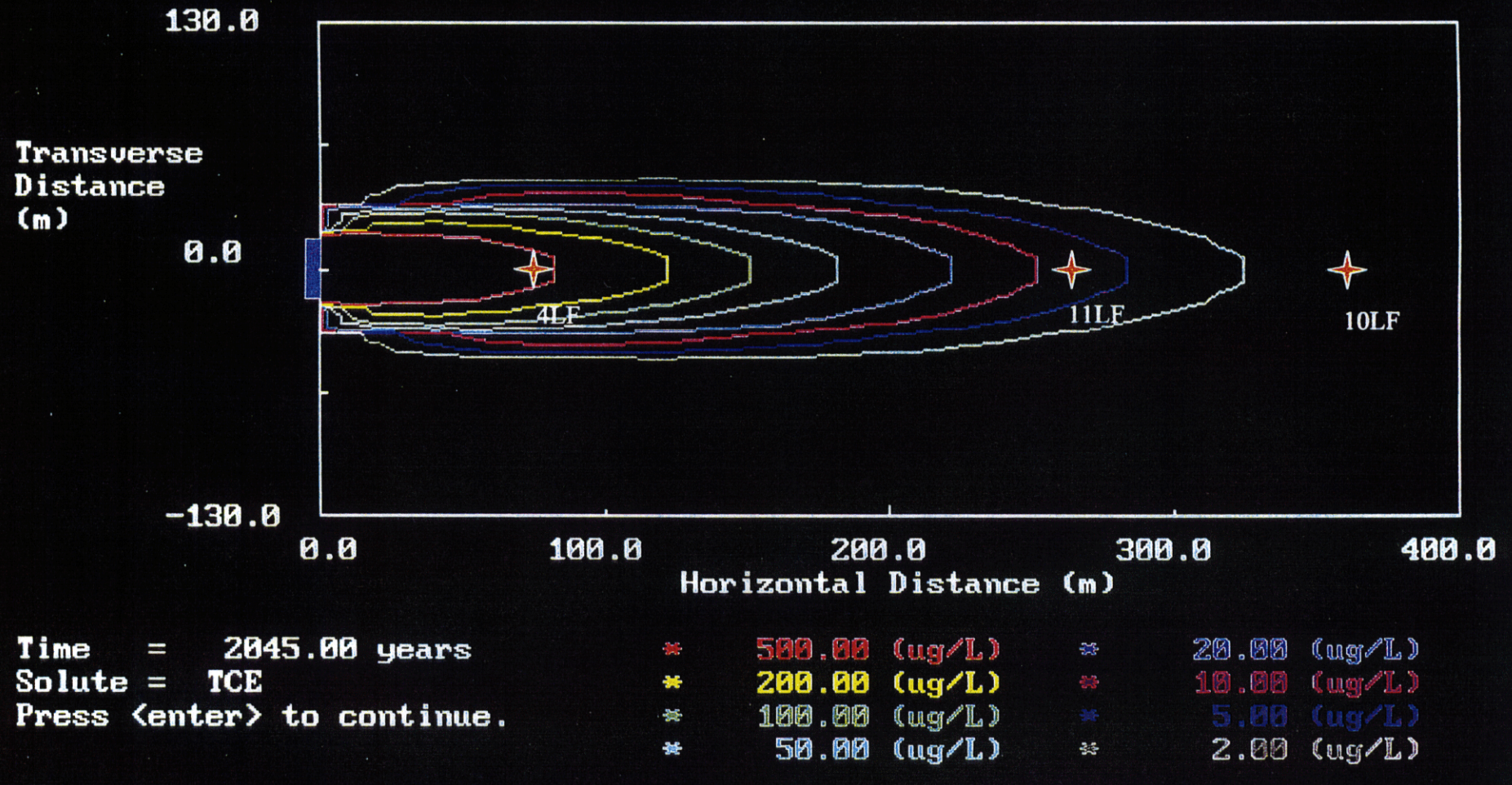


Time = 2035.00 years
Solute = TCE
Press <enter> to continue.

*	500.00 (ug/L)	*	20.00 (ug/L)
*	200.00 (ug/L)	*	10.00 (ug/L)
*	100.00 (ug/L)	*	5.00 (ug/L)
*	50.00 (ug/L)	*	2.00 (ug/L)

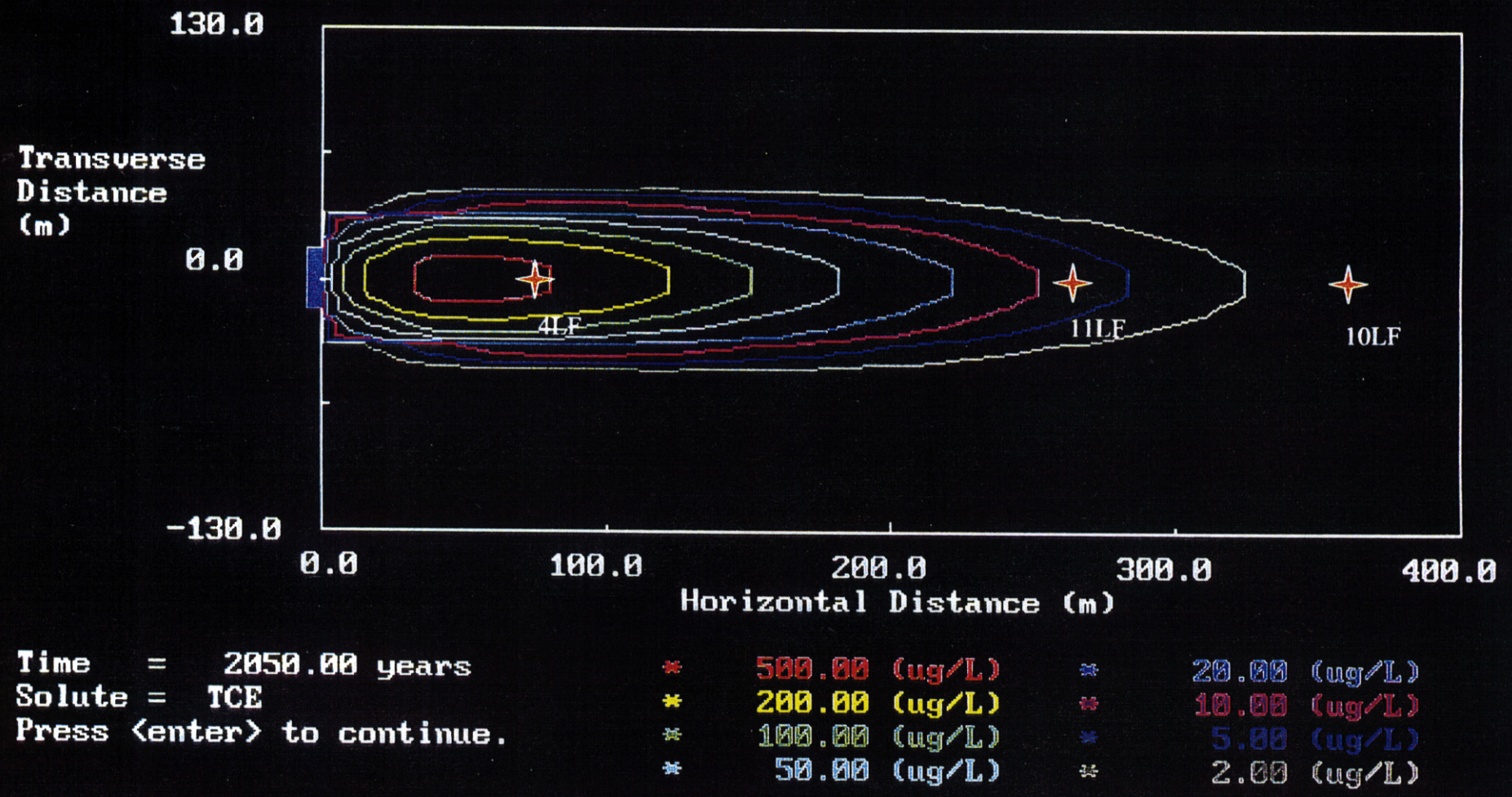
000056

Run 4b: "Grassy area" source, 2045



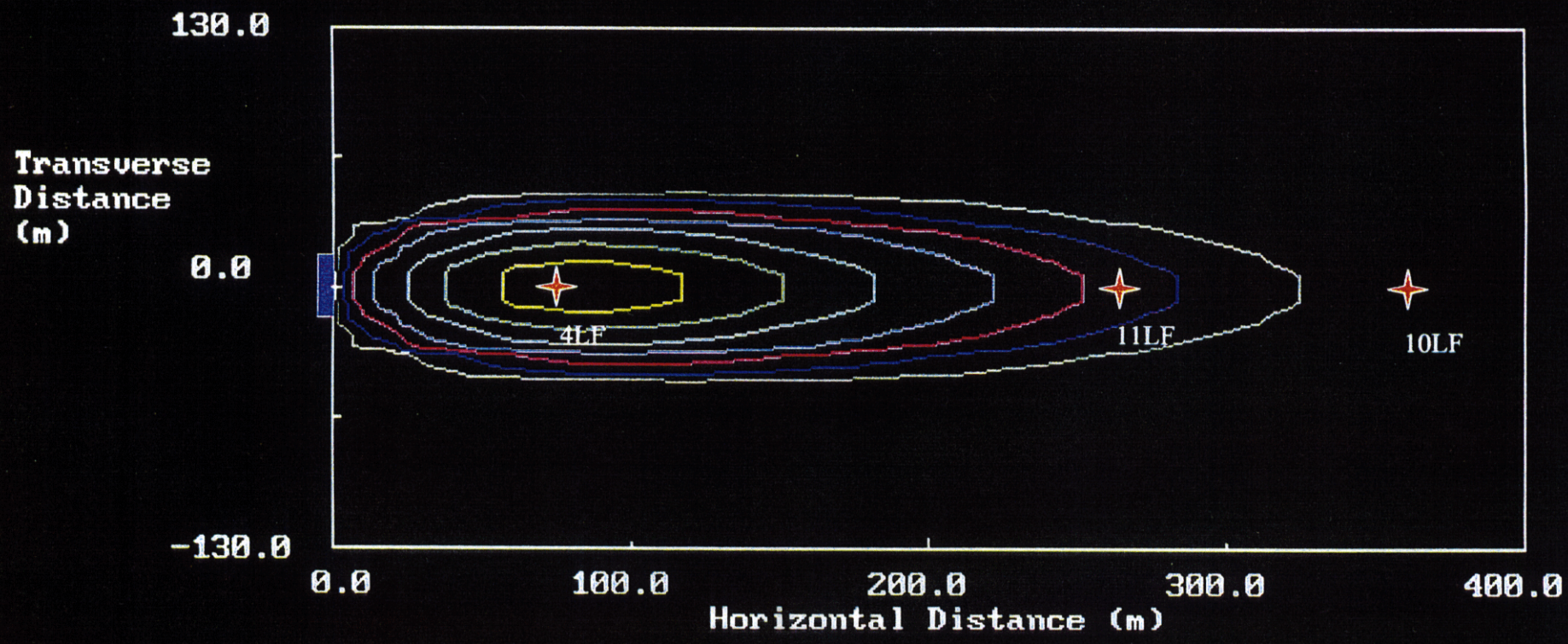
000357

Run 4b: "Grassy area" source, 2050



000358

Run 4b: "Grassy area" source, 2055

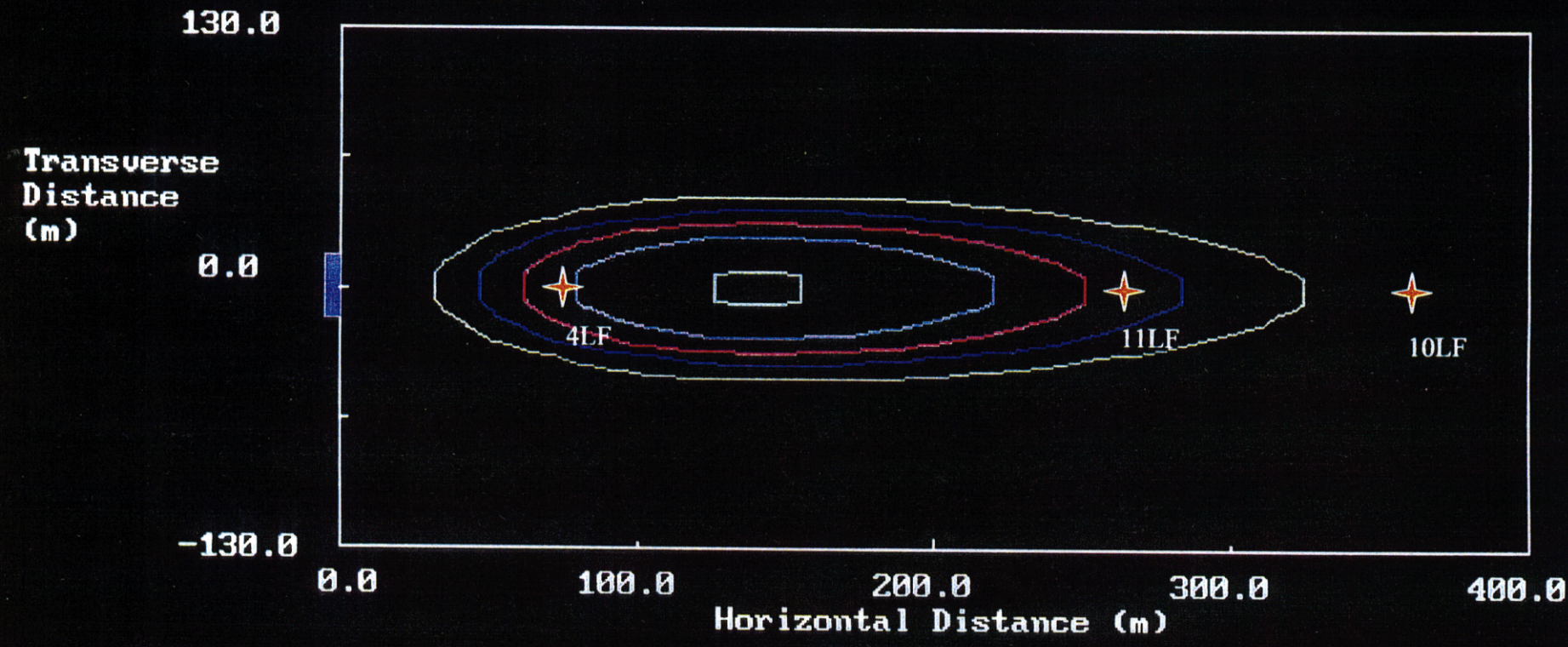


Time = 2055.00 years
Solute = TCE
Press <enter> to continue.

–	500.00 (ug/L)	*	20.00 (ug/L)
*	200.00 (ug/L)	*	10.00 (ug/L)
*	100.00 (ug/L)	*	5.00 (ug/L)
*	50.00 (ug/L)	*	2.00 (ug/L)

000039

Run 4b: "Grassy area" source, 2065

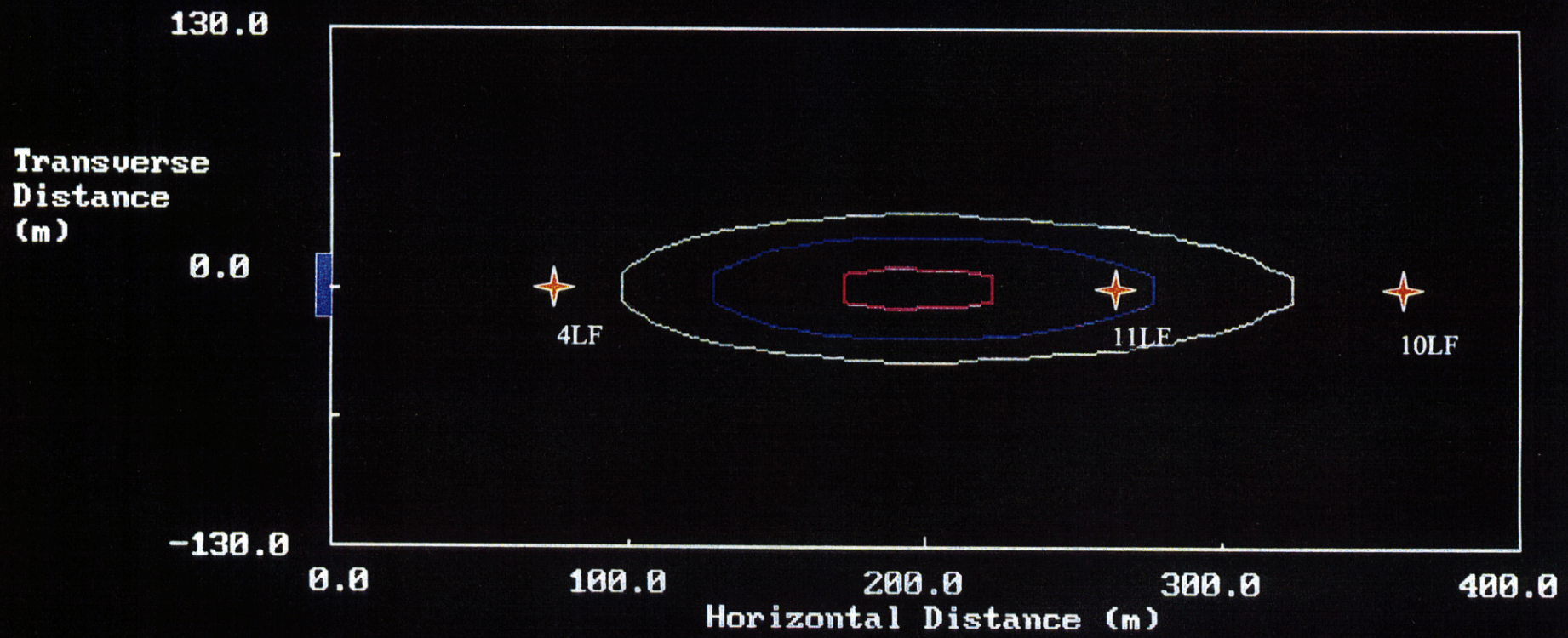


Time = 2065.00 years
Solute = TCE
Press <enter> to continue.

–	500.00 (ug/L)	*	20.00 (ug/L)
–	200.00 (ug/L)	*	10.00 (ug/L)
–	100.00 (ug/L)	*	5.00 (ug/L)
*	50.00 (ug/L)	*	2.00 (ug/L)

000060

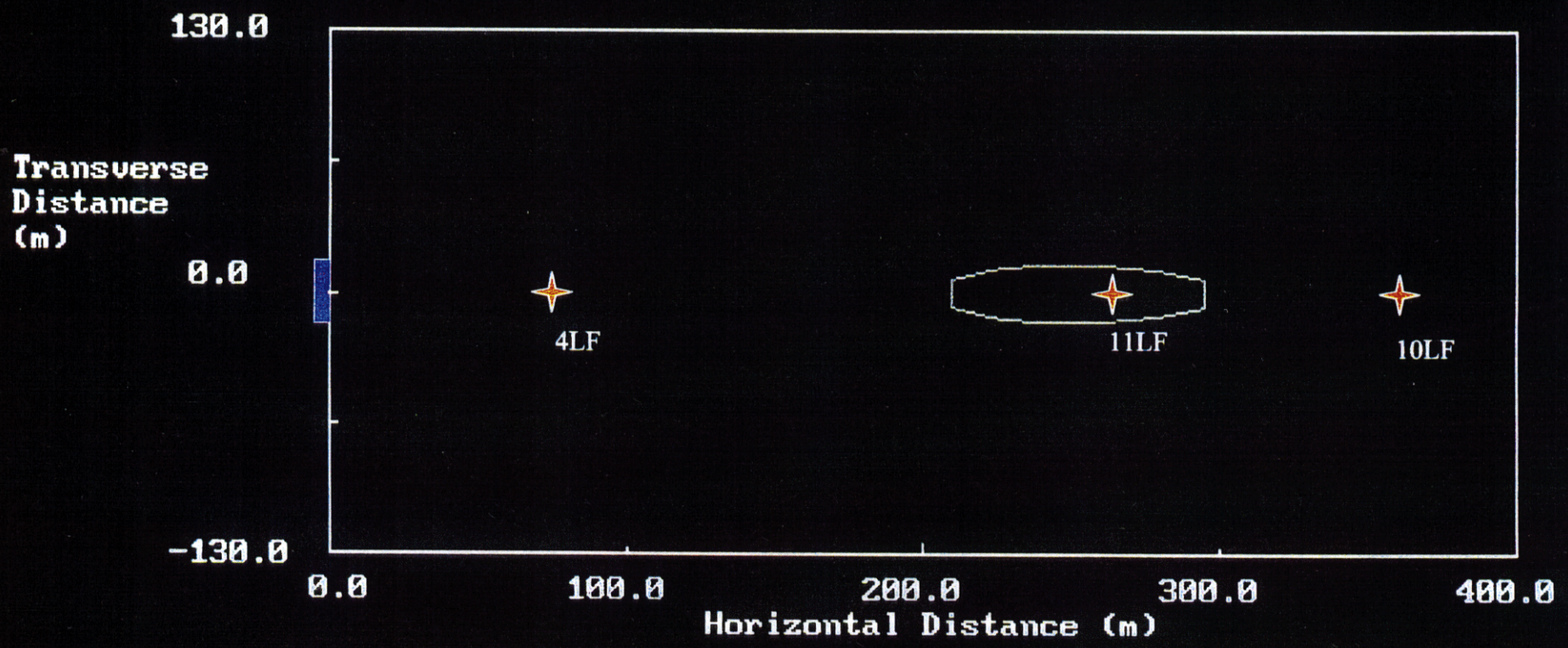
Run 4b: "Grassy area" source, 2075



Time = 2075.00 years
Solute = TCE
Press <enter> to continue.

–	500.00 (ug/L)	–	20.00 (ug/L)
–	200.00 (ug/L)	*	10.00 (ug/L)
–	100.00 (ug/L)	*	5.00 (ug/L)
–	50.00 (ug/L)	*	2.00 (ug/L)

Run 4b: "Grassy area" source, 2085

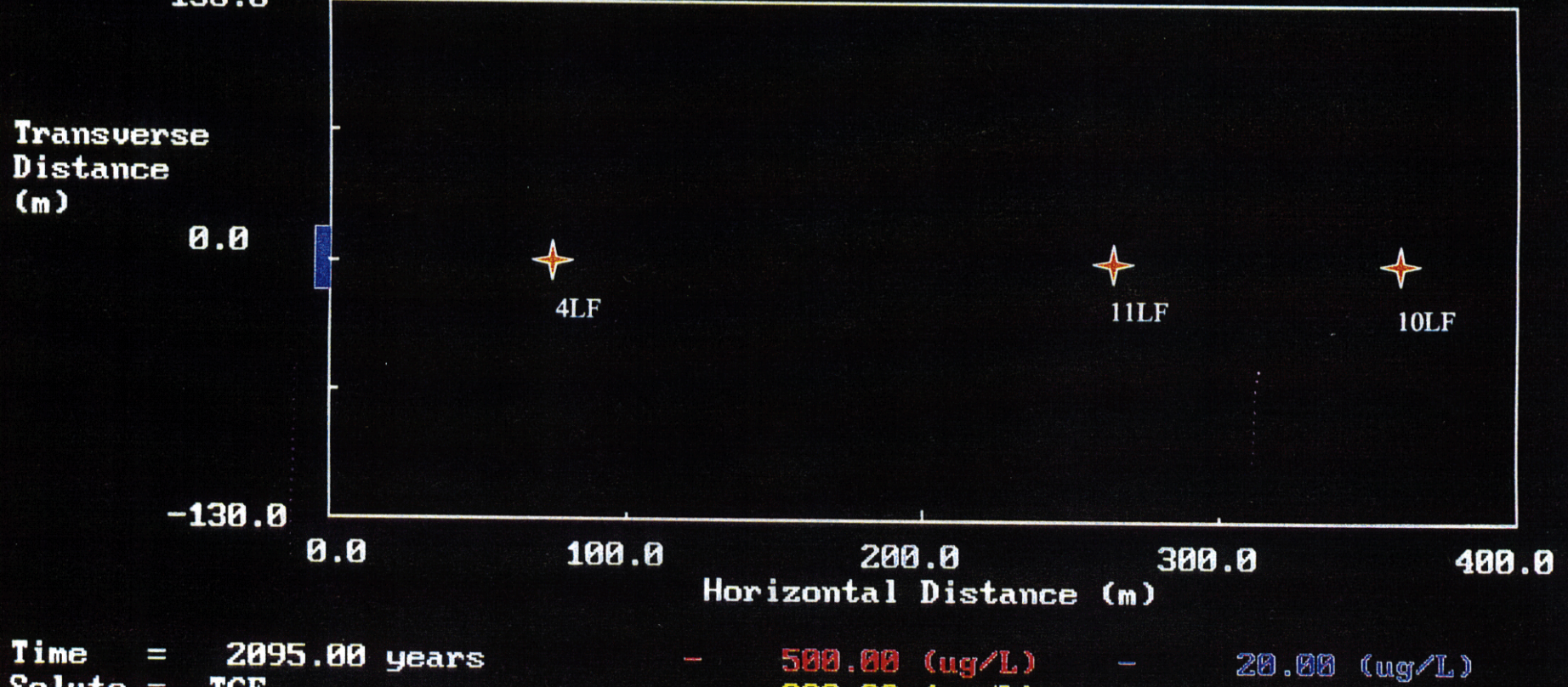


Time = 2085.00 years
Solute = TCE
Press <enter> to continue.

–	500.00 (ug/L)	–	20.00 (ug/L)
–	200.00 (ug/L)	–	10.00 (ug/L)
–	100.00 (ug/L)	–	5.00 (ug/L)
–	50.00 (ug/L)	*	2.00 (ug/L)

000142

Run 4b: "Grassy area" source, 2095



Time = 2095.00 years
Solute = TCE
Press <enter> to continue.

500.00 (ug/L)	20.00 (ug/L)
200.00 (ug/L)	10.00 (ug/L)
100.00 (ug/L)	5.00 (ug/L)
50.00 (ug/L)	2.00 (ug/L)

Results: "Grassy area" source

- 5 ug/L contour reaches steady-state in about 60 years.

- Once source is depleted, concentrations decay to below 5 ug/L in about 36 years.

P9A0900

#4c: N-6 source

Co = 820 ug/L

Dx = 73 m2/yr

Dy = 7.3 m2/yr

V = 7.34 m/yr

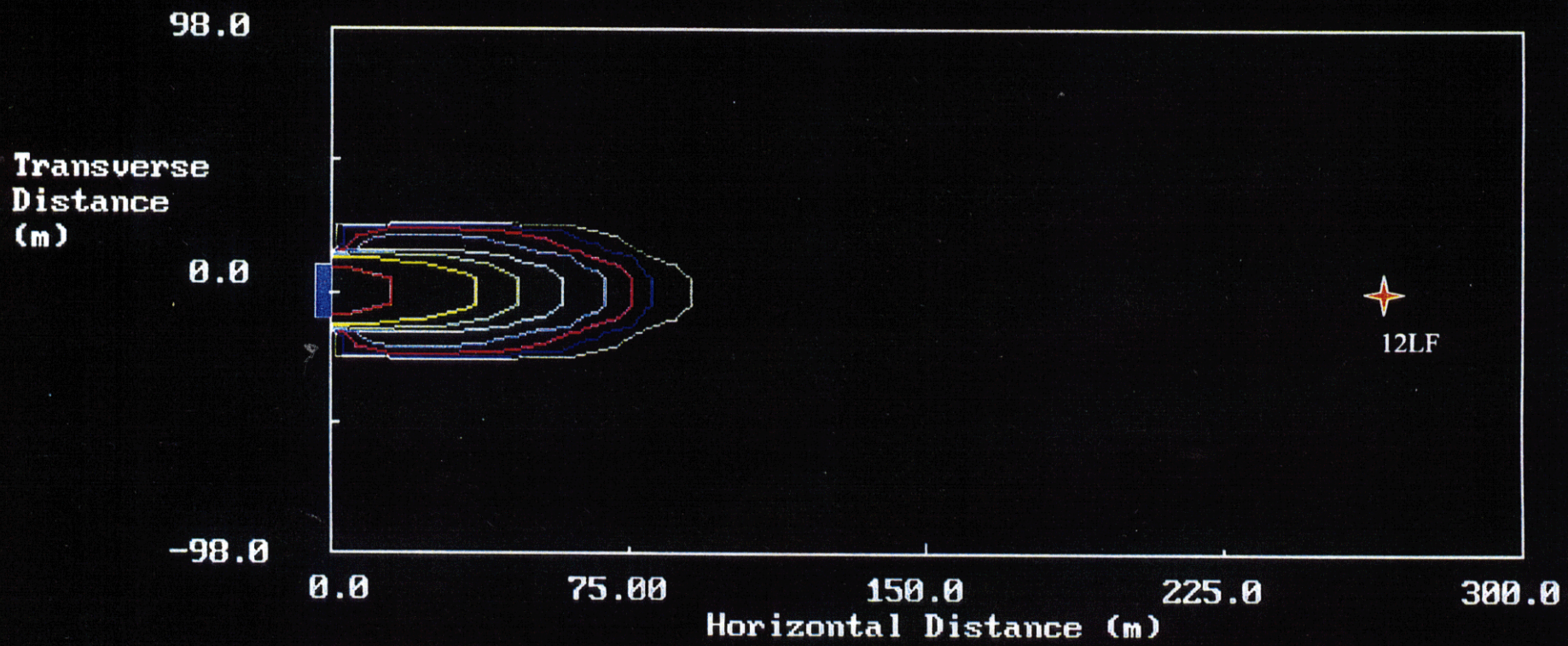
Rd = 1.4

λ = 0.13 yr^{-1} ($T_{1/2}$ = 5.3 yr)

Ton = 1945

Toff = 2045

Run 4c: N-6 source, 1950



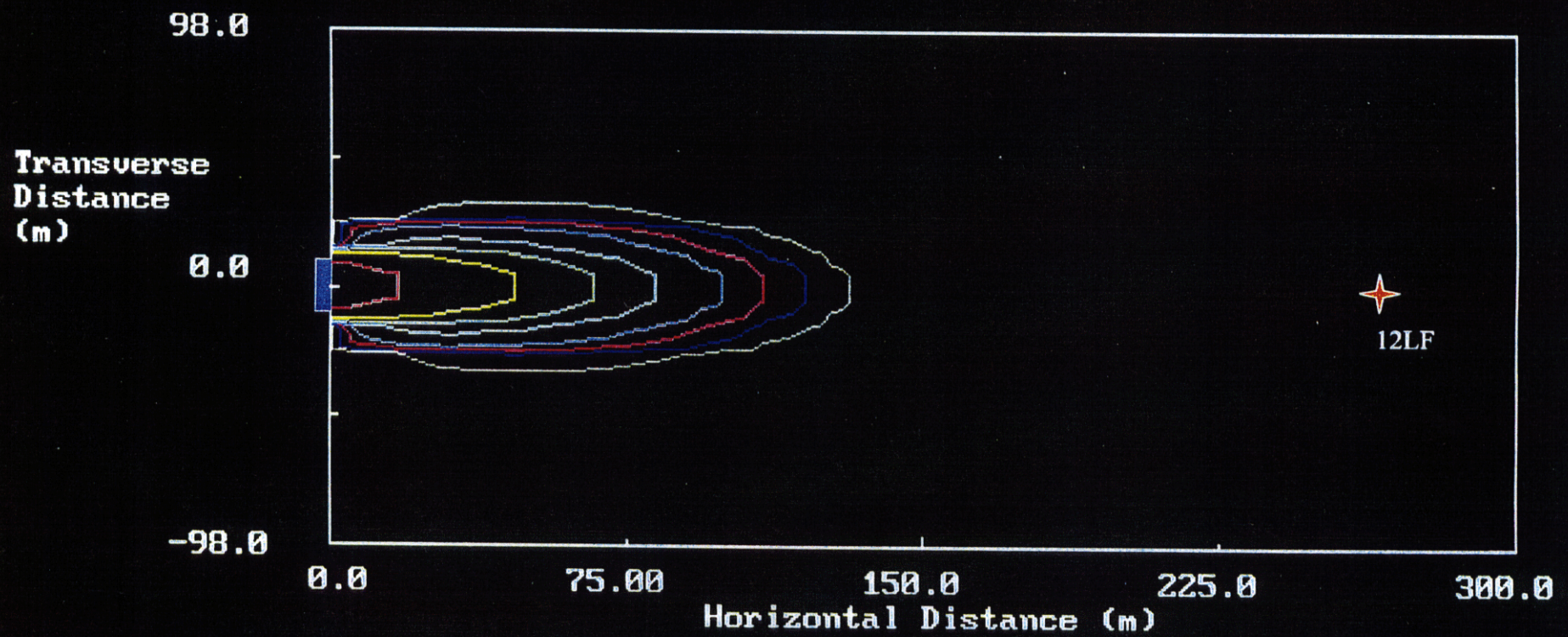
Time = 1950.00 years
Solute = TCE
Press <enter> to continue.

*	500.00 (ug/L)	*	20.00 (ug/L)
*	200.00 (ug/L)	*	10.00 (ug/L)
*	100.00 (ug/L)	*	5.00 (ug/L)
*	50.00 (ug/L)	*	2.00 (ug/L)

930000

00593CB3Y

Run 4c: N-6 source, 1955

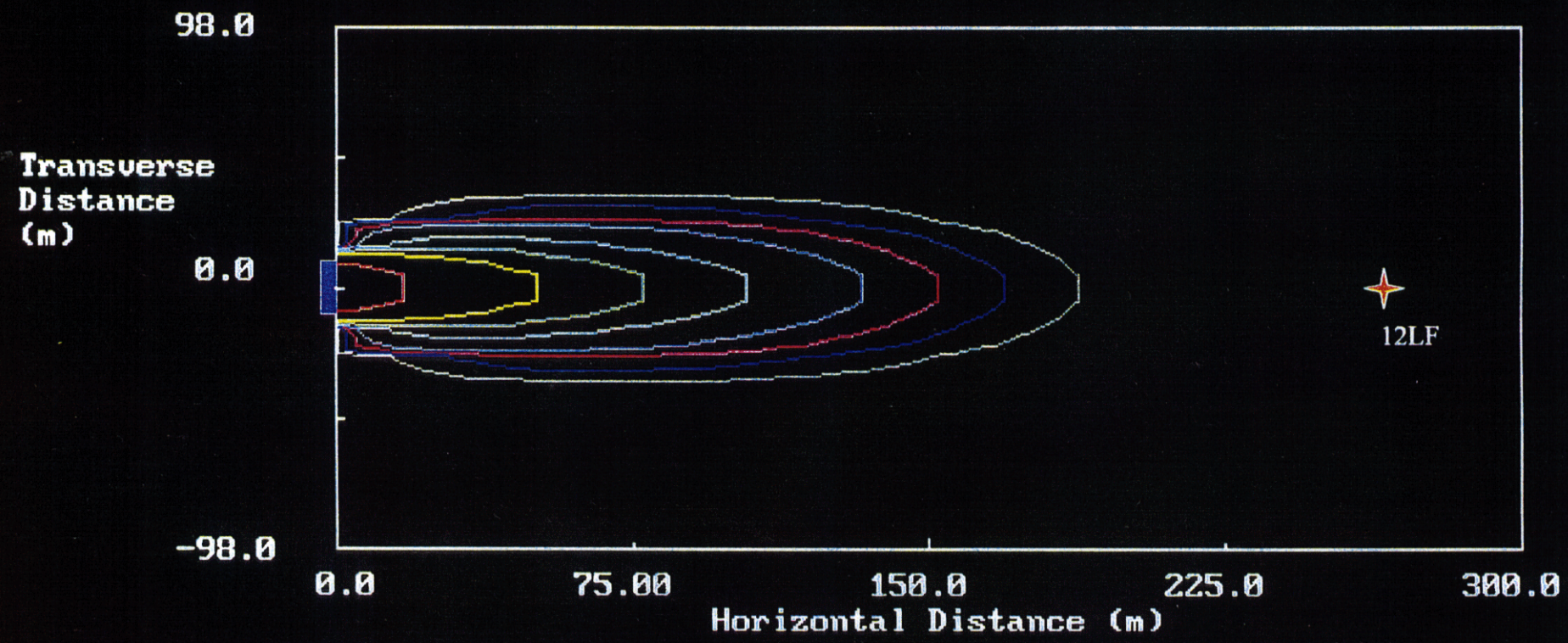


Time = 1955.00 years
Solute = TCE
Press <enter> to continue.

*	500.00 (ug/L)	*	20.00 (ug/L)
*	200.00 (ug/L)	*	10.00 (ug/L)
*	100.00 (ug/L)	*	5.00 (ug/L)
*	50.00 (ug/L)	*	2.00 (ug/L)

290000

Run 4c: N-6 source, 1965

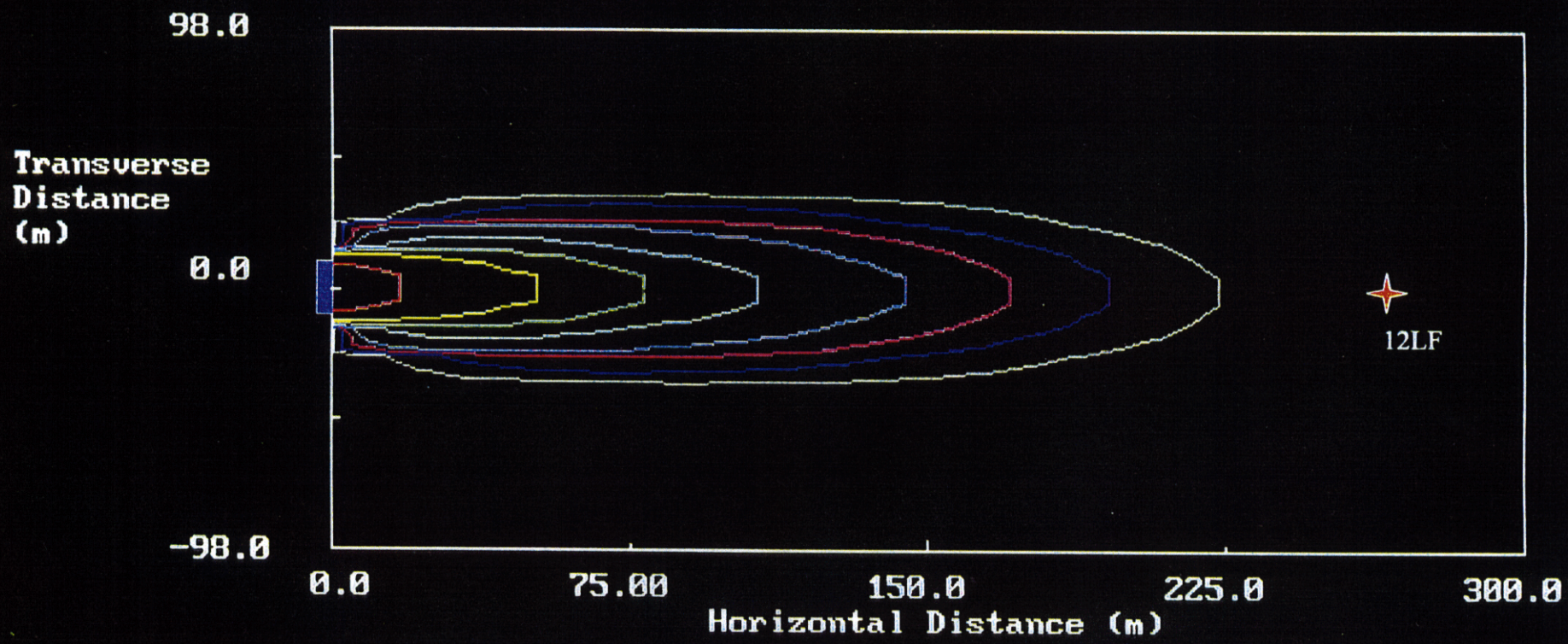


Time = 1965.00 years
Solute = TCE
Press <enter> to continue.

*	500.00 (ug/L)	*	20.00 (ug/L)
*	200.00 (ug/L)	*	10.00 (ug/L)
*	100.00 (ug/L)	*	5.00 (ug/L)
*	50.00 (ug/L)	*	2.00 (ug/L)

000038

Run 4c: N-6 source, 1975

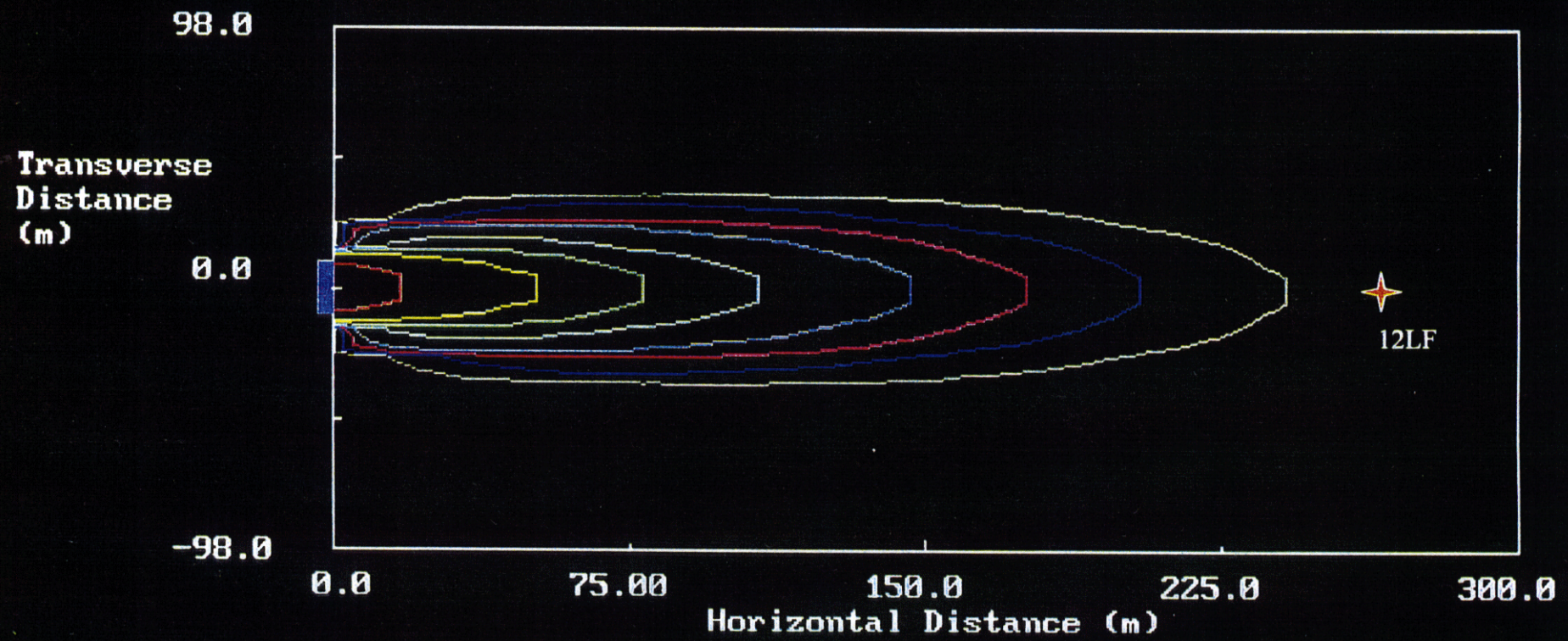


Time = 1975.00 years
Solute = TCE
Press <enter> to continue.

* 500.00 (ug/L)
* 200.00 (ug/L)
* 100.00 (ug/L)
* 50.00 (ug/L)
* 20.00 (ug/L)
* 10.00 (ug/L)
* 5.00 (ug/L)
* 2.00 (ug/L)

690000

Run 4c: N-6 source, 1985

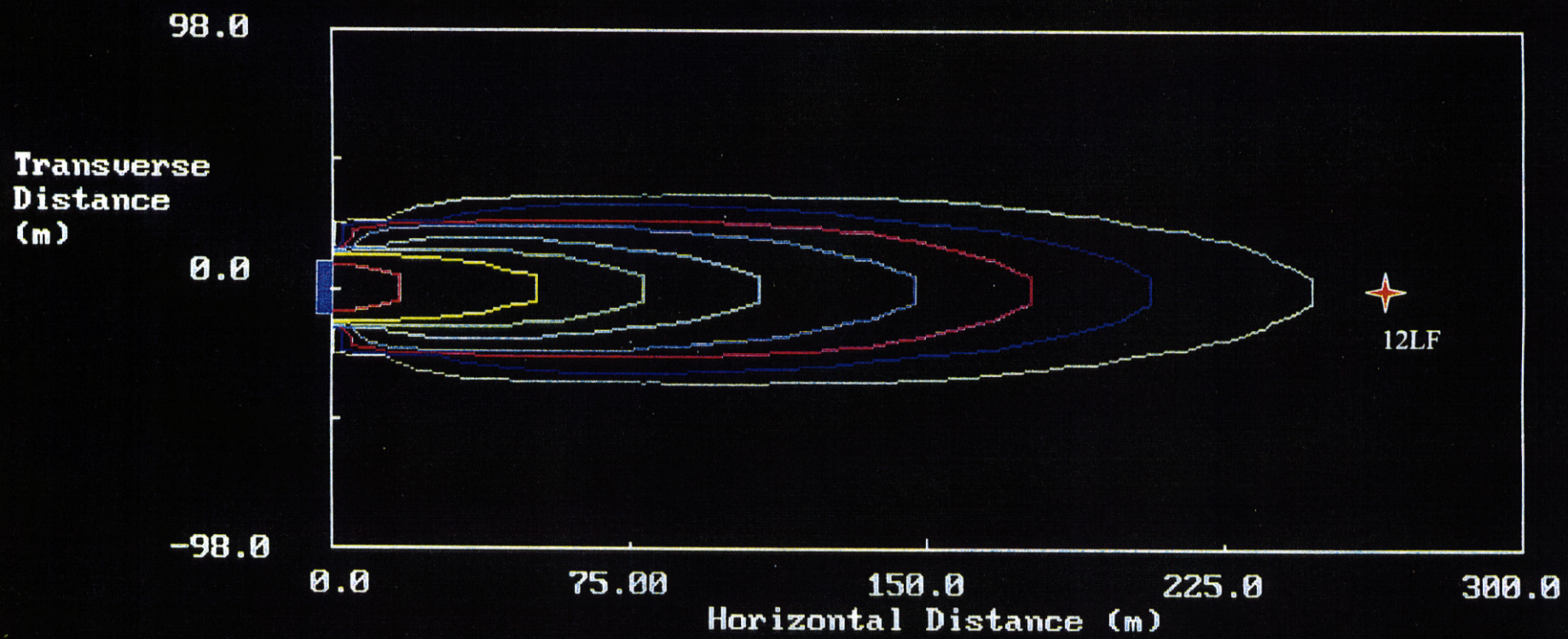


Time = 1985.00 years
Solute = TCE
Press <enter> to continue.

* 500.00 (ug/L)
* 200.00 (ug/L)
* 100.00 (ug/L)
* 50.00 (ug/L)
* 20.00 (ug/L)
* 10.00 (ug/L)
* 5.00 (ug/L)
* 2.00 (ug/L)

020000

Run 4c: N-6 source, 1995

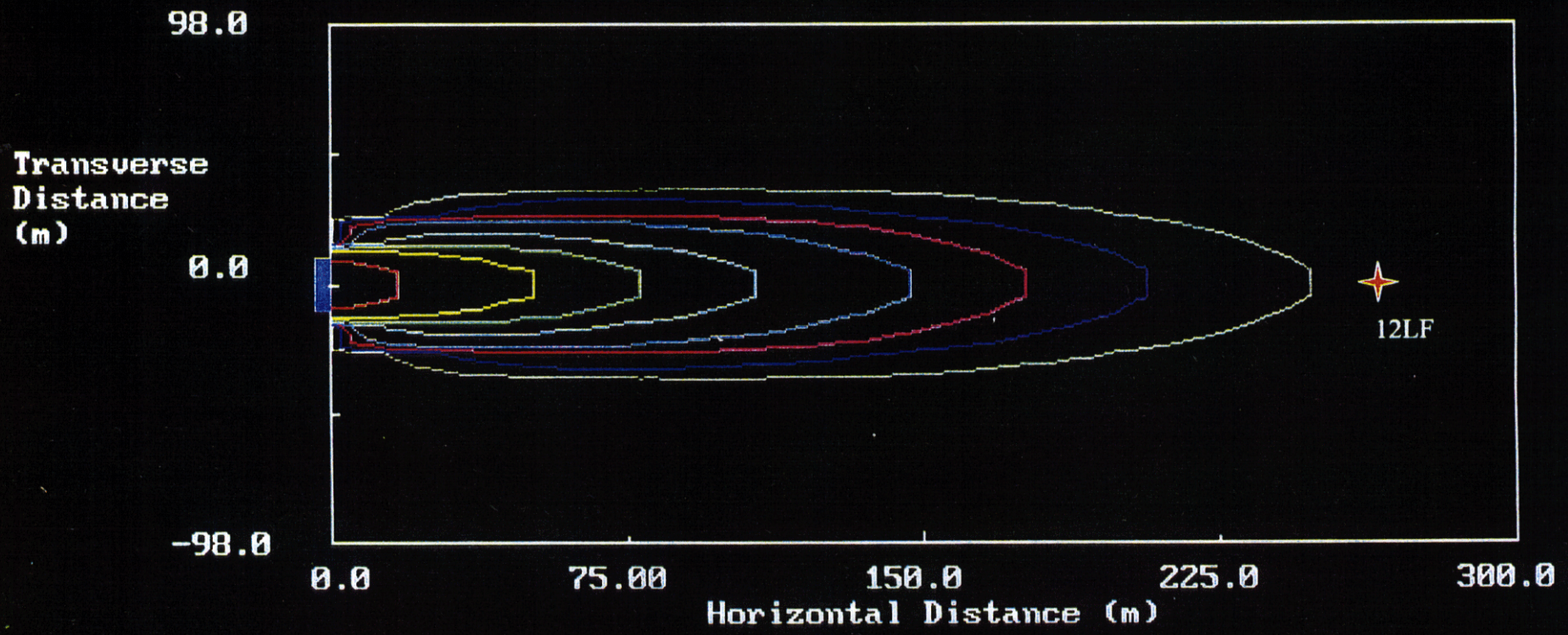


Time = 1995.00 years
Solute = TCE
Press <enter> to continue.

* 500.00 (ug/L)
* 200.00 (ug/L)
* 100.00 (ug/L)
* 50.00 (ug/L)
* 20.00 (ug/L)
* 10.00 (ug/L)
* 5.00 (ug/L)
* 2.00 (ug/L)

140000

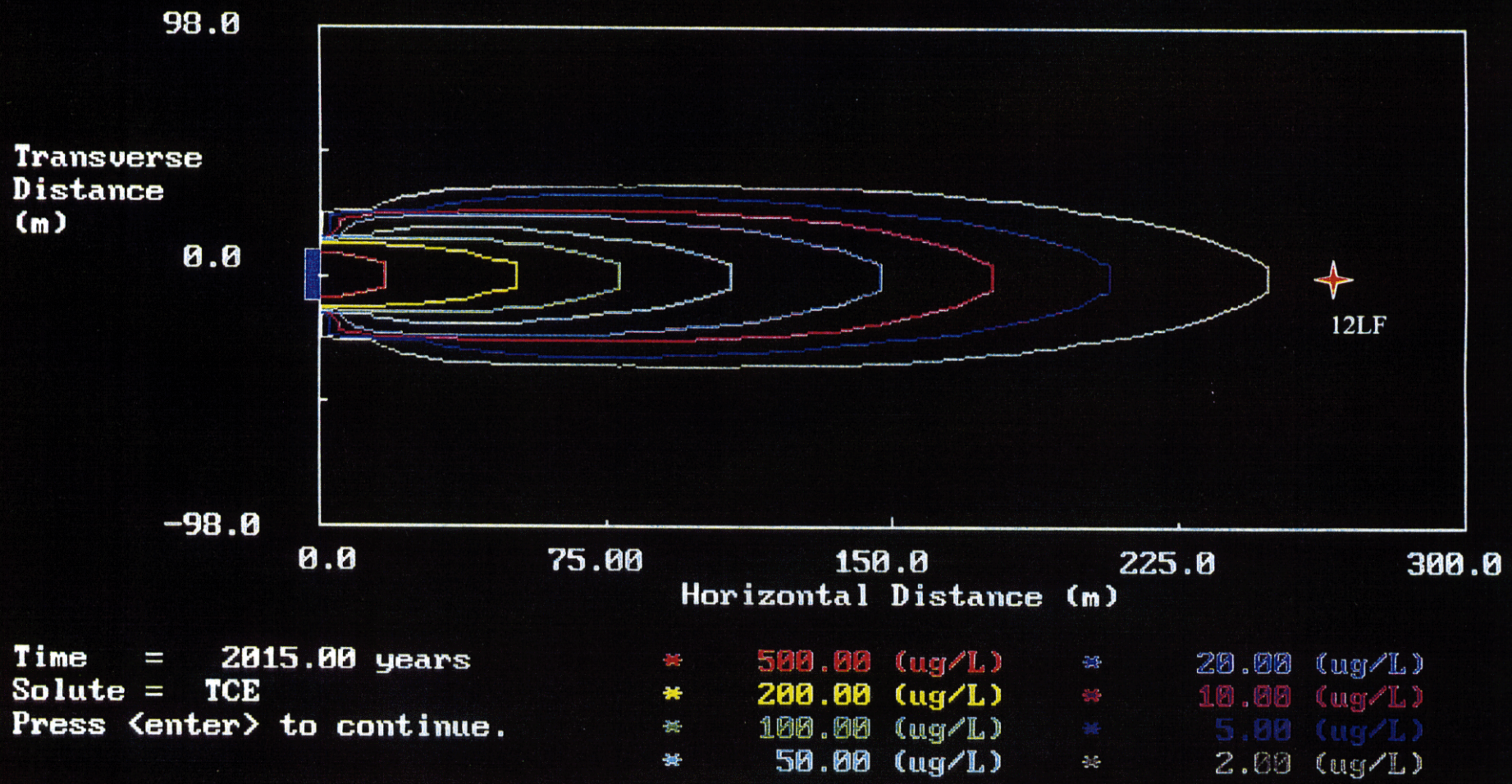
Run 4c: N-6 source, 2005



Time = 2005.00 years
Solute = TCE
Press <enter> to continue.

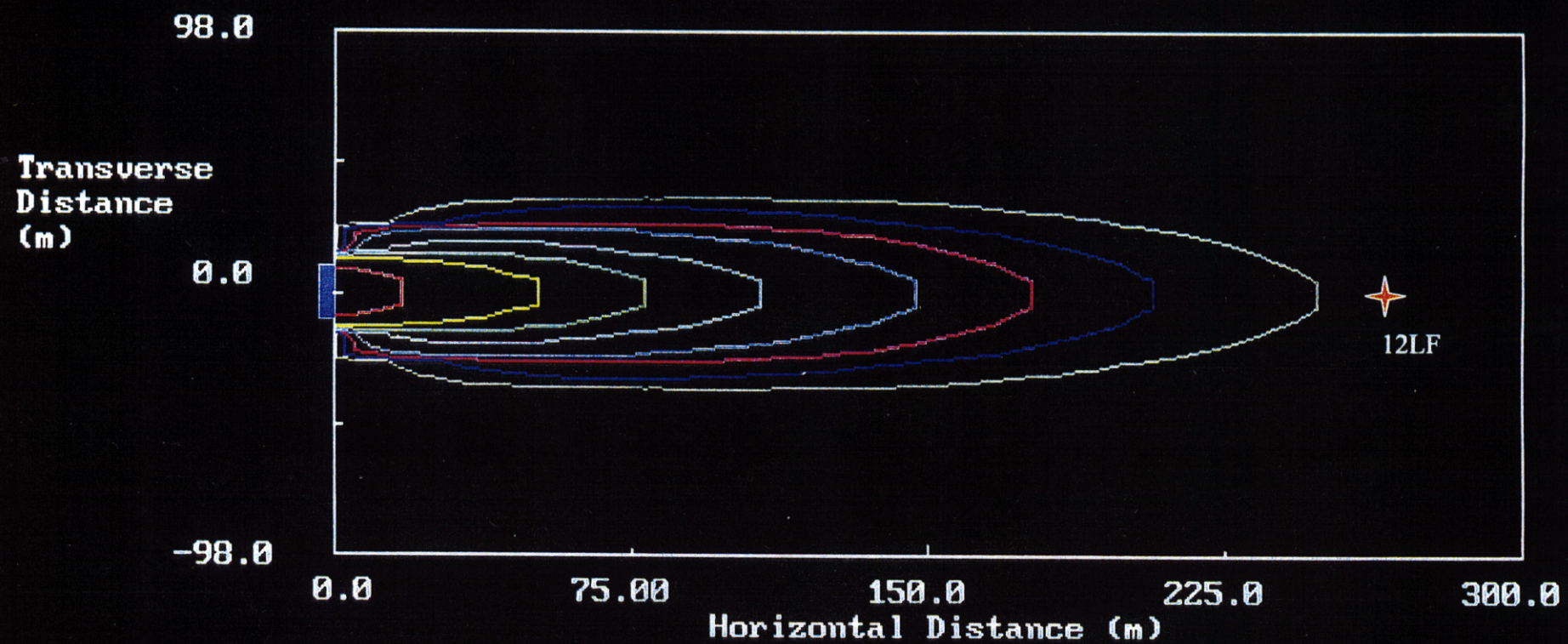
* 500.00 (ug/L)
* 200.00 (ug/L)
* 100.00 (ug/L)
* 50.00 (ug/L)
* 20.00 (ug/L)
* 10.00 (ug/L)
* 5.00 (ug/L)
* 2.00 (ug/L)

Run 4c: N-6 source, 2015



000073

Run 4c: N-6 source, 2025

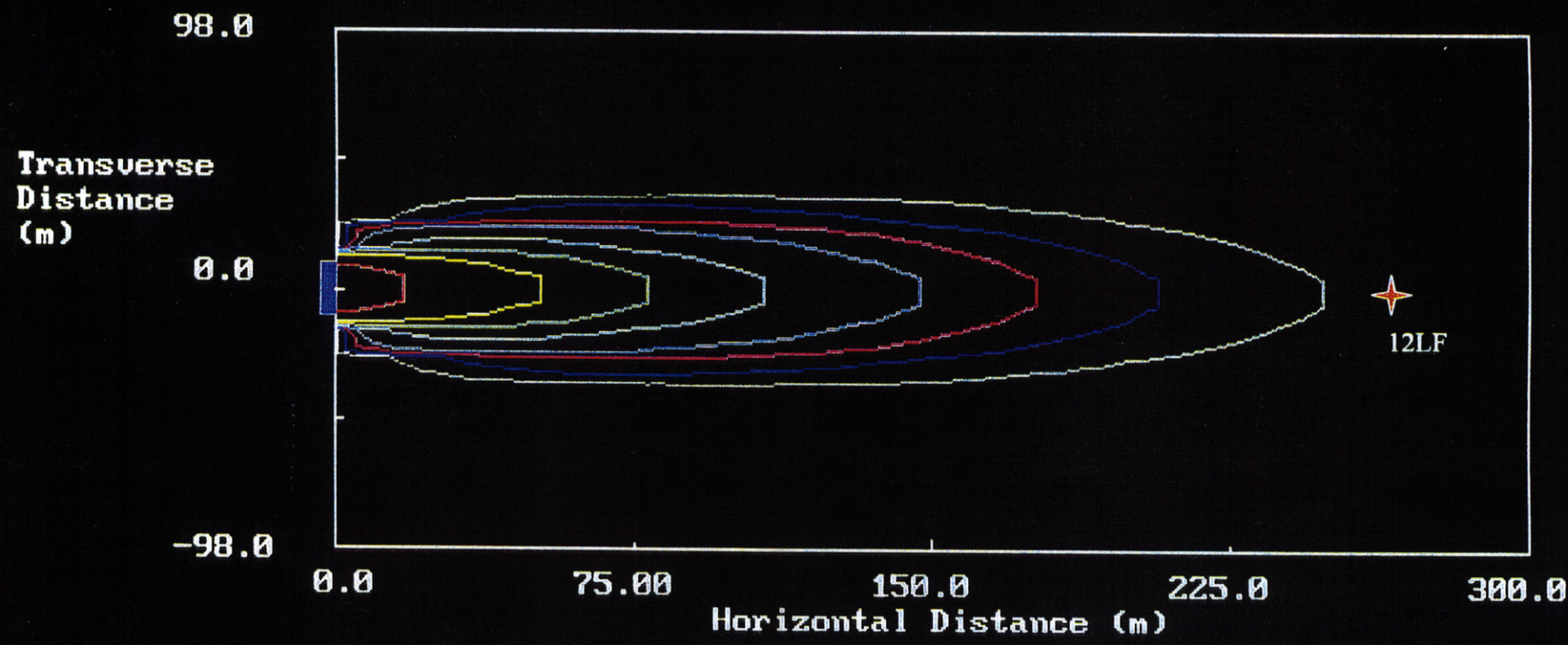


Time = 2025.00 years
Solute = TCE
Press <enter> to continue.

* 500.00 (ug/L)
* 200.00 (ug/L)
* 100.00 (ug/L)
* 50.00 (ug/L)
* 20.00 (ug/L)
* 10.00 (ug/L)
* 5.00 (ug/L)
* 2.00 (ug/L)

000074

Run 4c: N-6 source, 2045

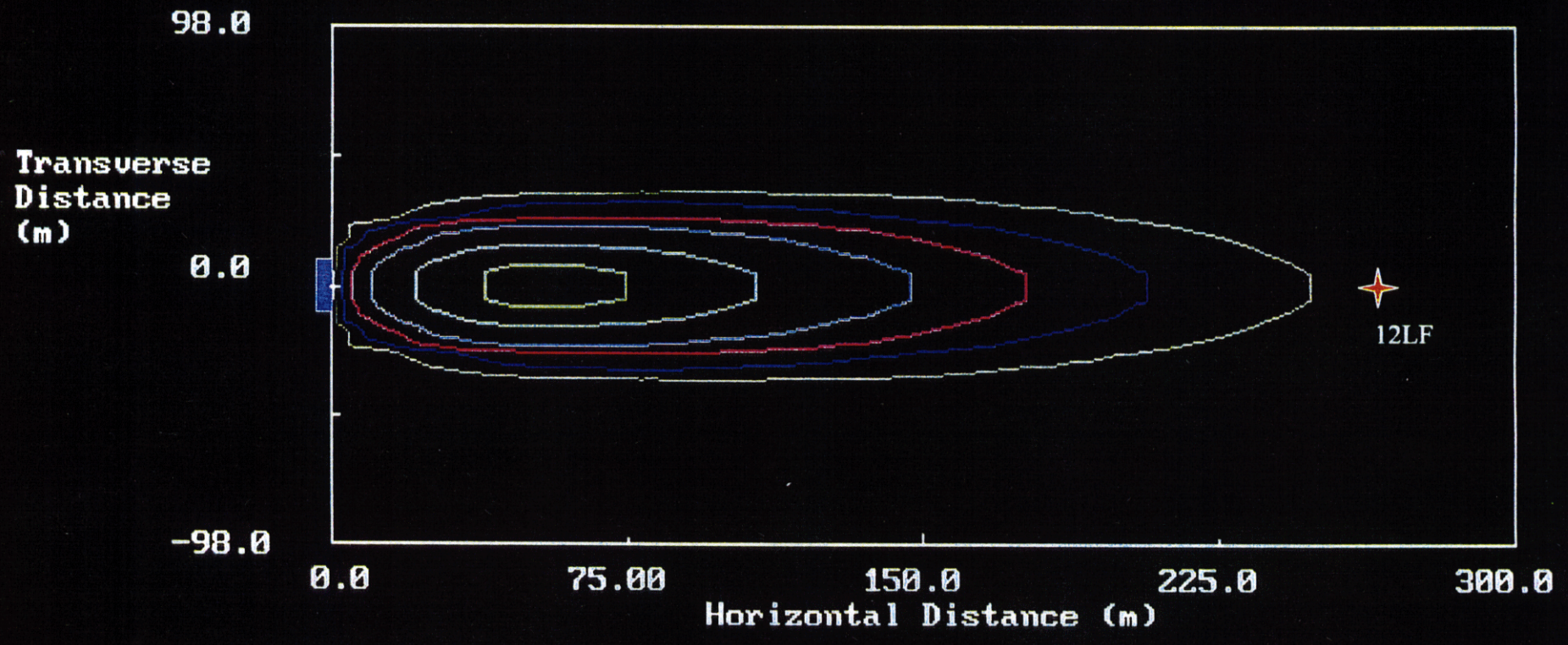


Time = 2045.00 years
Solute = TCE
Press <enter> to continue.

* 500.00 (ug/L)	* 20.00 (ug/L)
* 200.00 (ug/L)	* 10.00 (ug/L)
* 100.00 (ug/L)	* 5.00 (ug/L)
* 50.00 (ug/L)	* 2.00 (ug/L)

540000

Run 4c: N-6 source, 2050

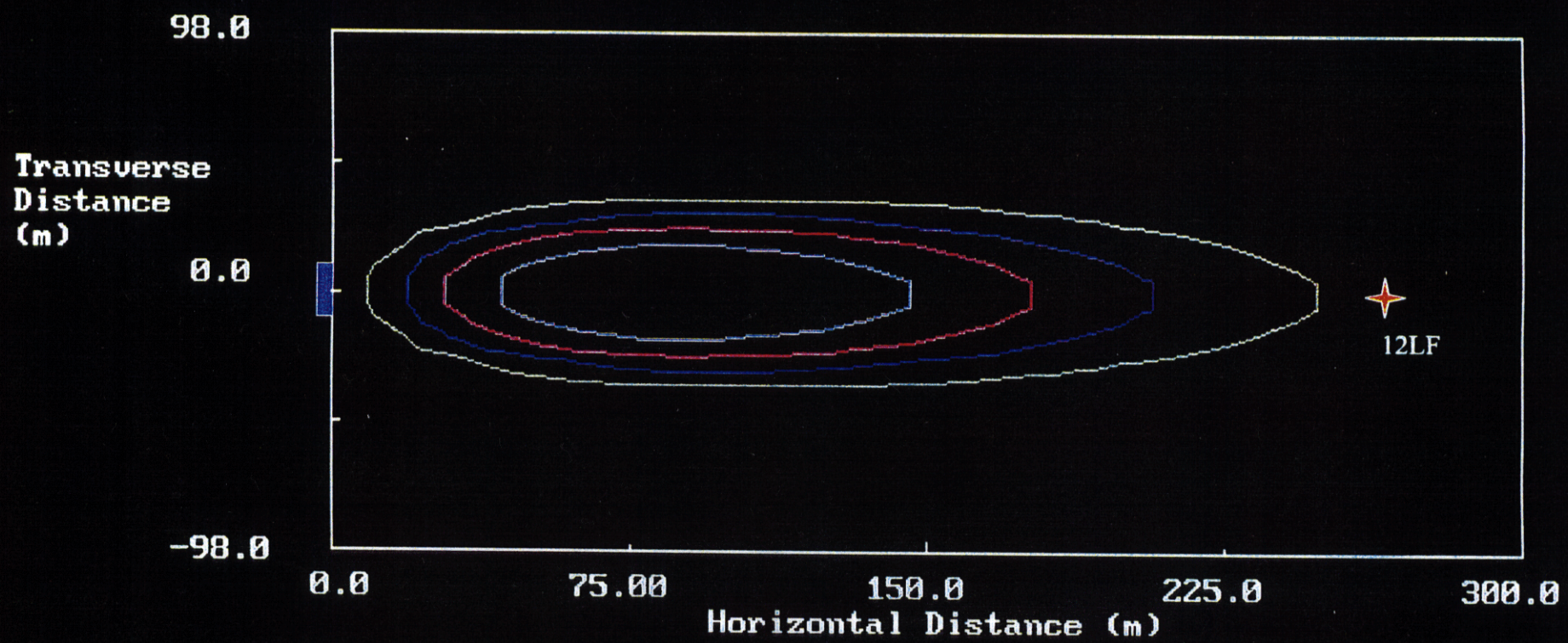


Time = 2050.00 years
Solute = TCE
Press <enter> to continue.

–	500.00 (ug/L)	*	20.00 (ug/L)
–	200.00 (ug/L)	*	10.00 (ug/L)
*	100.00 (ug/L)	*	5.00 (ug/L)
*	50.00 (ug/L)	*	2.00 (ug/L)

940000

Run 4c: N-6 source, 2055

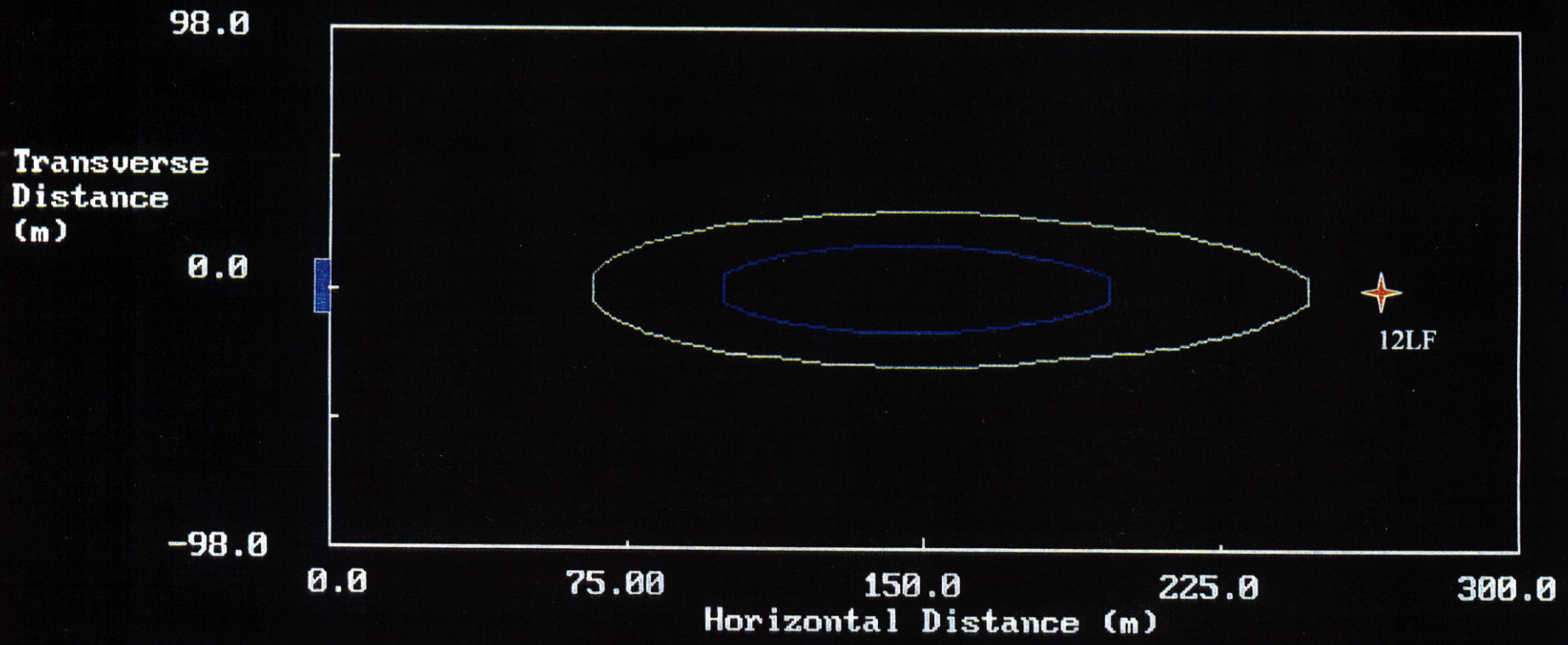


Time = 2055.00 years
Solute = TCE
Press <enter> to continue.

–	500.00 (ug/L)	*	20.00 (ug/L)
–	200.00 (ug/L)	*	10.00 (ug/L)
–	100.00 (ug/L)	*	5.00 (ug/L)
–	50.00 (ug/L)	*	2.00 (ug/L)

000077

Run 4c: N-6 source, 2065

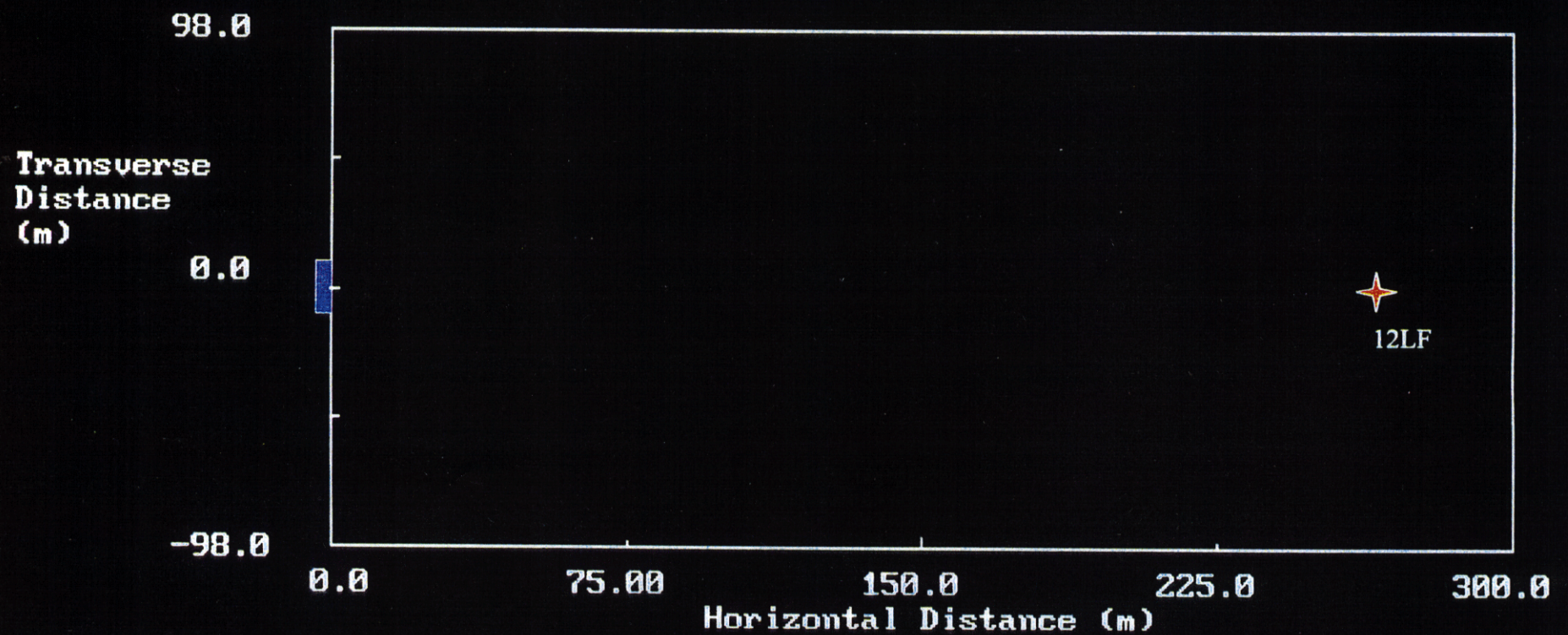


Time = 2065.00 years
Solute = TCE
Press <enter> to continue.

–	500.00 (ug/L)	–	20.00 (ug/L)
–	200.00 (ug/L)	–	10.00 (ug/L)
–	100.00 (ug/L)	*	5.00 (ug/L)
–	50.00 (ug/L)	*	2.00 (ug/L)

000078

Run 4c: N-6 source, 2075



Time = 2075.00 years
Solute = TCE
Press <enter> to continue.

- 500.00 (ug/L)
- 200.00 (ug/L)
- 100.00 (ug/L)
- 50.00 (ug/L)
- 20.00 (ug/L)
- 10.00 (ug/L)
- 5.00 (ug/L)
- 2.00 (ug/L)

000079

Results: N-6 source

- 5 ug/L contour reaches steady-state in about 60 years.

- Once source is depleted, concentrations decay to below 5 ug/L in about 23 years.

Plume Evolution Summary

- Source mass and concentrations effect the time for a plume to reach steady-state and the time for the plume to decay.

- Plume extents ranged from about 190 to 340 meters.

Plume Evolution Summary--continued

- Depending on when releases occurred and the duration of subsurface sources, current plumes at the Northside AOC may or may not presently be at steady state.

- Duration of subsurface source will be a major factor in determining duration of plume.

Summary

- All input parameters used are within expected ranges.
- Retardation and decay coefficient used are toward the conservative end of expected ranges.
- Simulated plumes generally agree with existing work and data.

000123

Question

- What if concentration of TCE leaving "grassy area" source is very high, near the solubility limit of TCE?

Base case "grassy area" source:

Input parameters

Co = 3,580 ug/L

Dx = 58 m^2/yr

Dy = 5.8 m^2/yr

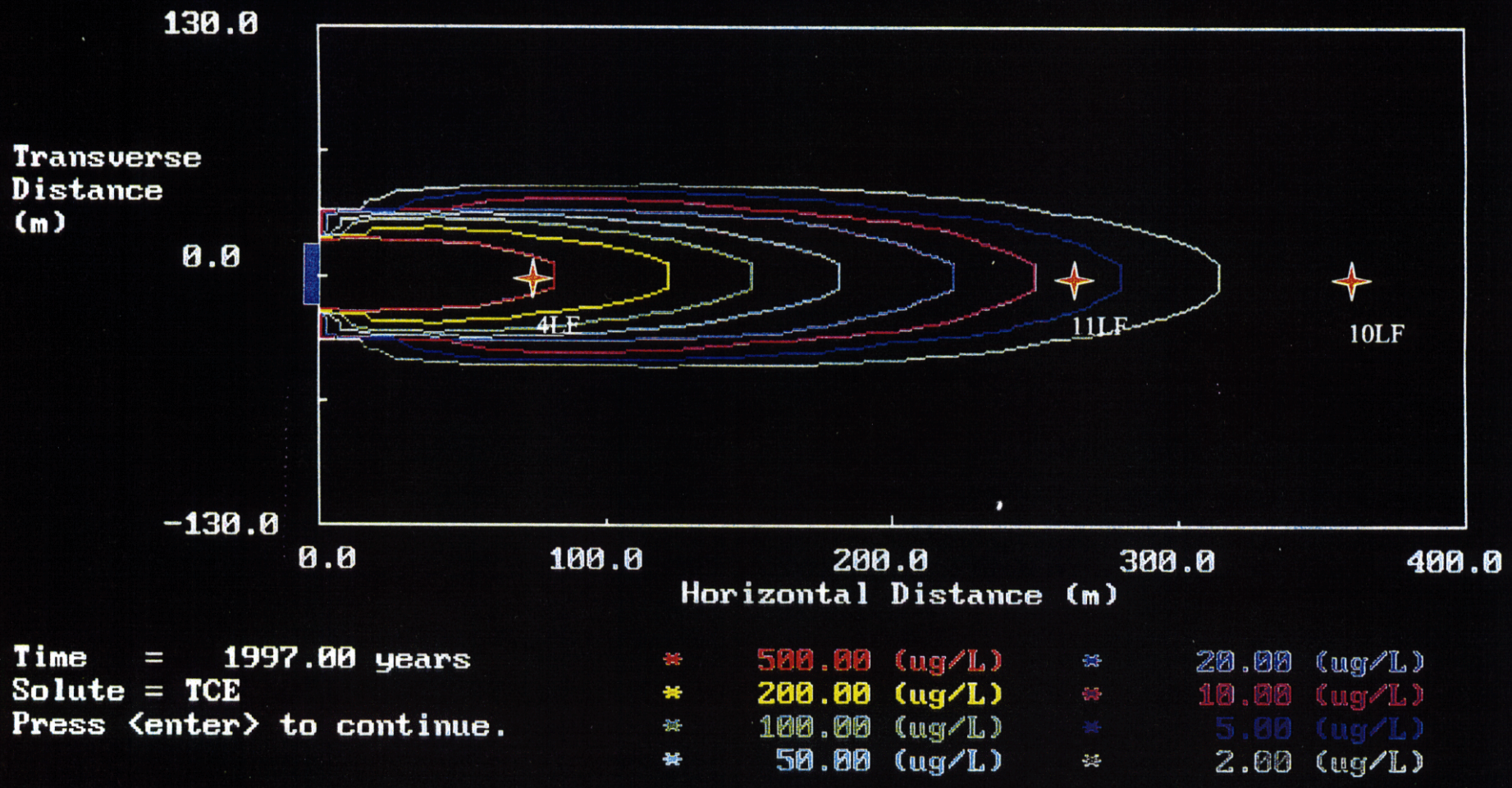
V = 7.34 m/yr

Rd = 1.4

λ = 0.13 yr^{-1} ($T_{1/2}$ = 5.3 yr)

Ton = 1945

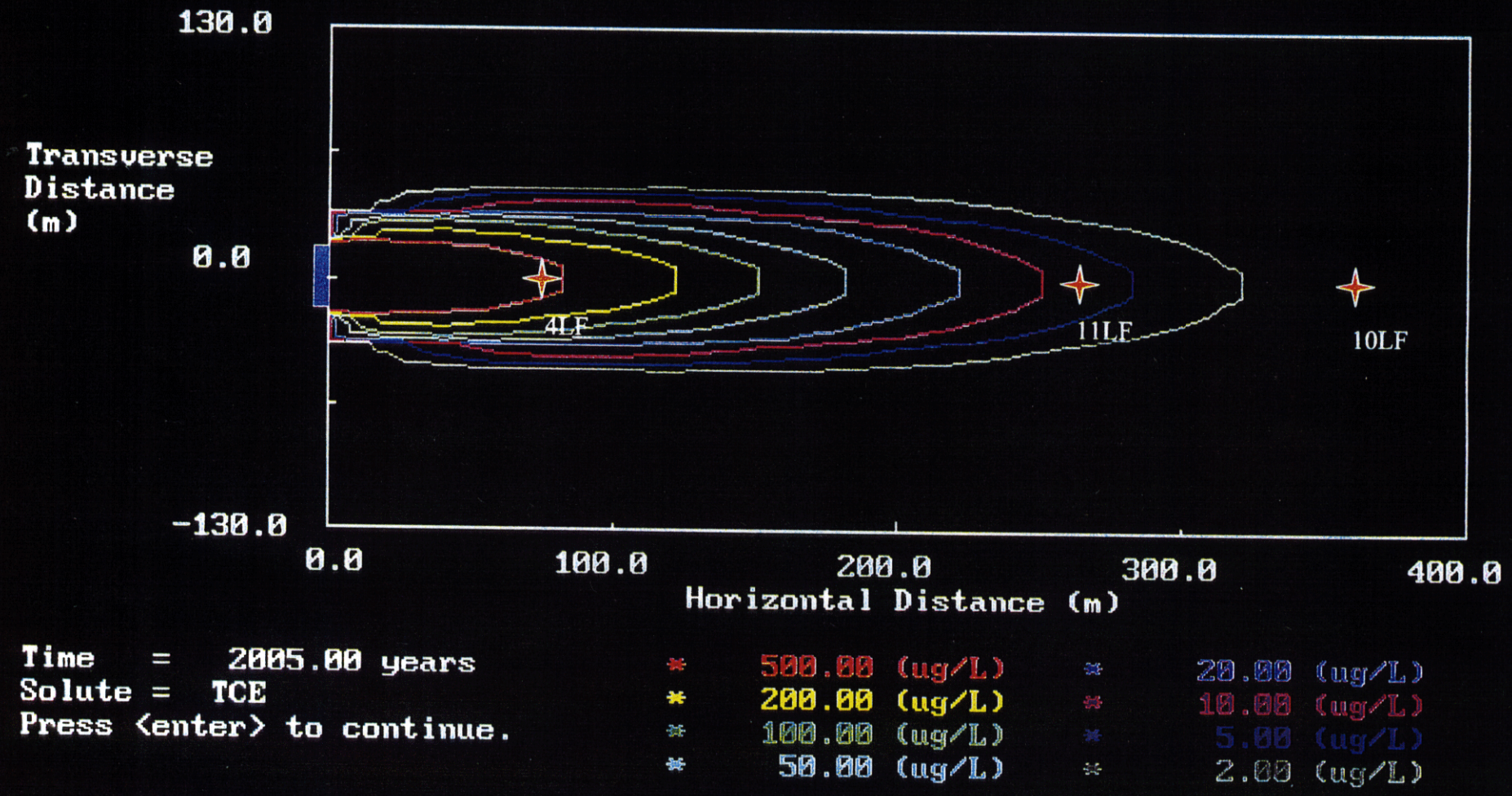
Base case: "Grassy area" source in 1997



980000

00593 CB4Y

Base case "Grassy area" source at steady state (2005)



000097

High source concentration: Input parameters

Co = 1,000,000 ug/L

Dx = 58 m^2/yr

Dy = 5.8 m^2/yr

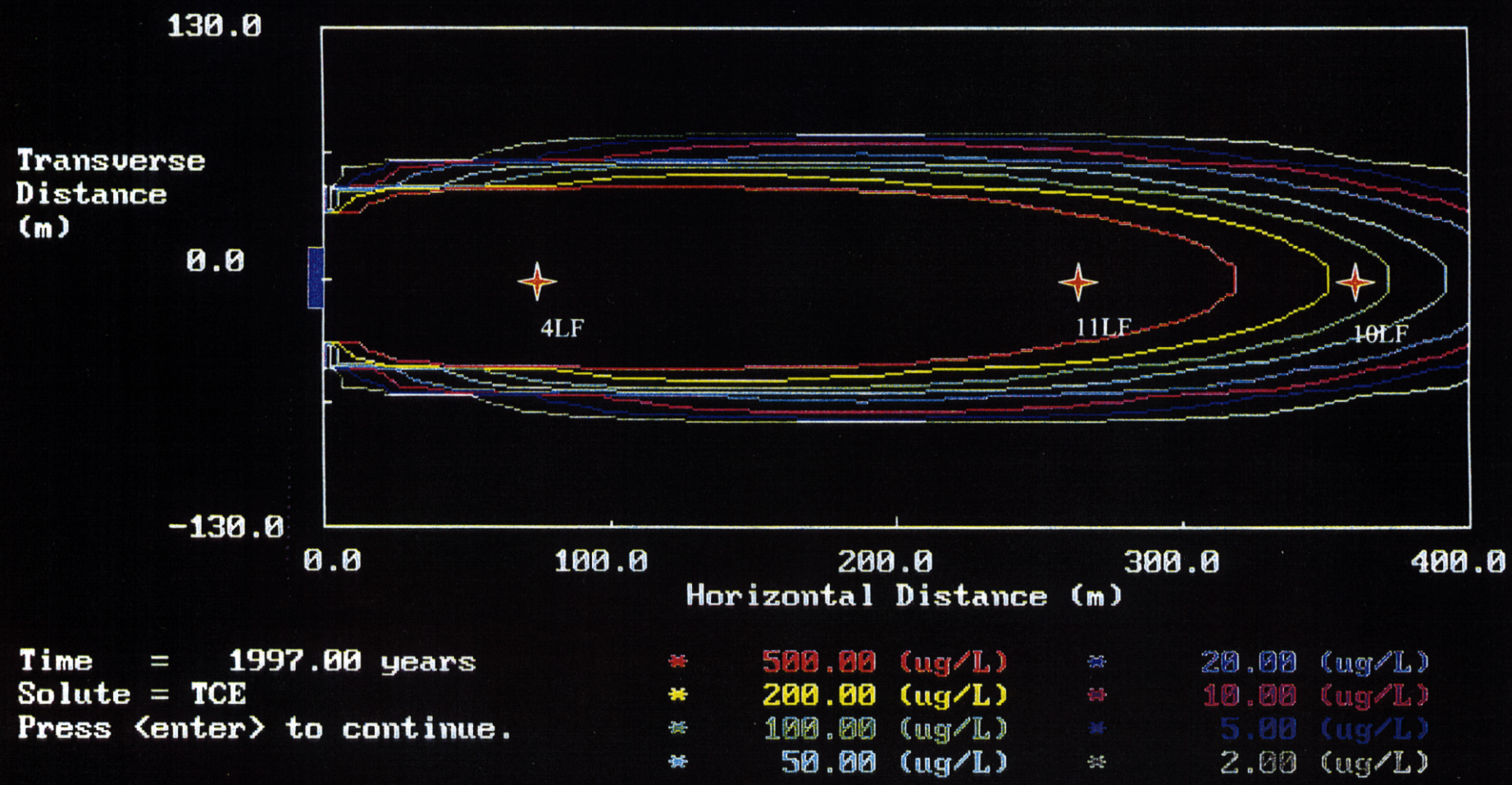
V = 7.34 m/yr

Rd = 1.4

λ = 0.13 yr^{-1} ($T_{1/2}$ = 5.3 yr)

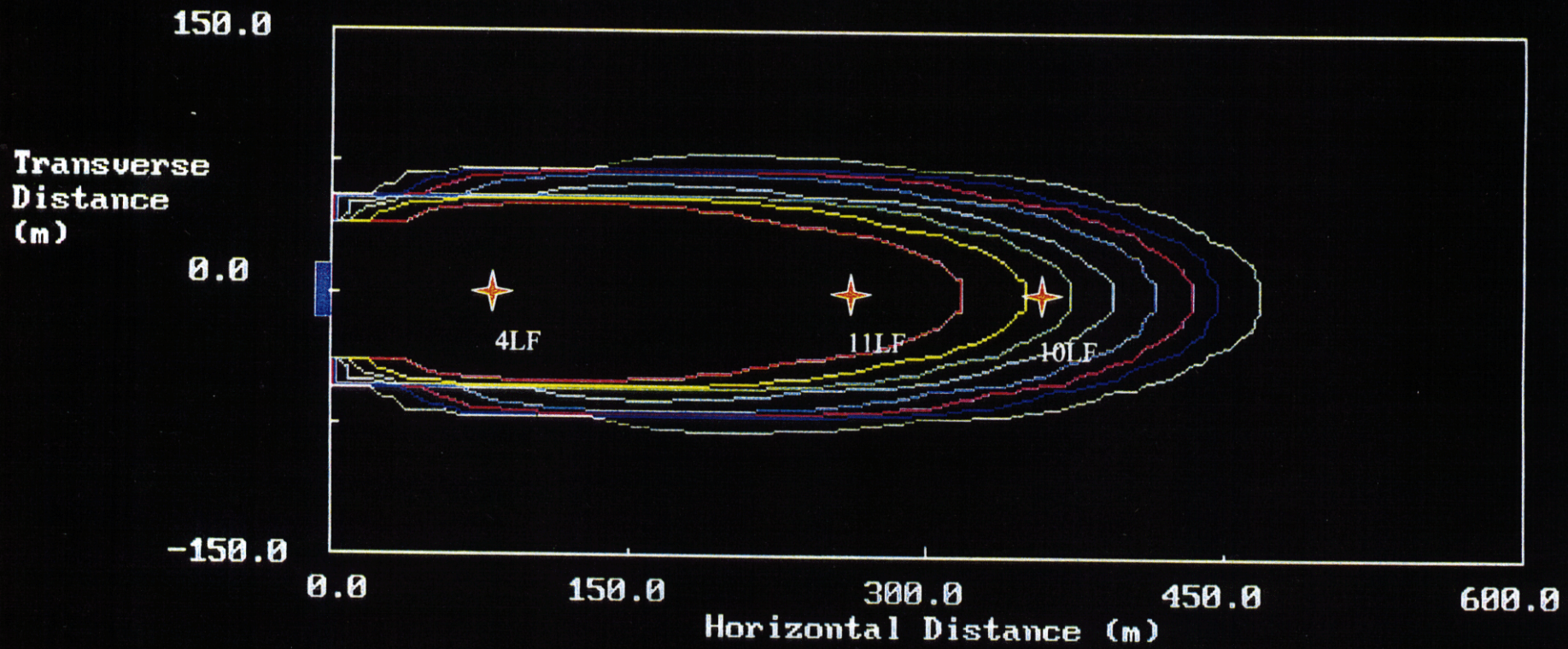
Ton = 1945

High source concentration "Grassy area" in 1997



00593 C B5Y

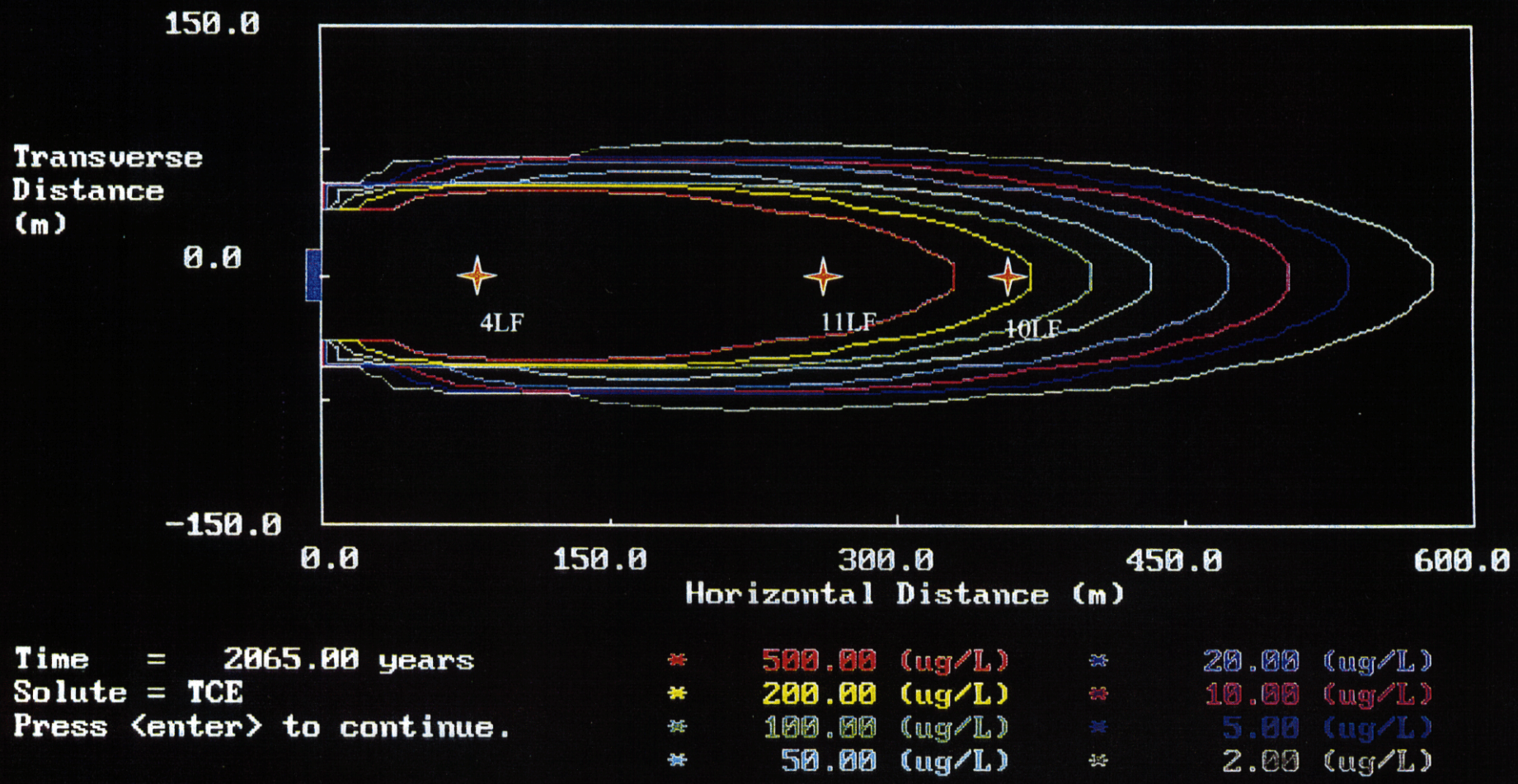
High source concentration "Grassy area" in 1997



Time = 1997.00 years
Solute = TCE
Press <enter> to continue.

*	500.00 (ug/L)	*	20.00 (ug/L)
*	200.00 (ug/L)	*	10.00 (ug/L)
*	100.00 (ug/L)	*	5.00 (ug/L)
*	50.00 (ug/L)	*	2.00 (ug/L)

High source concentration "Grassy area" at steady state (2065)



160000

Comparisons

- Co= 3,580 ug/L
- Steady state: 60 years
- Max size: 270 x 90 m
- Decay from steady state size to <5 ug/L in 36 years

- Co = 1,000,000 ug/L
- Steady state: 120 years
- Max size: 560 x 150 m
- Decay from steady state size to <5 ug/L in 75 years

000192