

Murdock, Nebraska, Groundwater Flow and Transport Modeling in Support of Long-Term Monitoring

prepared by
Environmental Research Division
Argonne National Laboratory



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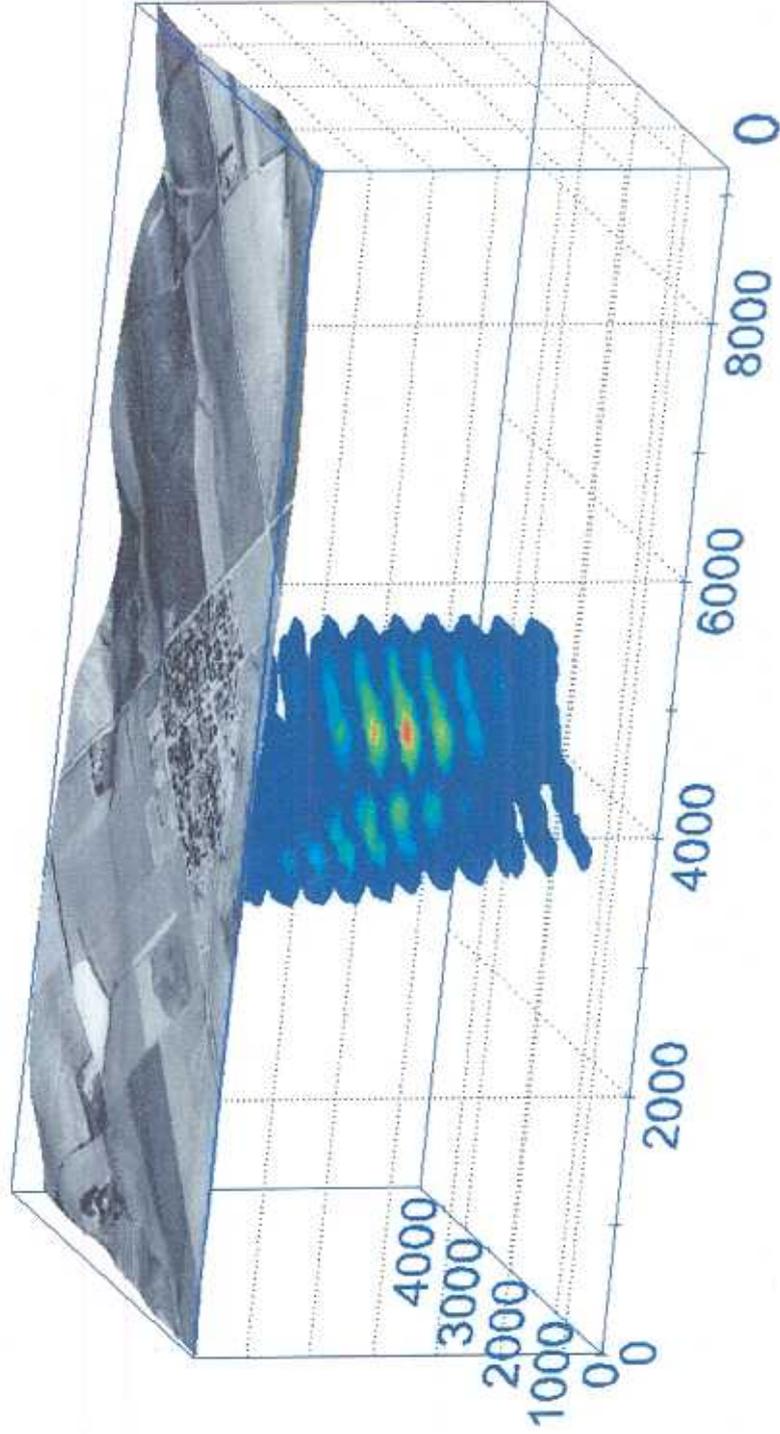
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Murdock, Nebraska, Groundwater Flow and Transport Modeling in Support of Long-Term Monitoring

by
Applied Geosciences and Environmental Management Section
Environmental Research Division, Argonne National Laboratory

January 2003

Murdock, Nebraska Groundwater Flow and Transport Modeling in Support of Long-Term Monitoring



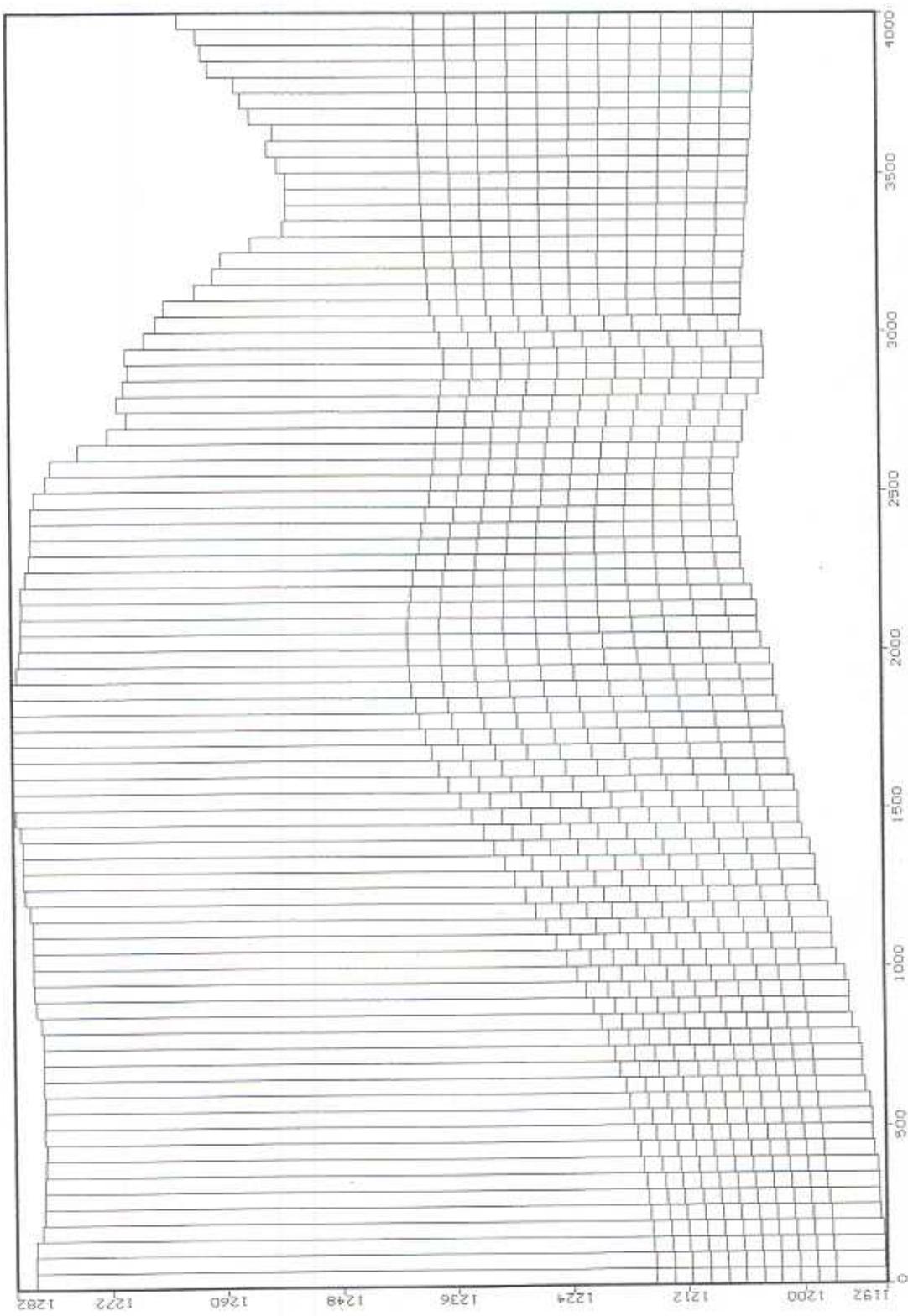
January 2003

MURDOCK, NEBRASKA GROUNDWATER FLOW AND TRANSPORT MODELING AND LONG-TERM GROUNDWATER QUALITY MONITORING RECOMMENDATIONS

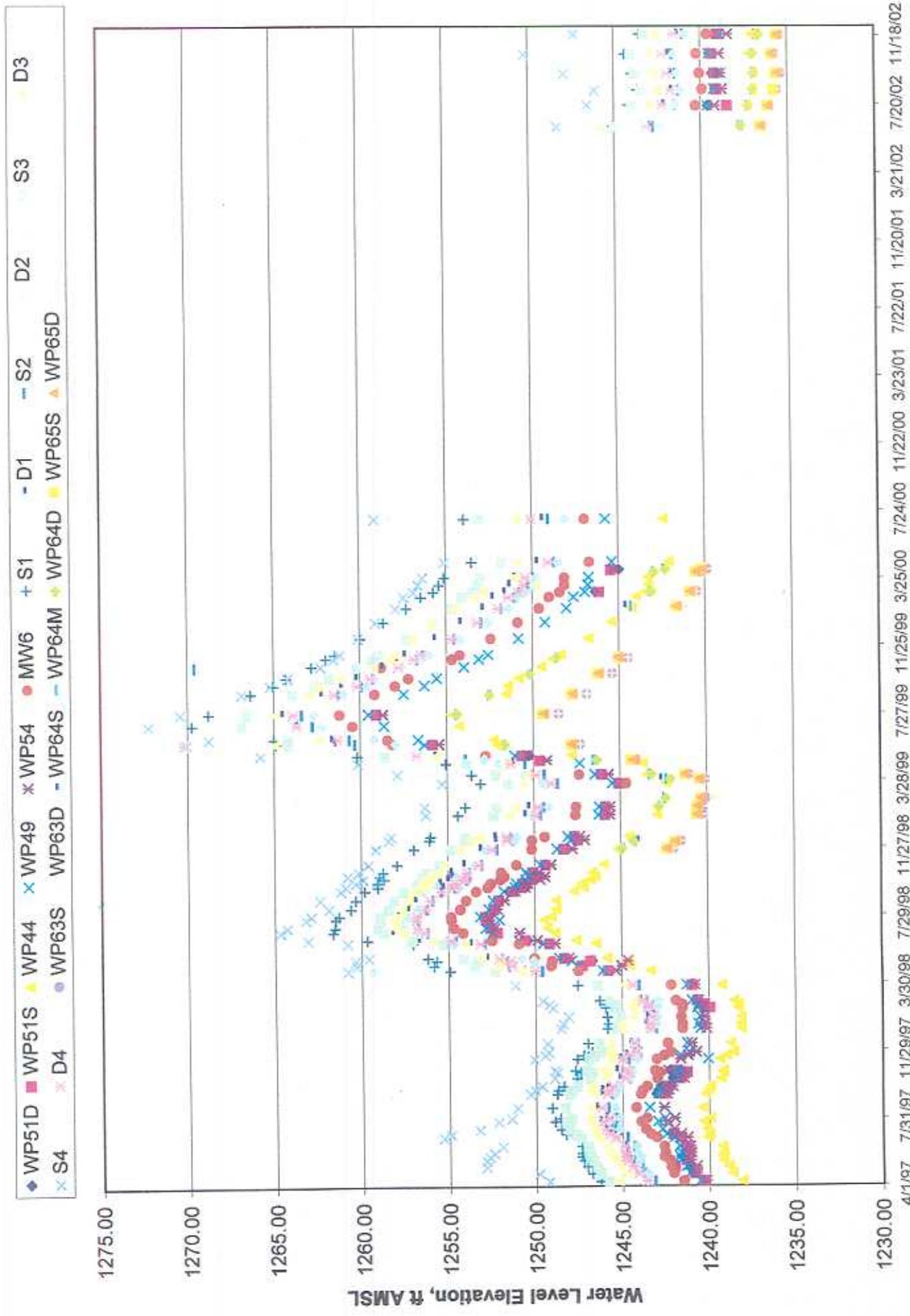
Fall 2002 Assignments

- Update all models to MODFLOW-2000
- Re-calibrate original Murdock steady-state groundwater flow model to November 25, 1998 observed water levels (Phase 1 Hydrology)
- Determine time when climatologic/hydrologic regime changed in eastern Nebraska. Groundwater levels observed in 2002 are significantly lower than all values observed previously (1997-1999). Palmer Hydrologic Drought Index
- Determine appropriate groundwater level data for calibration of new (Phase 2) groundwater flow model representing current hydrologic regime (avg. of 2002 observations)
- Re-evaluate/recalculate initial CCl_4 concentrations for MT3D-99 solute transport model calibration - 1996/97 concentration data. Too much CCl_4 mass in eastern portions of original transport model
- Re-calibrate Murdock MT3D-99 solute transport model to November 1999 observed concentrations using revised initial 1996/97 concentrations
- Include historical average concentrations at S2 as a constant concentration in transport model
- With re-calibrated solute transport model simulate CCl_4 dissolved phase transport from December 12, 1996 to December 31, 1999 with Phase 1 groundwater flow model.
- Simulate CCl_4 solute transport from January 1, 2000 to December 12, 2012 with Phase 2 groundwater flow model and CCl_4 initial conditions set at December 31, 1999 simulated values (i.e., Phase 1 model ending concentrations)
- Plot simulated CCl_4 concentration time series for all trigger action wells, and non-trigger action wells monitored during 2002 for all layers inclusive in each well screened interval
- Set the trigger action level to the maximum simulated screen interval concentration for each trigger action well
- Present results (graphs/tables - but no written report) end of January 2003





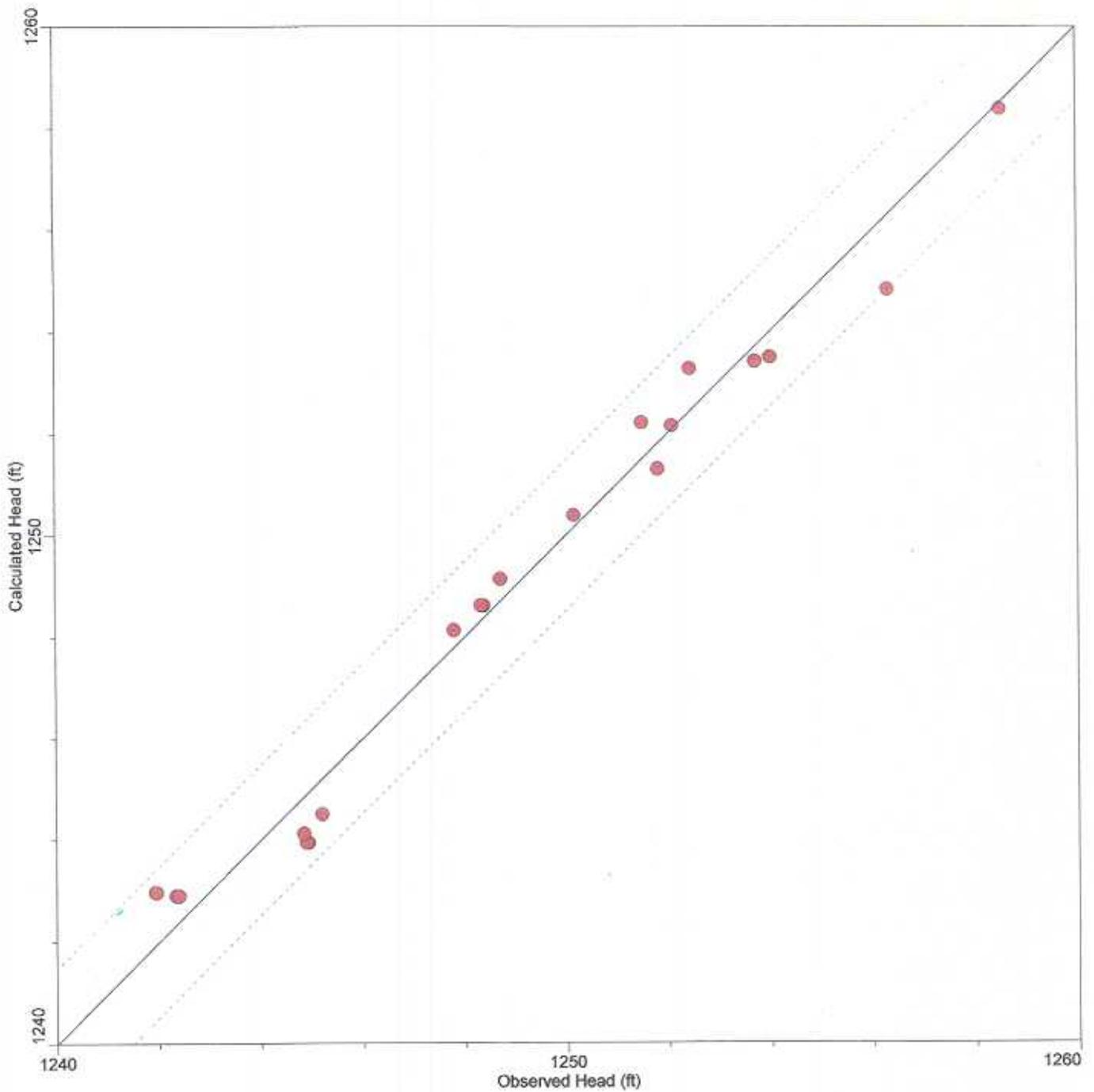
Murdock, NE Groundwater Levels



4/1/87 7/31/87 11/29/87 3/30/88 7/29/88 11/27/88 3/28/89 7/27/89 11/25/89 3/25/00 7/24/00 11/22/00 3/23/01 7/22/01 11/20/01 3/21/02 7/20/02 11/18/02

Calculated vs. Observed Head : Steady state

Calibration to November 25, 1998
groundwater water levels (original modeling)

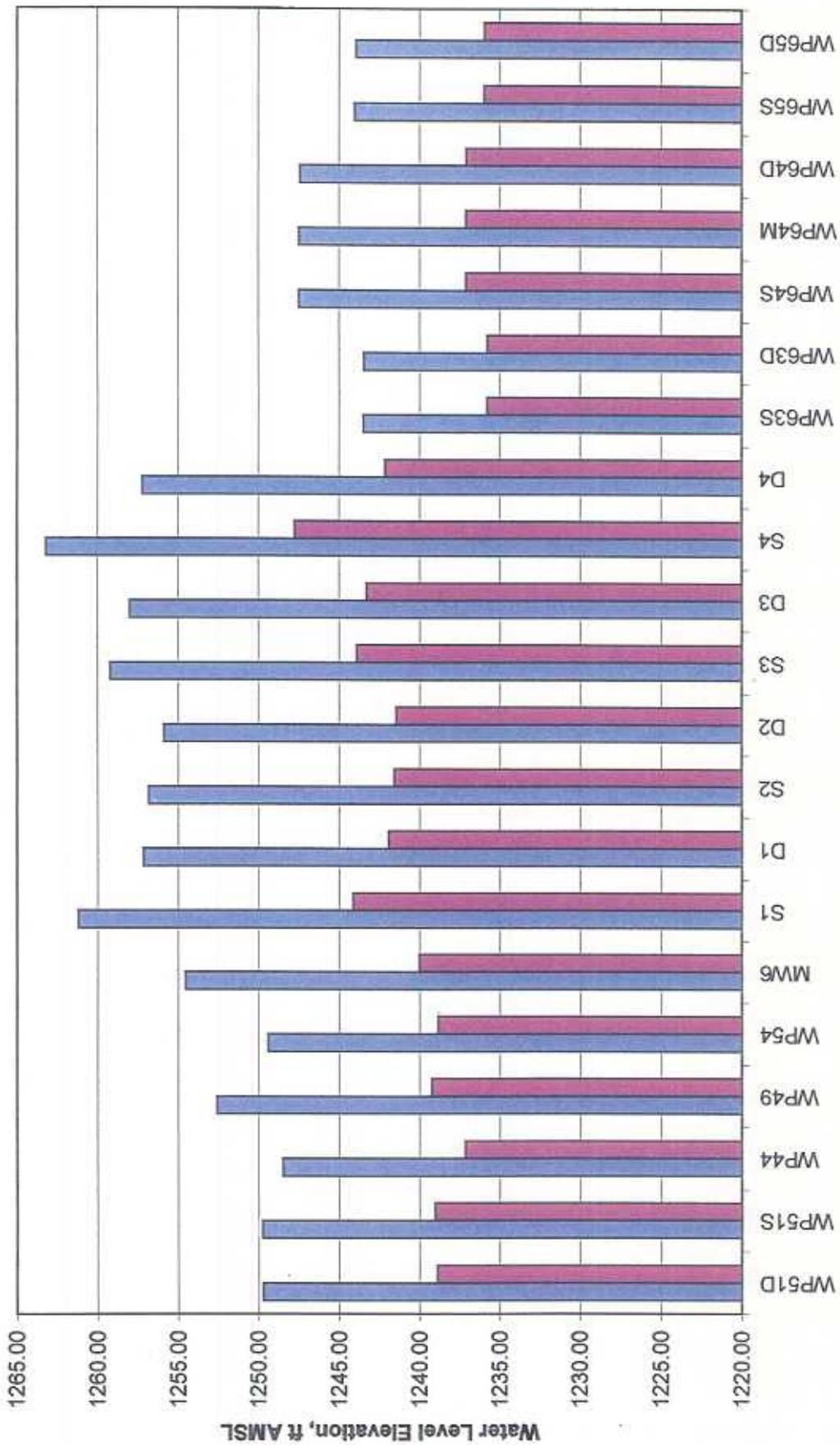


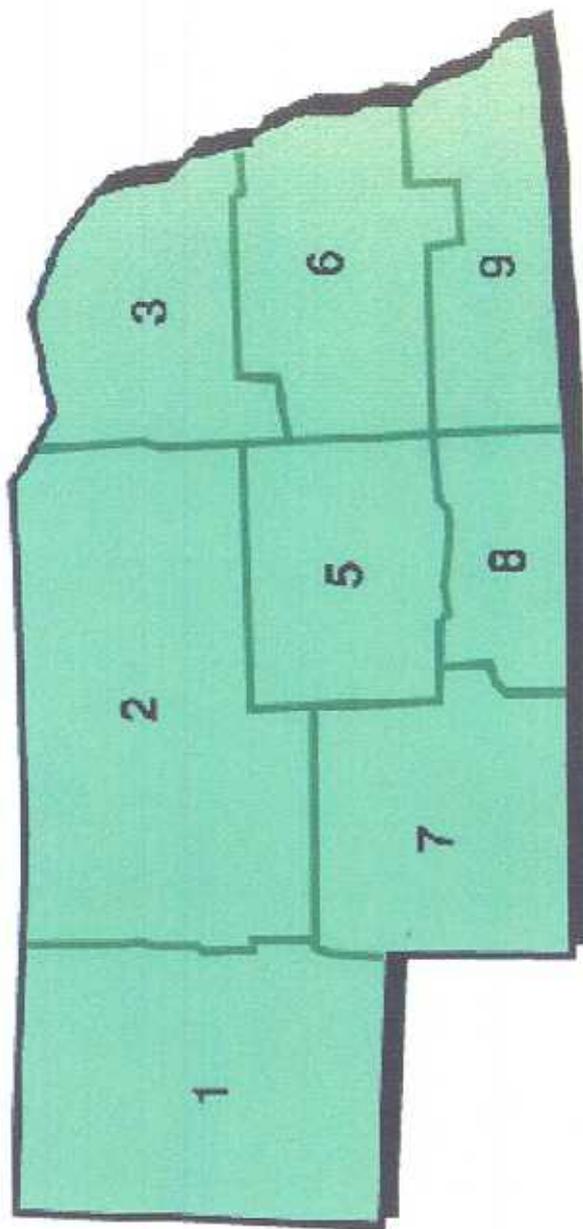
Num.Points : 21
Max. Residual: -1.462842 (ft) at S1/S1
Min. Residual: 0.06526367 (ft) at D2/D2
Residual Mean : 0.004922805 (ft)
Absolute Residual Mean : 0.5984584 (ft)

Standard Error of the Estimate : 0.1549392 (ft)
Root mean squared : 0.6929269 (ft)
Normalized RMS : 4.181816 (%)

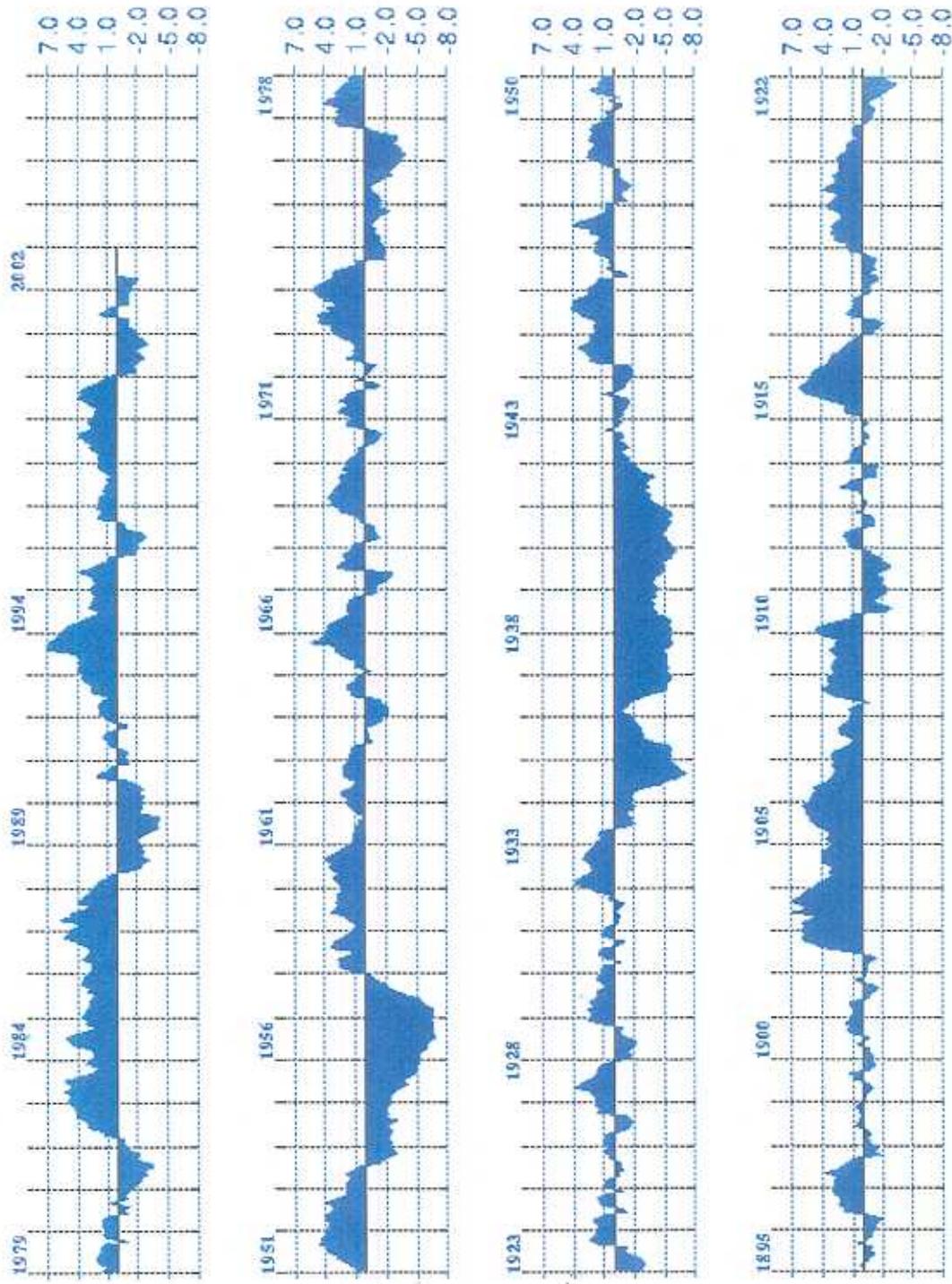
Murdock, NE Groudwater Levels

■ 1999 Average ■ 2002 Average



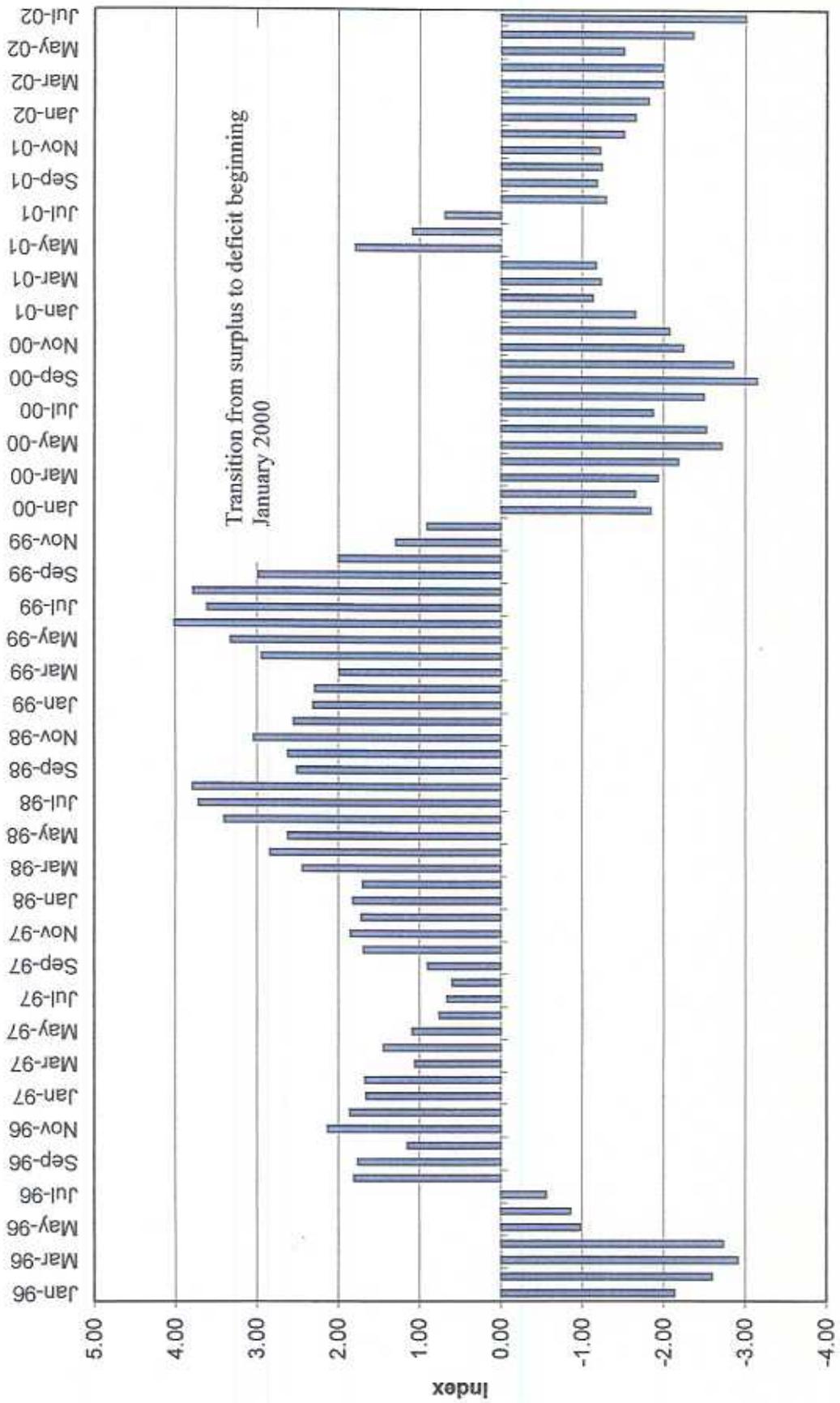


Palmer Hydrological Drought Index



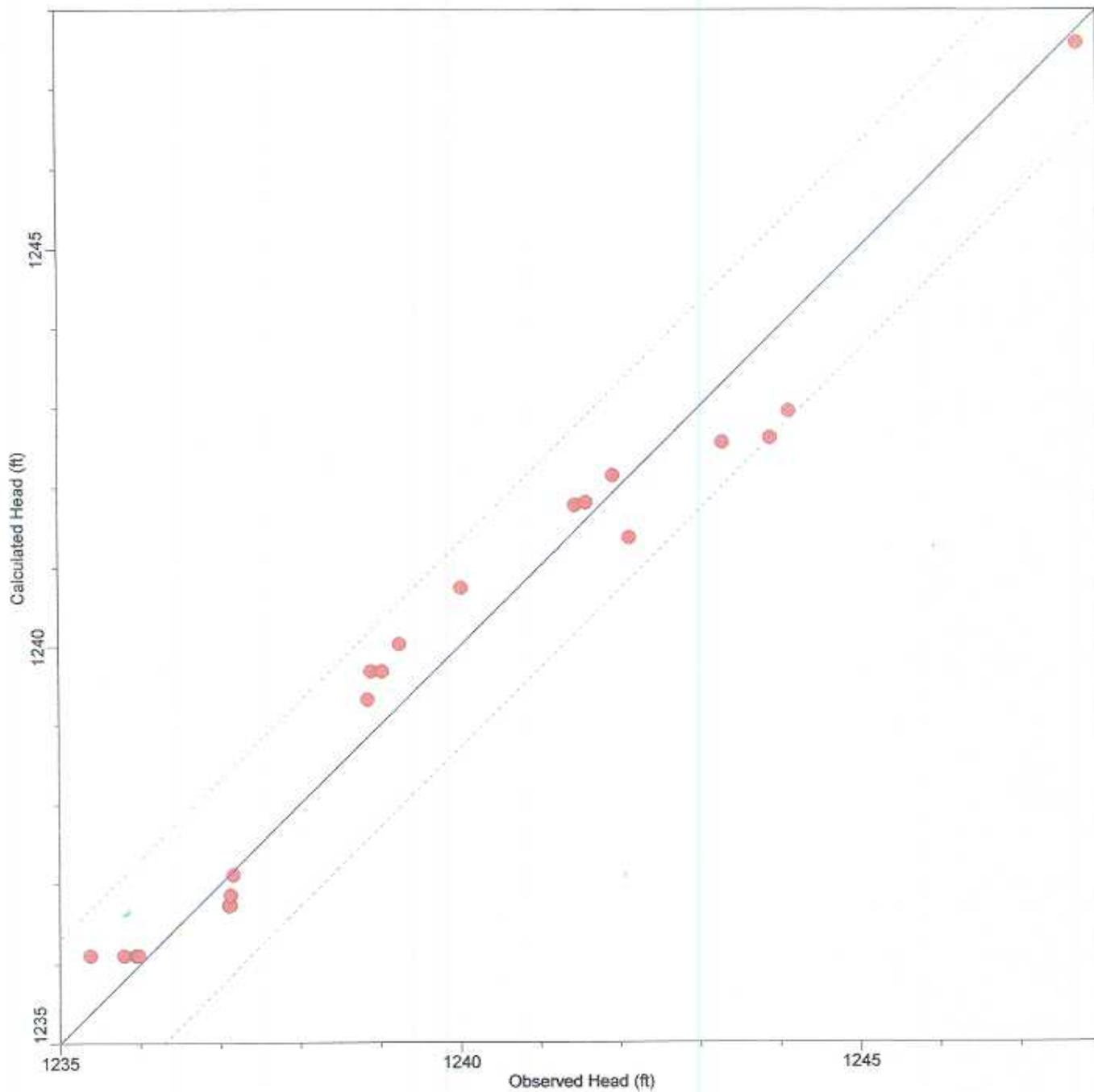
Nebraska - Division 06: 1895-2002 (Monthly Averages)

Palmer Hydrologic Drought Index
Nebraska Division 6



Calculated vs. Observed Head : Steady state

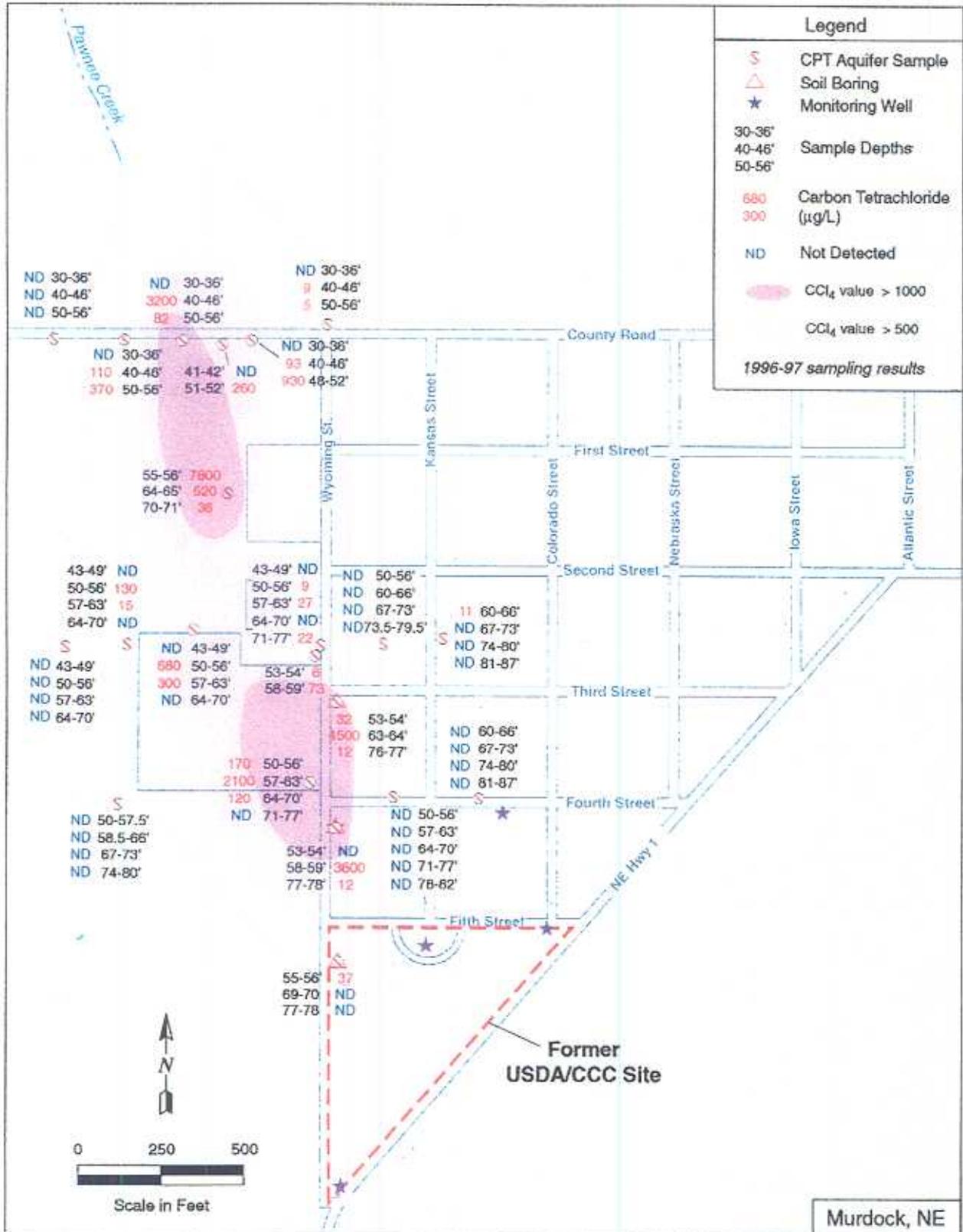
Calibration to average observed 2002 groundwater levels



Num.Points : 21
Max. Residual: -1.27854 (ft) at S3/S3
Min. Residual: -0.04317871 (ft) at WP44/WP44
Residual Mean : 0.01155576 (ft)
Absolute Residual Mean : 0.5081736 (ft)

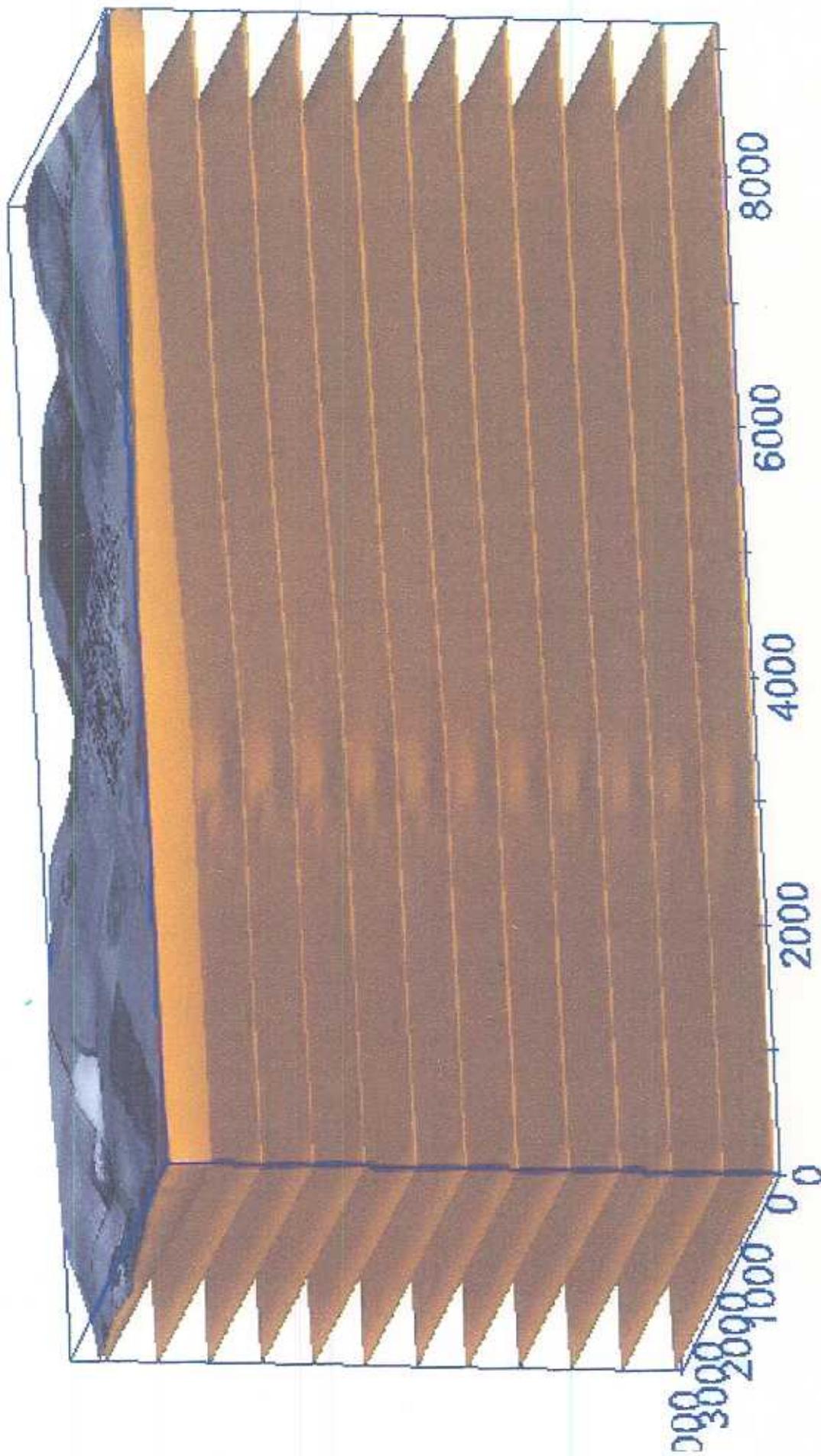
Standard Error of the Estimate : 0.1360946 (ft)
Root mean squared : 0.6087433 (ft)
Normalized RMS : 4.921126 (%)

Initial CCl₄ concentration distribution for transport model calibration

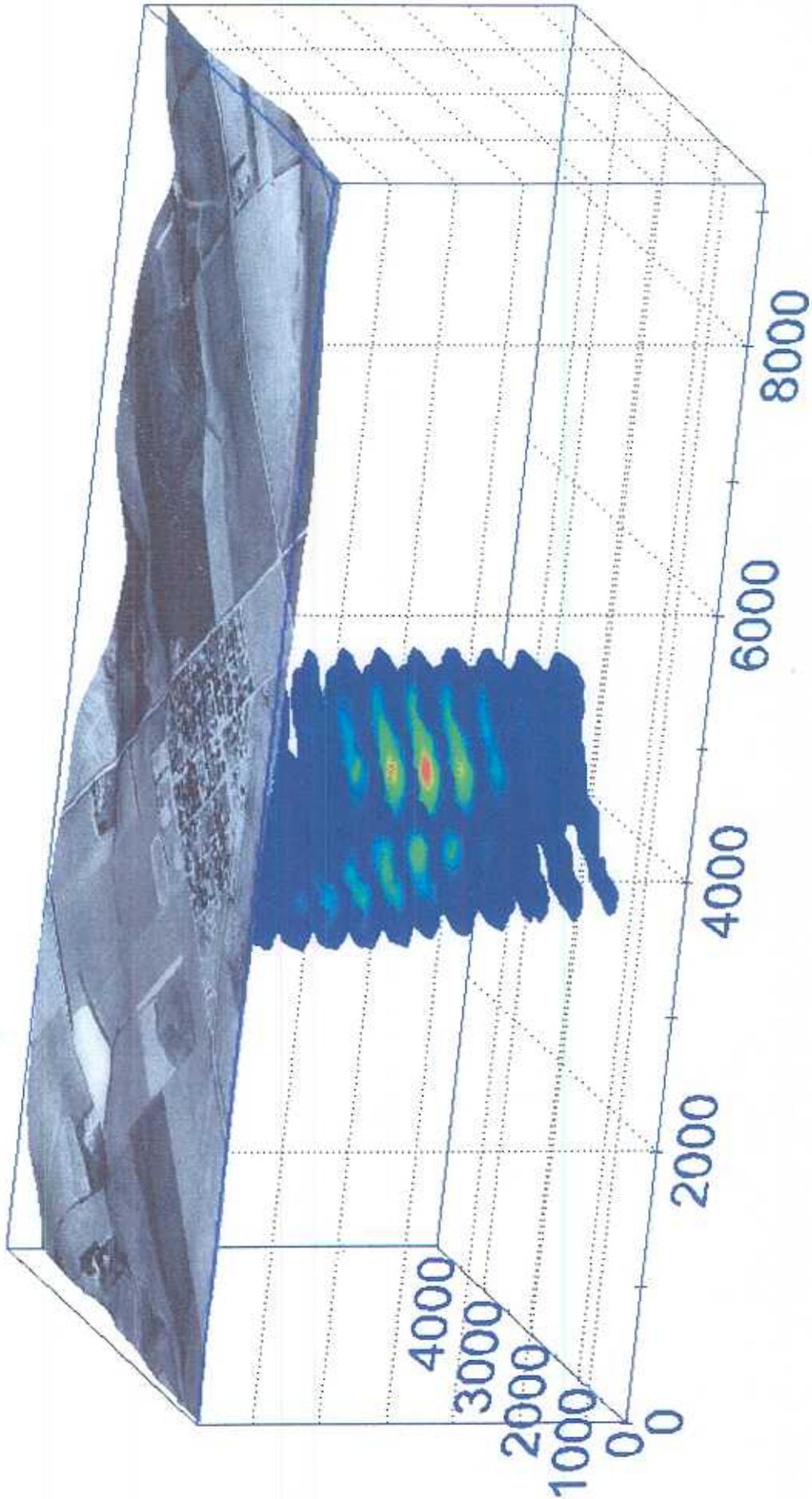


Murdock Monitoring Program -- CCl₄ and ChCl₃

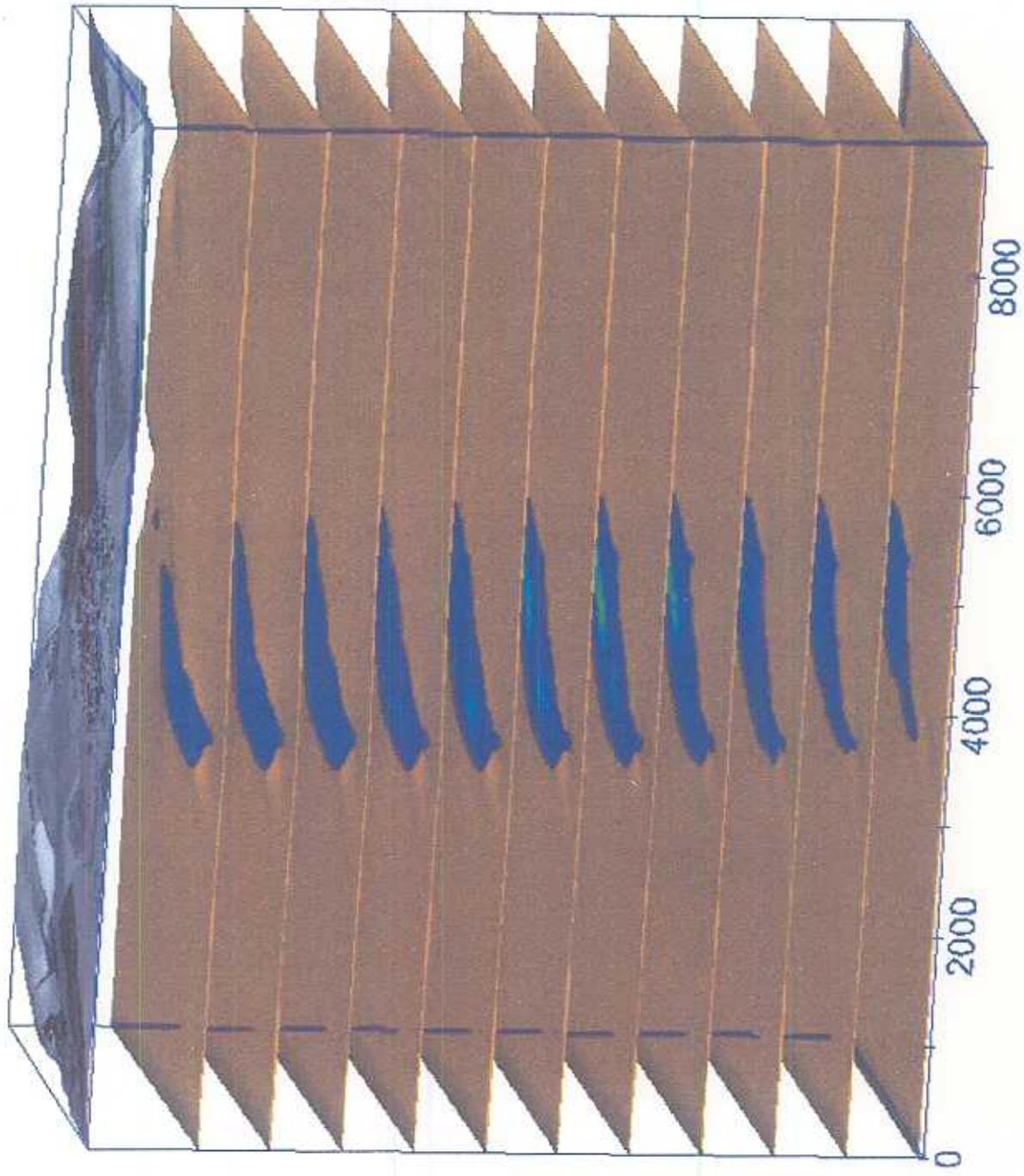
ID	Grid X (ft)	Grid Y (ft)	Measuring Pt. Elevation (ft AMSL)	Depth From (ft)	Depth To (ft)	Midpoint Depth (ft)	Midpoint Elev. (ft AMSL)	Date	Type	CCl ₄ ug/L CLP	Layer	Row	Col
SB05	3188.73	987.62	1281.76	55	56	55.5	1226.26	12/11/1996	CPT	37	2	61	27
SB57	3589.84	1444.55	1281.96	50	56	53.0	1228.96	3/11/1997	CPT	170	3	52	35
SB19	3834.21	1550.47	1285.95	53	54	53.5	1232.45	12/10/1996	CPT	32	4	49	40
SB51	3930.67	1700.31	1284.25	50	56	53.0	1231.25	3/11/1997	CPT	9	4	46	42
SB42	3904.41	1663.85	1284.01	53	54	53.5	1230.51	12/12/1996	CPT	6	4	47	42
SB49	4186.31	1428.82	1287.87	60	66	63.0	1224.87	3/10/1997	CPT	11	4	52	47
SB53	3711.18	2018.84	1282.82	50	56	53.0	1229.82	2/19/1997	CPT	680	5	40	38
SB06	3508.54	1259.45	1282.12	58	59	58.5	1223.62	12/12/1996	CPT	3600	5	55	34
SB57	3589.84	1444.55	1281.96	57	63	60.0	1221.96	3/11/1997	CPT	2200	5	52	35
SB54	3544.83	2140.47	1281.60	50	56	53.0	1228.60	2/17/1997	CPT	130	6	38	34
SB42	3804.41	1663.85	1284.01	58	59	58.5	1225.51	12/12/1996	CPT	73	6	47	42
SB51	3930.67	1700.31	1284.25	57	63	60.0	1224.25	3/11/1997	CPT	27	6	46	42
SB53	3711.18	2018.84	1282.82	57	63	60.0	1222.82	2/19/1997	CPT	300	7	40	38
SB19	3834.21	1550.47	1285.95	63	64	63.5	1222.45	12/10/1996	CPT	4500	7	49	40
SB29	4100.52	2216.47	1277.23	55	56	55.5	1221.73	12/12/1996	CPT	7800	7	36	46
SB54	3544.83	2140.47	1281.60	57	63	60.0	1221.60	2/17/1997	CPT	15	7	38	34
SB57	3589.84	1444.55	1281.96	64	70	67.0	1214.96	3/11/1997	CPT	120	7	52	35
SB44	4679.03	2324.11	1266.20	40	46	43.0	1223.20	3/6/1997	CPT	9	8	34	57
SB46	4372.48	2640.94	1263.96	40	46	43.0	1220.96	3/5/1997	CPT	3200	8	28	51
SB47	4259.06	2773.60	1263.81	40	46	43.0	1220.81	3/5/1997	CPT	110	8	25	49
SB45	4510.51	2483.03	1262.23	40	46	43.0	1219.23	3/5/1997	CPT	93	9	31	54
SB29	4100.52	2216.47	1277.23	64	65	64.5	1212.73	12/12/1996	CPT	520	10	36	46
SB51	3930.67	1700.31	1284.25	71	77	74.0	1210.25	3/12/1997	CPT	22	10	46	42
SB47	4259.06	2773.60	1263.81	50	56	53.0	1210.81	3/5/1997	CPT	370	11	25	49
SB19	3834.21	1550.47	1285.95	76	77	76.5	1209.45	12/10/1996	CPT	12	11	49	40
SB06	3508.54	1259.45	1282.12	77	78	77.5	1204.62	12/12/1996	CPT	12	11	55	34
SB44	4679.03	2324.11	1266.20	50	56	53.0	1213.20	3/6/1997	CPT	5	12	34	57
SB45	4510.51	2483.03	1262.23	48	52	50.0	1212.23	3/5/1997	CPT	930	12	31	54
SB46	4372.48	2640.94	1263.96	50	56	53.0	1210.96	3/5/1997	CPT	82	12	28	51
SB25	4477.31	2562.33	1262.12	51	52	51.5	1210.62	12/11/1996	CPT	260	12	29	53
SB29	4100.52	2216.47	1277.23	70	71	70.5	1206.73	12/12/1996	CPT	36	12	36	46
MW06	3514.09	1266.47	1282.12	78	83	80.5	1201.62	12/10/1996	MW	8	12	55	34

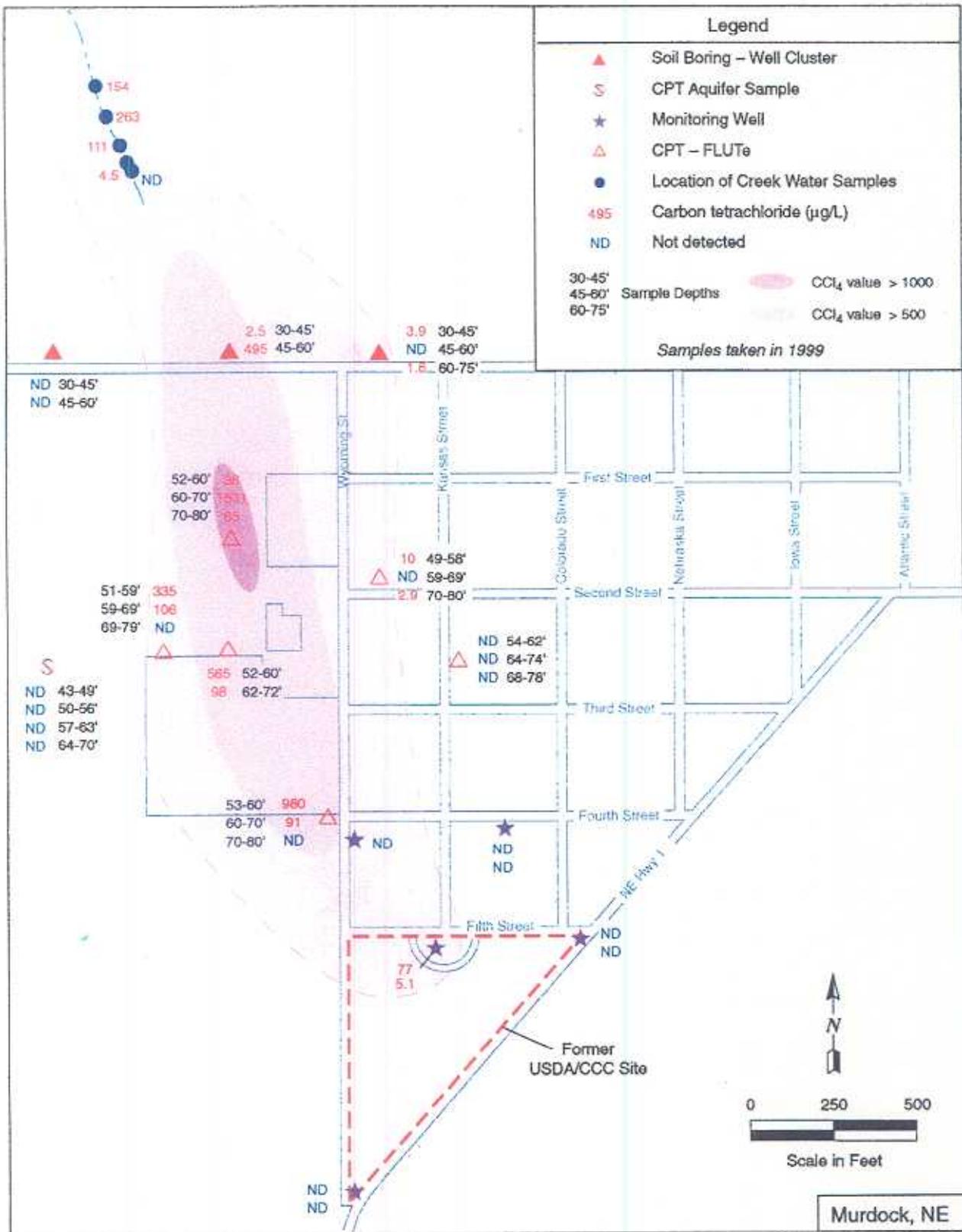


Initial CCl_4 concentrations for MT3D-99 transport modeling by model layer

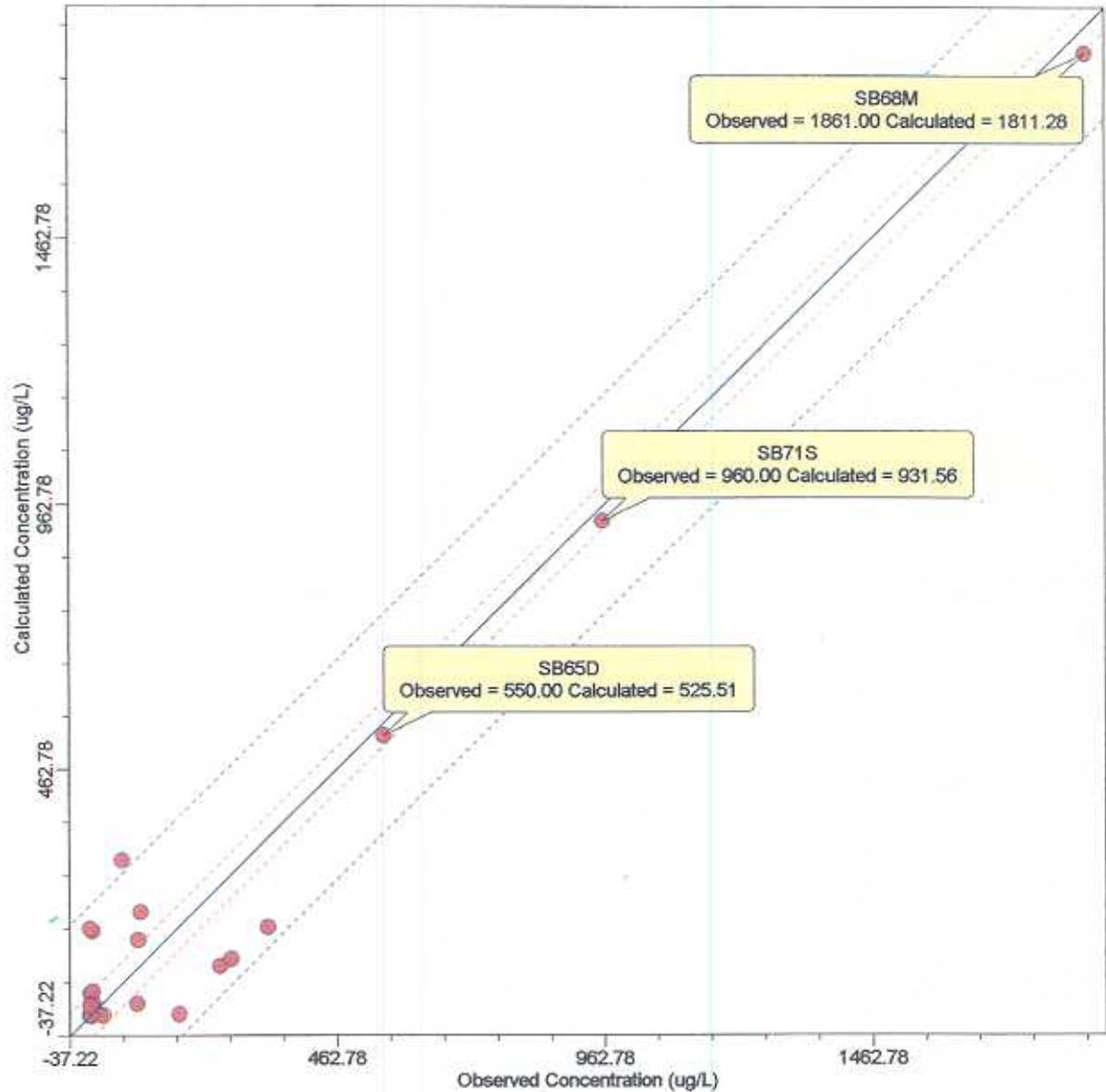
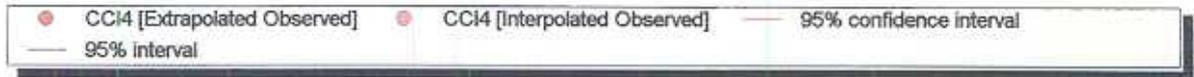


1996/97 CCl₄ concentrations mapped to model grid structure for initial conditions





Calculated vs. Observed Concentration : Time = 1056 days



Num. Points : 24

Max. Residual: 230.3179 (ug/L) at SB71M/SB71M

Min. Residual: 0.07512894 (ug/L) at SB63S/SB63S

Residual Mean : -0.5727512 (ug/L)

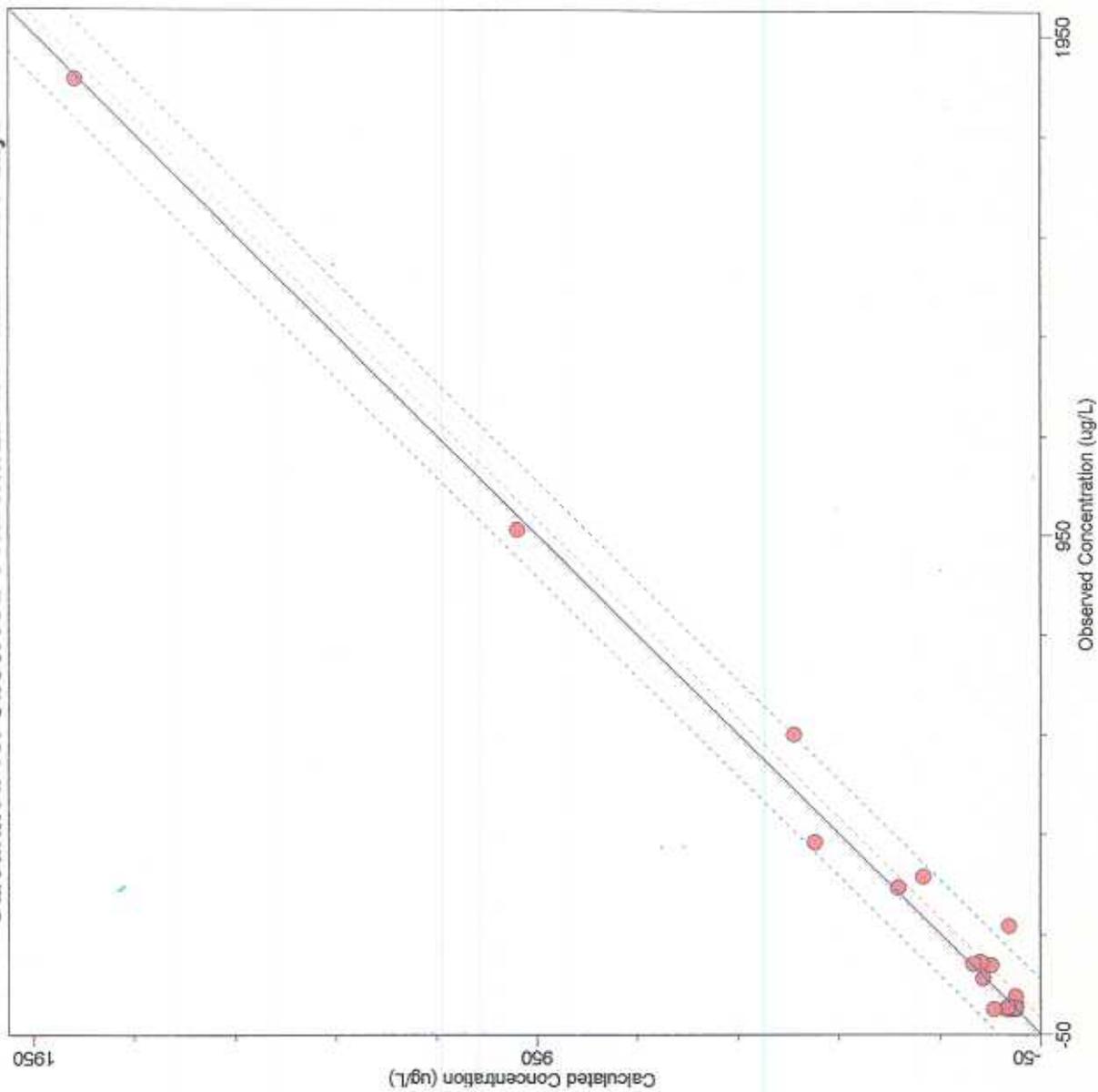
Absolute Residual Mean : 69.42724 (ug/L)

Standard Error of the Estimate : 20.49186 (ug/L)

Root mean squared : 98.27717 (ug/L)

Normalized RMS : 5.280879 (%)

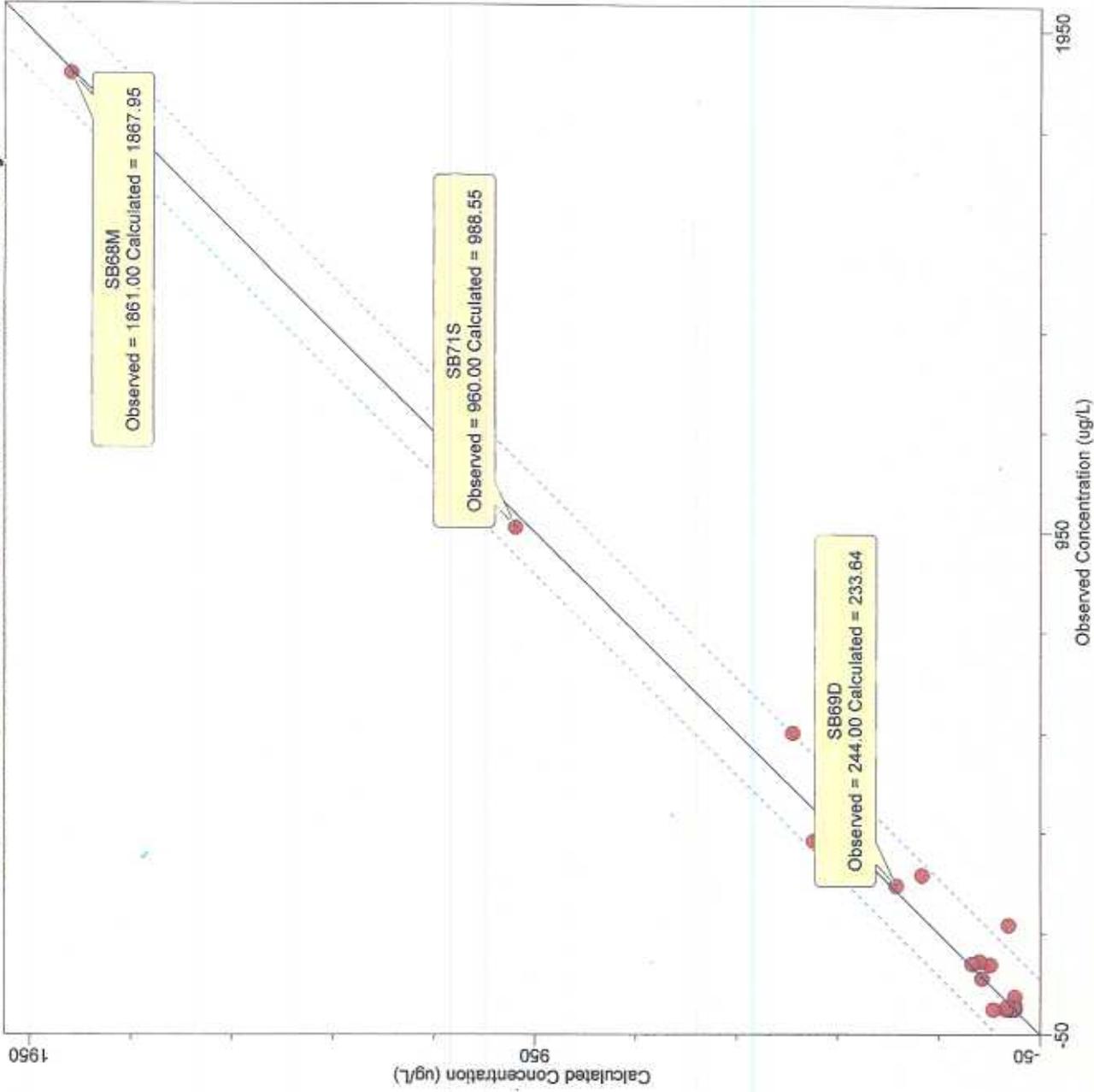
Calculated vs. Observed Concentration : Time = 1056 days



Num. Points : 24
Max. Residual: -154.5781 (ug/L) at SB72S/SB72S
Min. Residual: -0.008305454 (ug/L) at SB65S/SB65S
Residual Mean : -11.70134 (ug/L)
Absolute Residual Mean : 27.50025 (ug/L)

Standard Error of the Estimate : 9.522373 (ug/L)
Root mean squared : 47.14297 (ug/L)
Normalized RMS : 2.533207 (%)

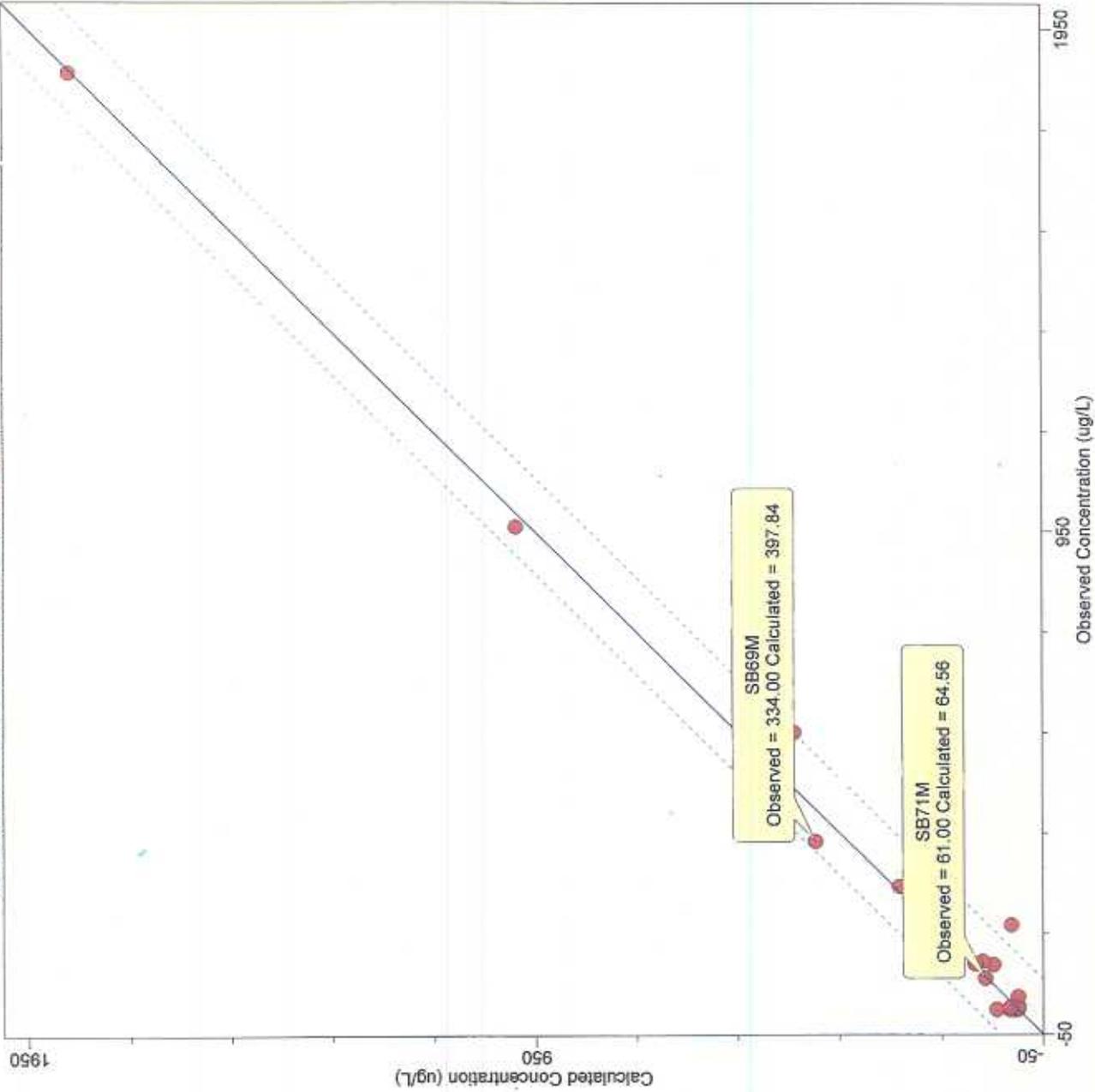
Calculated vs. Observed Concentration : Time = 1056 days



Num. Points : 24
Max. Residual: -154.5781 (ug/L) at SB72S/SB72S
Min. Residual: -0.009305454 (ug/L) at SB65S/SB65S
Residual Mean : -11.70134 (ug/L)
Absolute Residual Mean : 27.50025 (ug/L)

Standard Error of the Estimate : 9.522373 (ug/L)
Root mean squared : 47.14297 (ug/L)
Normalized RMS : 2.533207 (%)

Calculated vs. Observed Concentration : Time = 1056 days



Num. Points : 24
Max. Residual: -154.5781 (ug/L) at SB72S/SB72S
Min. Residual: -0.009305454 (ug/L) at SB65S/SB65S
Residual Mean : -11.70134 (ug/L)
Absolute Residual Mean : 27.50025 (ug/L)

Standard Error of the Estimate : 9.522373 (ug/L)
Root mean squared : 47.14297 (ug/L)
Normalized RMS : 2.533207 (%)

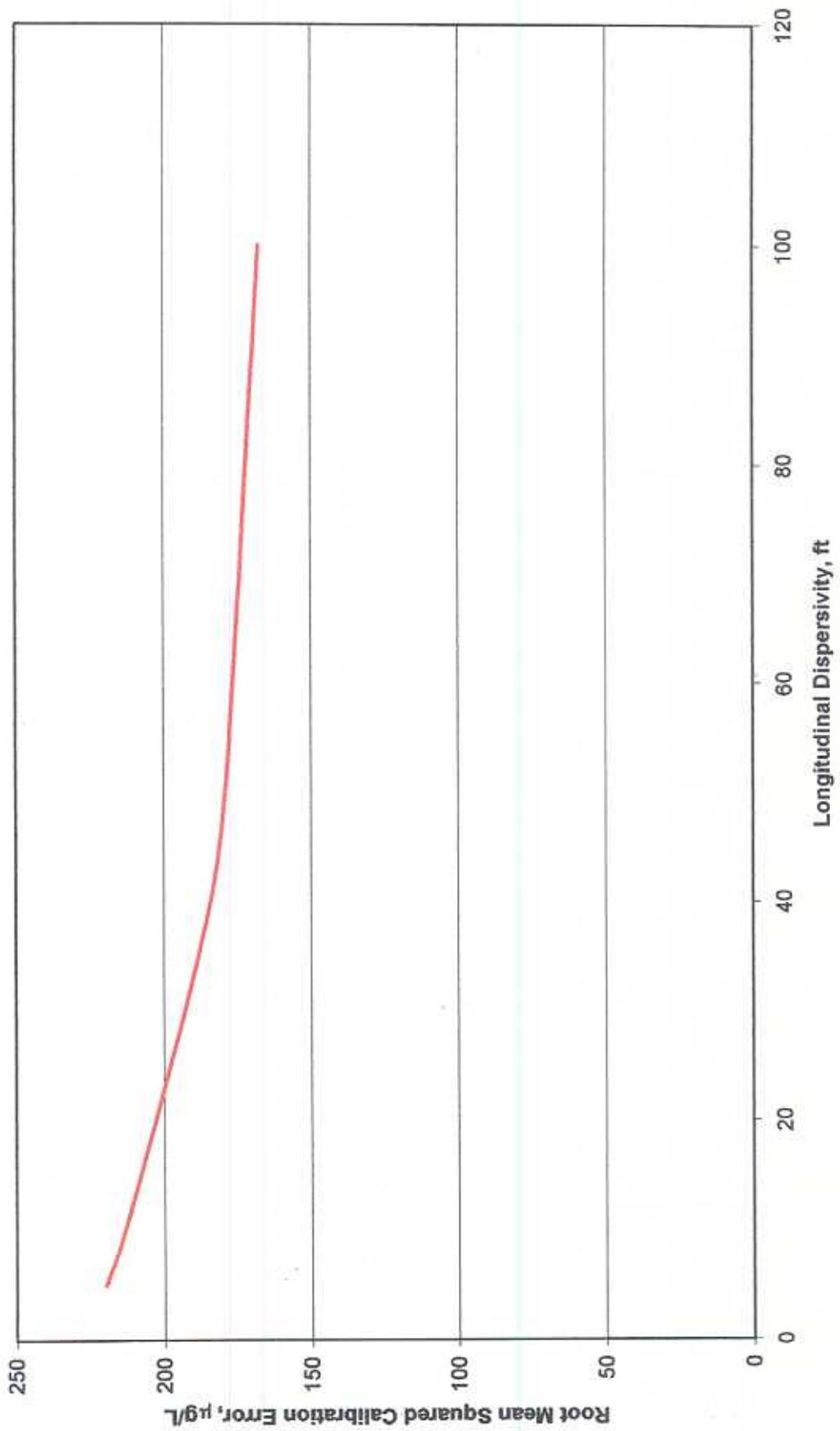
Model	Stratigraphic Unit	Effective Porosity ¹	Total Porosity ²	Longitudinal Dispersivity ft	Transverse Dispersivity ft	Vertical Dispersivity ft	Bulk Density lb/ft ³	K _d ft ² /lb	K _d L/μg	Retardation Factor
Layer 1	Silt/Clay	0.32	0.39	34.8	1.0	0.0	101.0	7.337E-03	4.580E-10	2.90
Layer 2	Sand	0.25	0.40	34.8	1.0	0.0	99.3	7.654E-03	4.778E-10	2.90
Layer 3	Sand	0.24	0.43	34.8	1.0	0.0	94.6	8.636E-03	5.391E-10	2.90
Layer 4	Sand	0.25	0.43	34.8	1.0	0.0	94.6	8.636E-03	5.391E-10	2.90
Layer 5	Sand	0.27	0.40	34.8	1.0	0.0	98.9	7.685E-03	4.797E-10	2.90
Layer 6	Sand	0.28	0.42	34.8	1.0	0.0	95.3	8.374E-03	5.227E-10	2.90
Layer 7	Sand	0.28	0.39	34.8	1.0	0.0	99.9	7.417E-03	4.630E-10	2.90
Layer 8	Sand	0.27	0.40	34.8	1.0	0.0	98.5	7.716E-03	4.817E-10	2.90
Layer 8	Clay	0.33	0.41	34.8	1.0	0.0	96.8	8.048E-03	5.024E-10	2.90
Layer 9	Sand	0.28	0.41	34.8	1.0	0.0	96.8	8.048E-03	5.024E-10	2.90
Layer 9	Clay	0.33	0.41	34.8	1.0	0.0	96.8	8.048E-03	5.024E-10	2.90
Layer 10	Sand	0.27	0.42	34.8	1.0	0.0	96.4	8.278E-03	5.168E-10	2.90
Layer 11	Sand	0.28	0.37	34.8	1.0	0.0	103.3	6.805E-03	4.248E-10	2.90
Layer 12	Sand	0.25	0.43	34.8	1.0	0.0	94.7	8.627E-03	5.386E-10	2.90

¹Estimated from de Marsily, G., 1986, *Quantitative Hydrogeology*, Academic Press, Inc., Orlando, FL, p. 36.

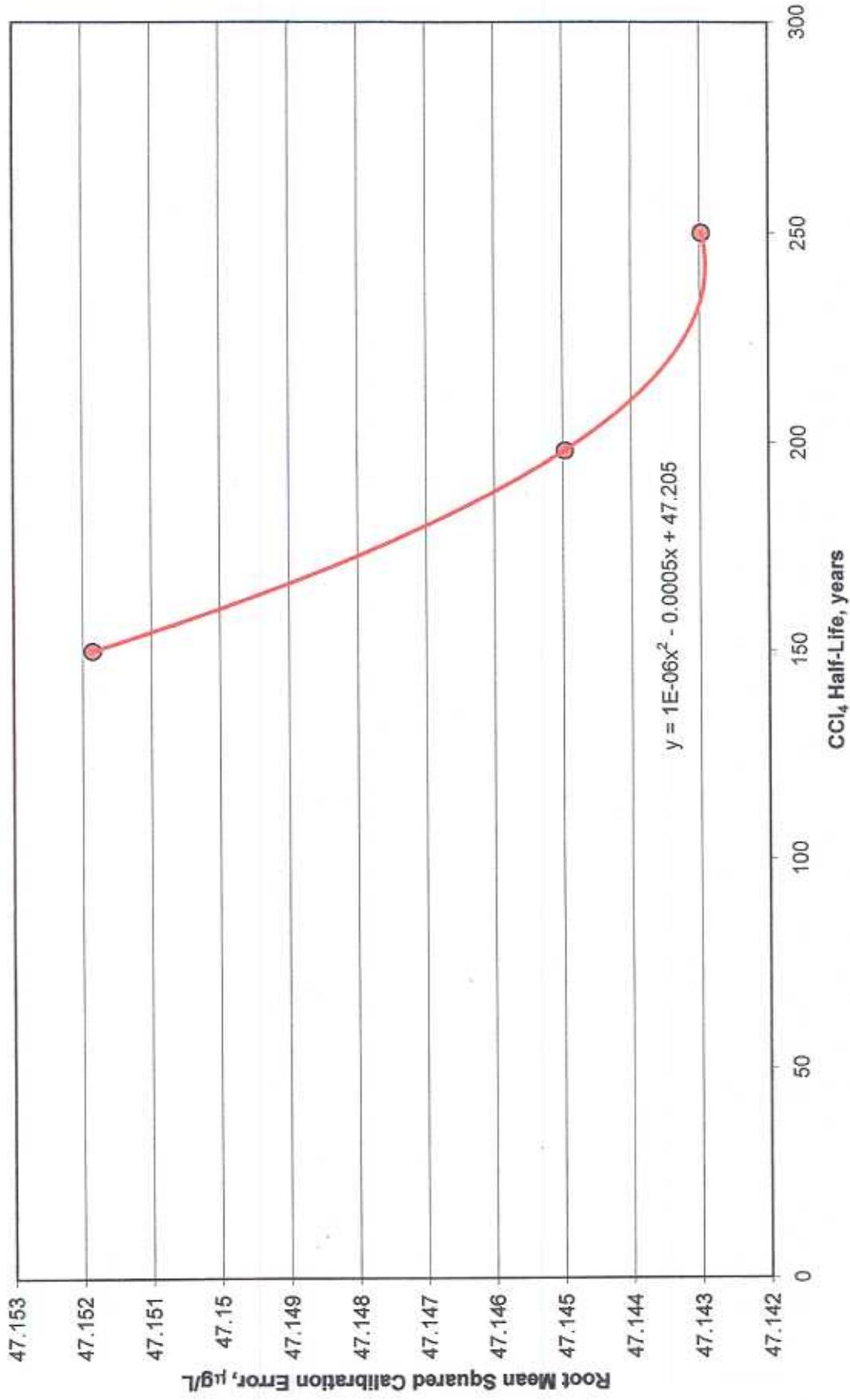
² $n = (1 - \rho_s/\rho_d)$; assume $\rho_d = 165.0857 \text{ lb/ft}^3$

Model	Stratigraphic Unit	Effective Porosity ¹	Total Porosity ²	Bulk Density lb/ft ³	f _{oc} fraction	K _d mL/g (K _{oc} X f _{oc})	K _d L/μg	Retardation Factor	1 st Order Natural Decay Coefficient 1/day	CCl ₄ Half-life years
Layer 1	Silt/Clay	0.32	0.39	101.0	0.00114	4.976E-01	4.976E-10	3.06	7.591E-06	250
Layer 2	Sand	0.25	0.40	99.3	0.00114	4.976E-01	4.976E-10	2.98	7.591E-06	250
Layer 3	Sand	0.24	0.43	94.6	0.00114	4.976E-01	4.976E-10	2.75	7.591E-06	250
Layer 4	Sand	0.25	0.43	94.6	0.00114	4.976E-01	4.976E-10	2.75	7.591E-06	250
Layer 5	Sand	0.27	0.40	98.9	0.00114	4.976E-01	4.976E-10	2.97	7.591E-06	250
Layer 6	Sand	0.28	0.42	95.3	0.00114	4.976E-01	4.976E-10	2.81	7.591E-06	250
Layer 7	Sand	0.28	0.39	99.9	0.00114	4.976E-01	4.976E-10	3.04	7.591E-06	250
Layer 8	Sand	0.27	0.40	96.5	0.00114	4.976E-01	4.976E-10	2.96	7.591E-06	250
Layer 8	Clay	0.33	0.41	96.8	0.00114	4.976E-01	4.976E-10	2.88	7.591E-06	250
Layer 9	Sand	0.28	0.41	96.8	0.00114	4.976E-01	4.976E-10	2.88	7.591E-06	250
Layer 9	Clay	0.33	0.41	96.8	0.00114	4.976E-01	4.976E-10	2.88	7.591E-06	250
Layer 10	Sand	0.27	0.42	96.4	0.00114	4.976E-01	4.976E-10	2.83	7.591E-06	250
Layer 11	Sand	0.28	0.37	103.3	0.00114	4.976E-01	4.976E-10	3.23	7.591E-06	250
Layer 12	Sand	0.25	0.43	94.7	0.00114	4.976E-01	4.976E-10	2.76	7.591E-06	250
								2.91		

**Murdock, NE Transport Model Calibration with Retardation Factor = 1.8
and No Decay**

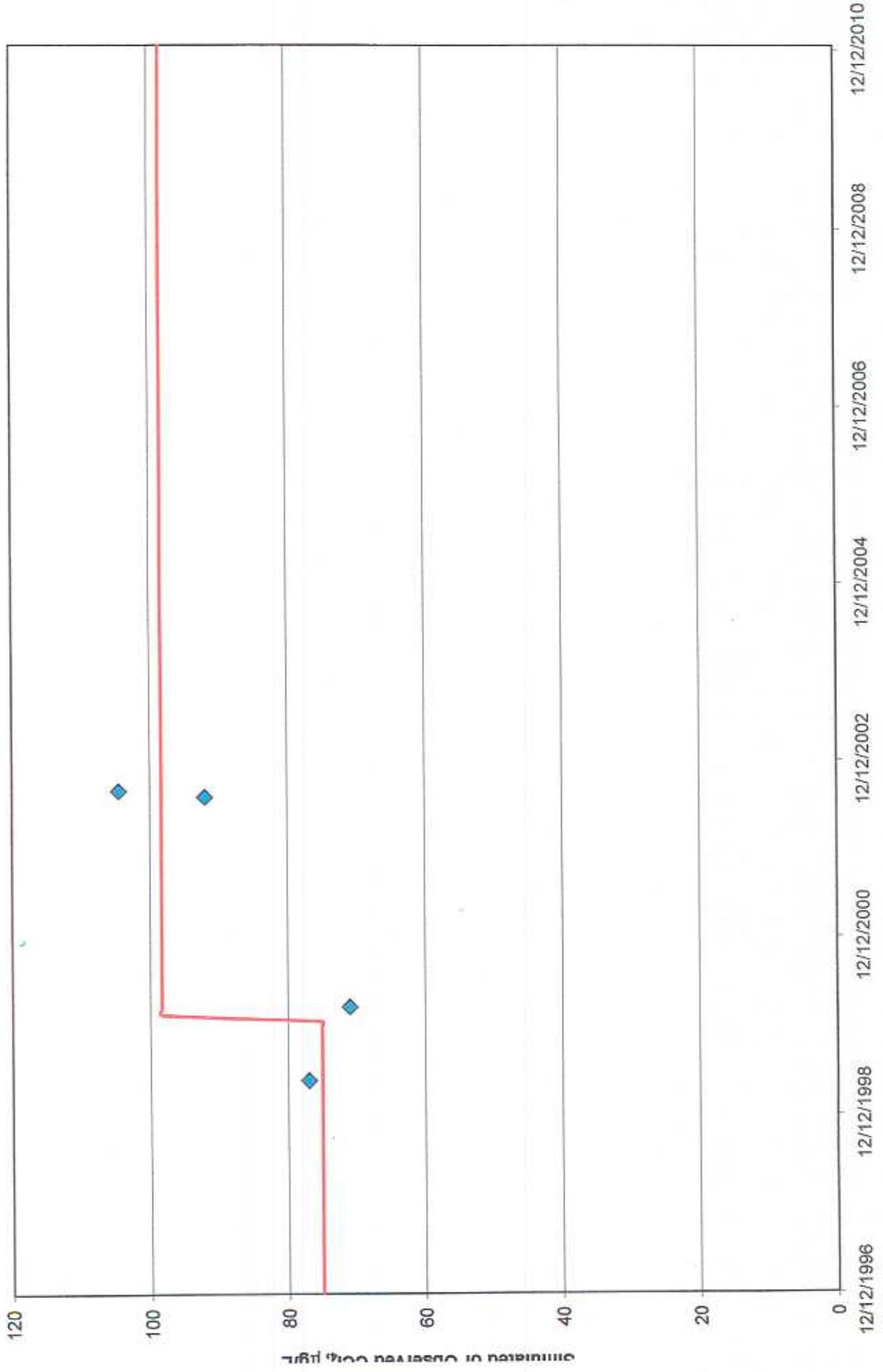


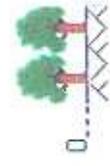
Murdock, NE Transport Model Calibration of Decay Half-Life



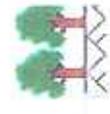
S2

— Constant Concentration
◆ Observed Concentrations

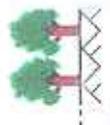




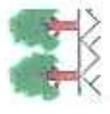
SB71S



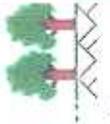
46.80005	.....
49.90002	.....
53	.....
56.20007	.....
59.30005	.....
62.40002	.....
65.5	.....
68.6001	.....
71.80005	.....
74.90002	.....
78	.....
81.20007	.....



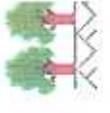
SB71M



46.80005	.....
49.90002	.....
53	.....
56.20007	.....
59.30005	.....
62.40002	.....
65.5	.....
68.6001	.....
71.80005	.....
74.90002	.....
78	.....
81.20007	.....



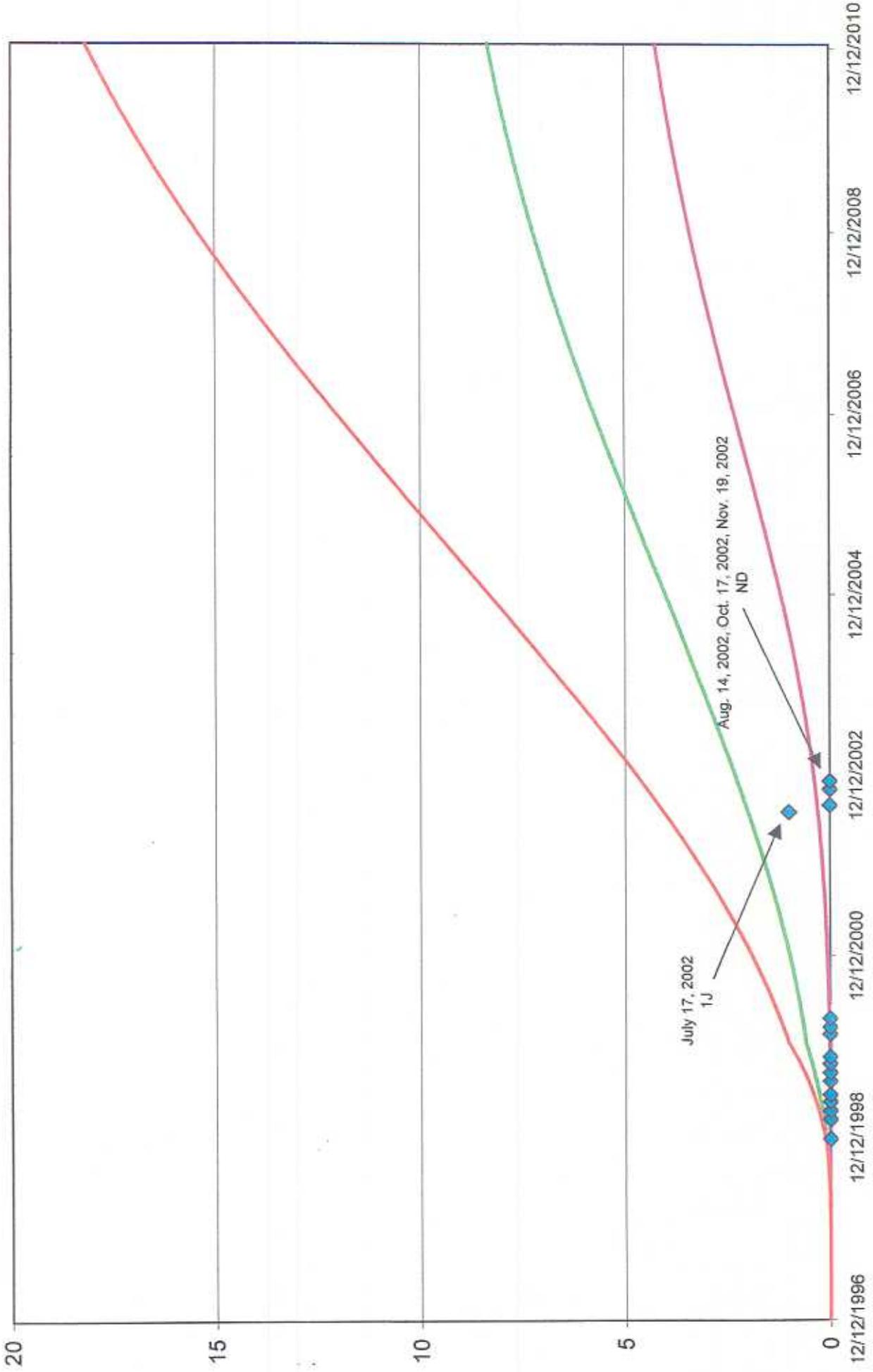
SB71D



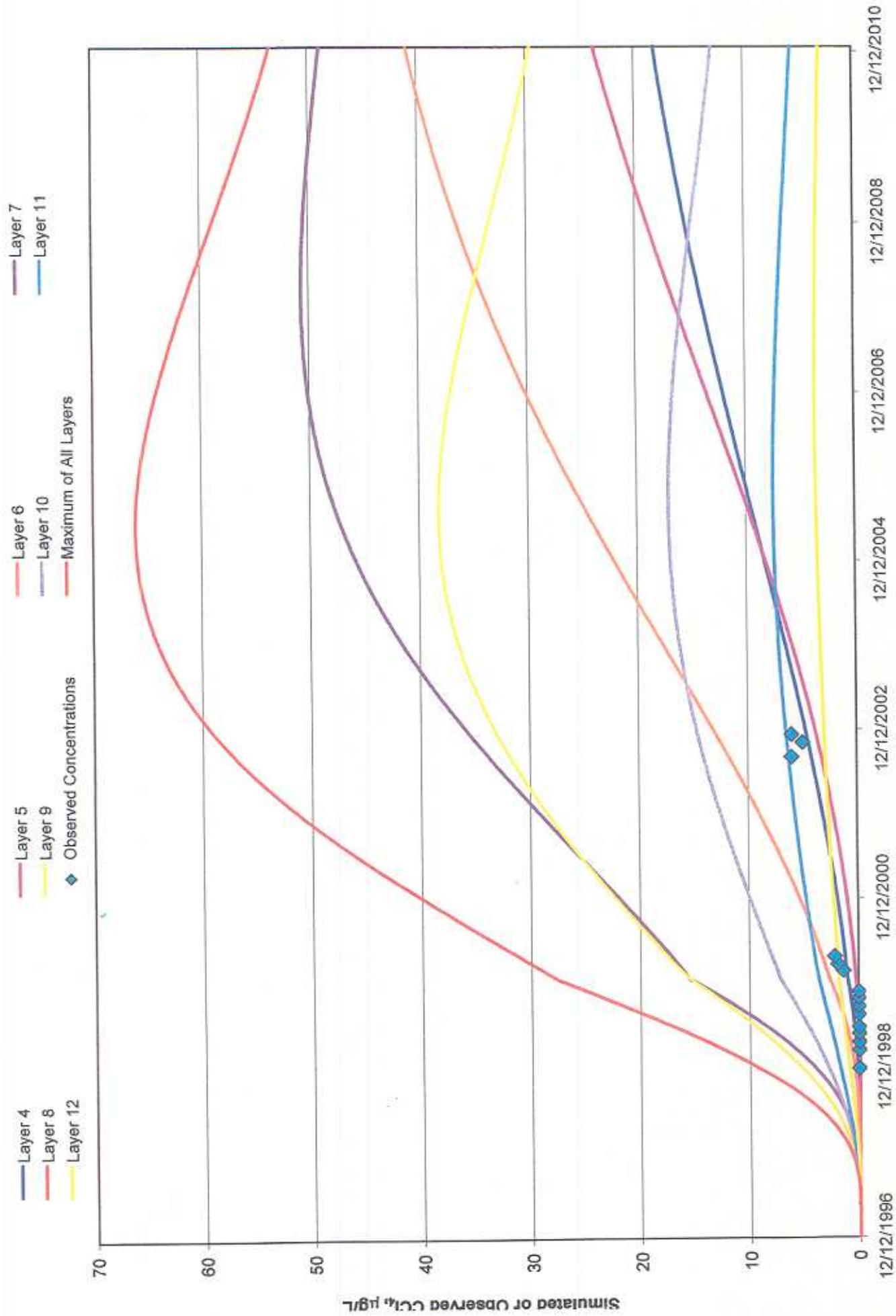
46.80005	.....
49.90002	.....
53	.....
56.20007	.....
59.30005	.....
62.40002	.....
65.5	.....
68.6001	.....
71.80005	.....
74.90002	.....
78	.....
81.20007	.....

SB63S

Layer 1 Layer 2 Layer 3 Layer 4 Observed Concentrations Maximum of All Layers

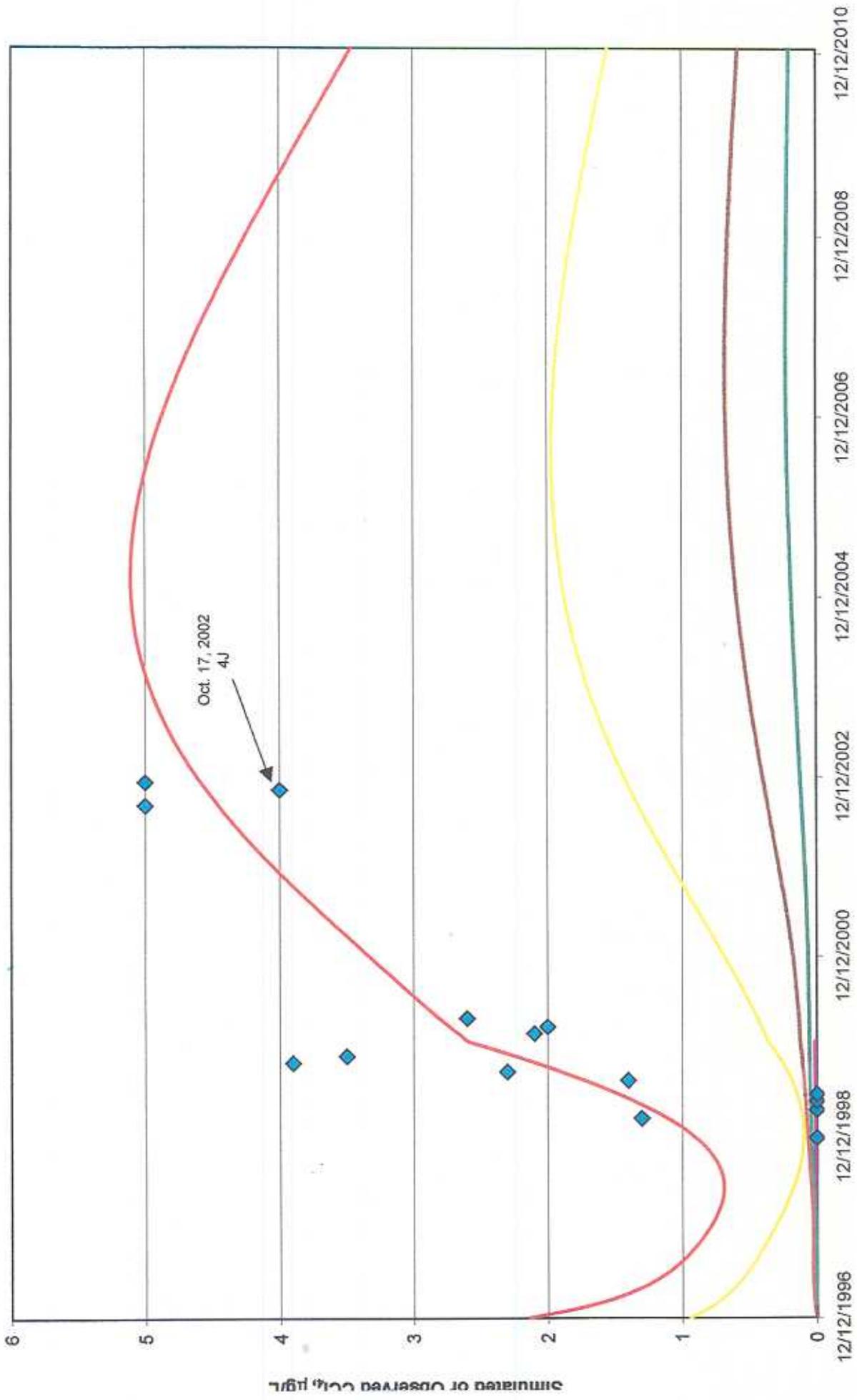


SB63D



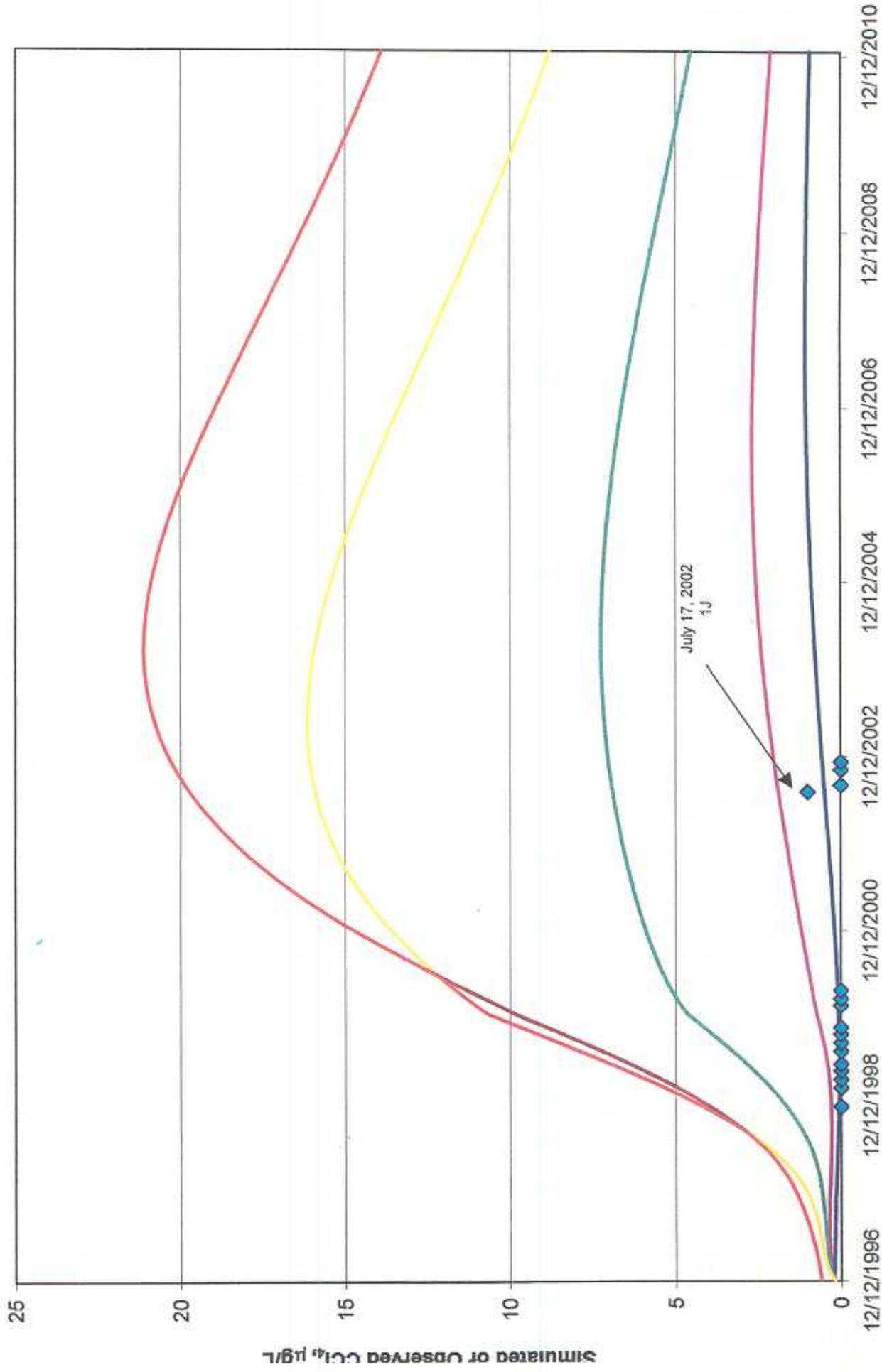
SB64S

Layer 1 Layer 2 Layer 3 Layer 4 Layer 5 Layer 6 Observed Concentrations Maximum of All Layers



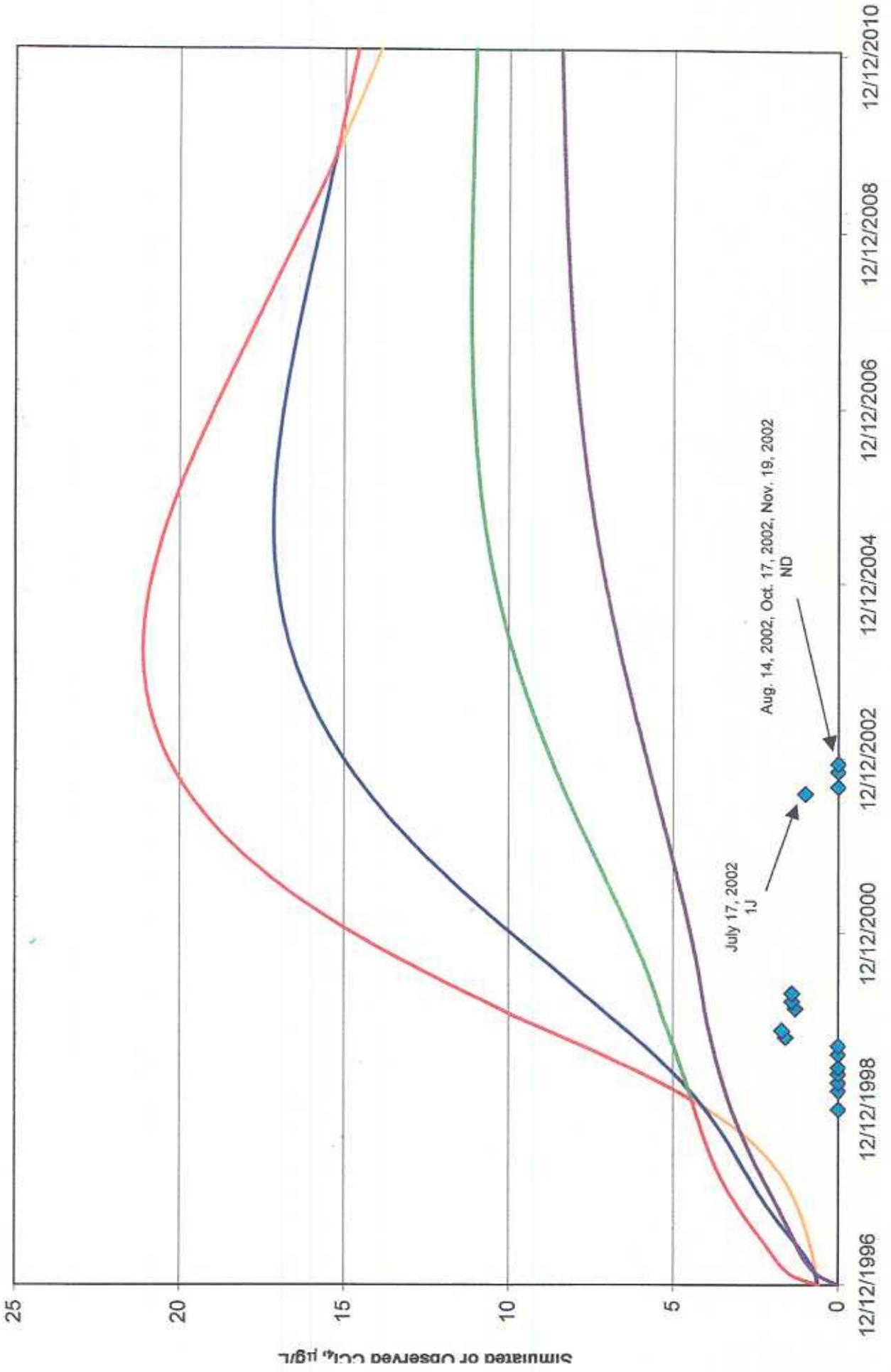
SB64M

Layer 5 Layer 6 Layer 7 Layer 8 Layer 9 Observed Concentration Maximum of All Layers



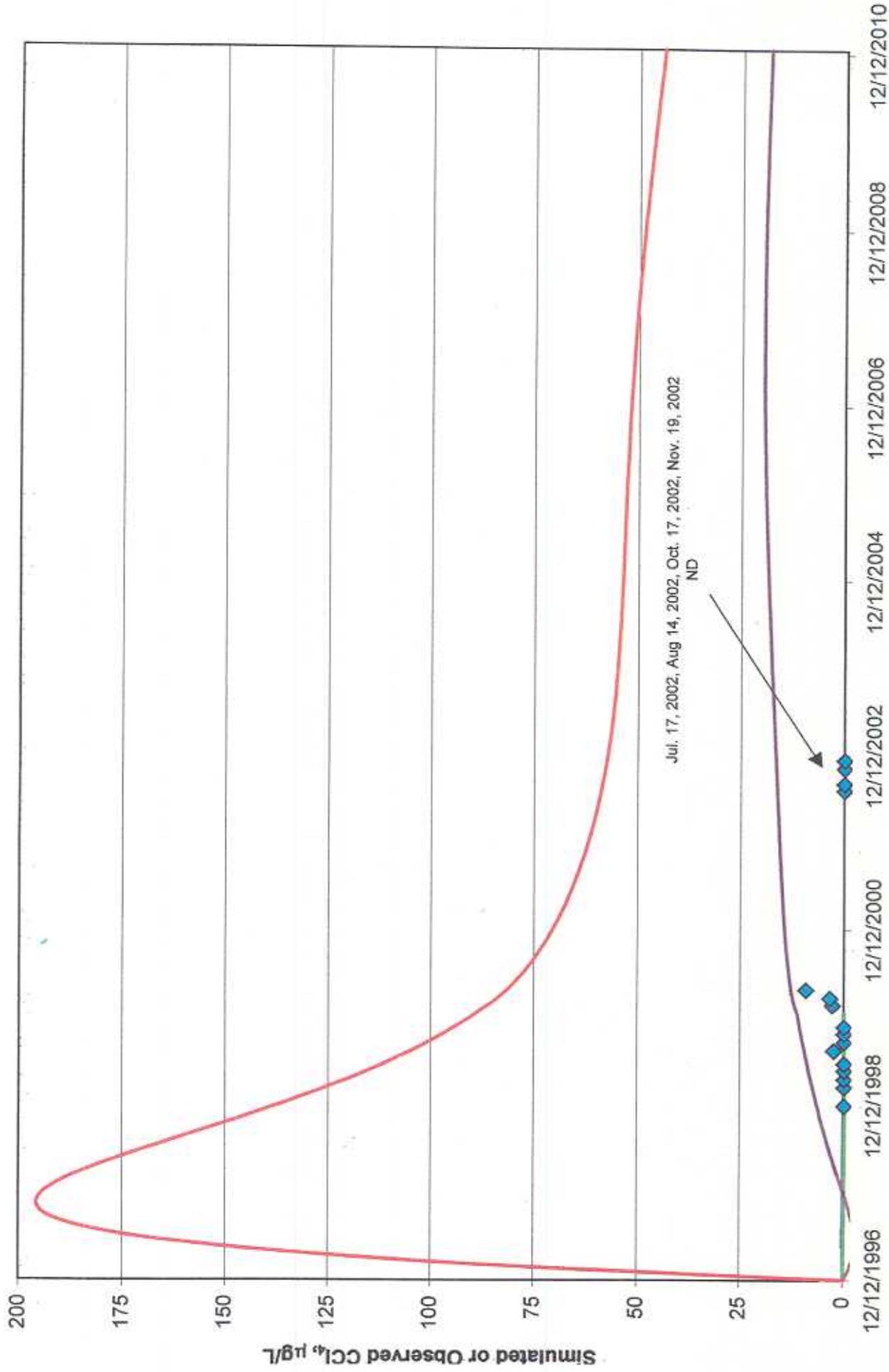
SB64D

Layer 9 Layer 10 Layer 11 Layer 12 Observed Concentration Maximum of All Layers



SB65S

— Layer 1 — Layer 2 — Layer 3 — Layer 4 ◆ Observed Concentrations — Maximum of All Layers



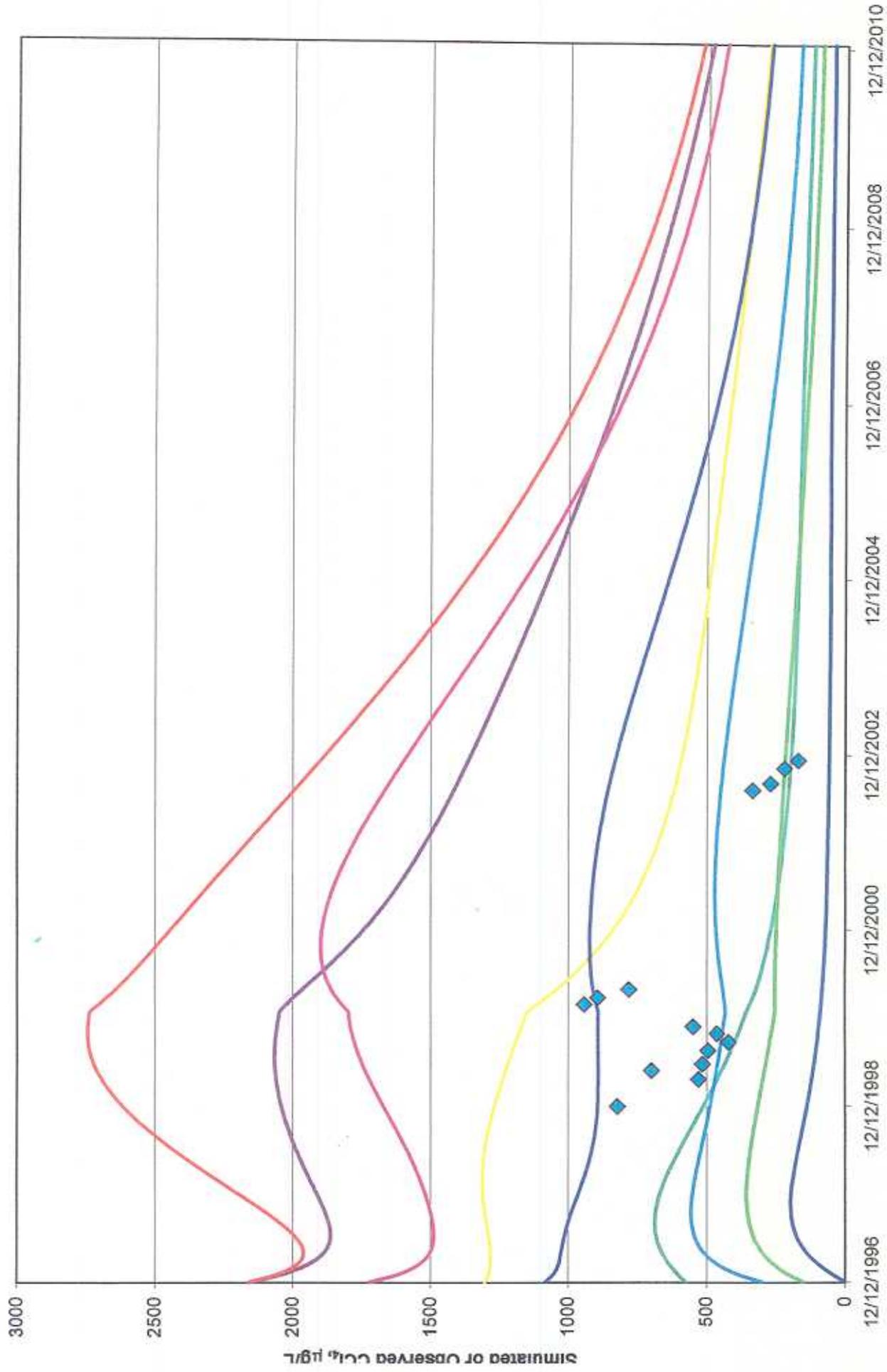
SB65D

Layer 7
Layer 11

Layer 6
Layer 10
Maximum of All Layers

Layer 5
Layer 9
Observed Concentrations

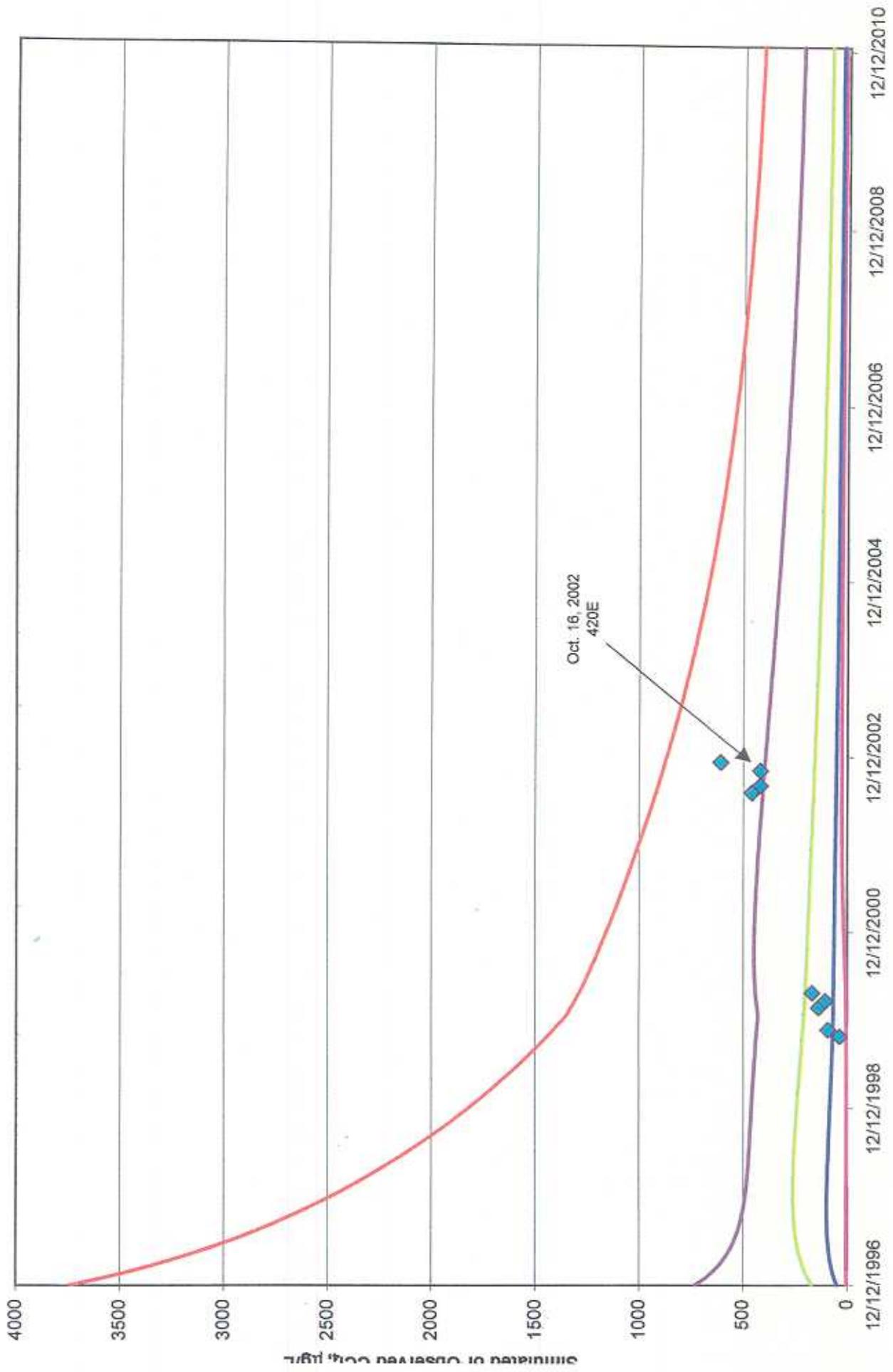
Layer 4
Layer 8
Layer 12



1/17/2003

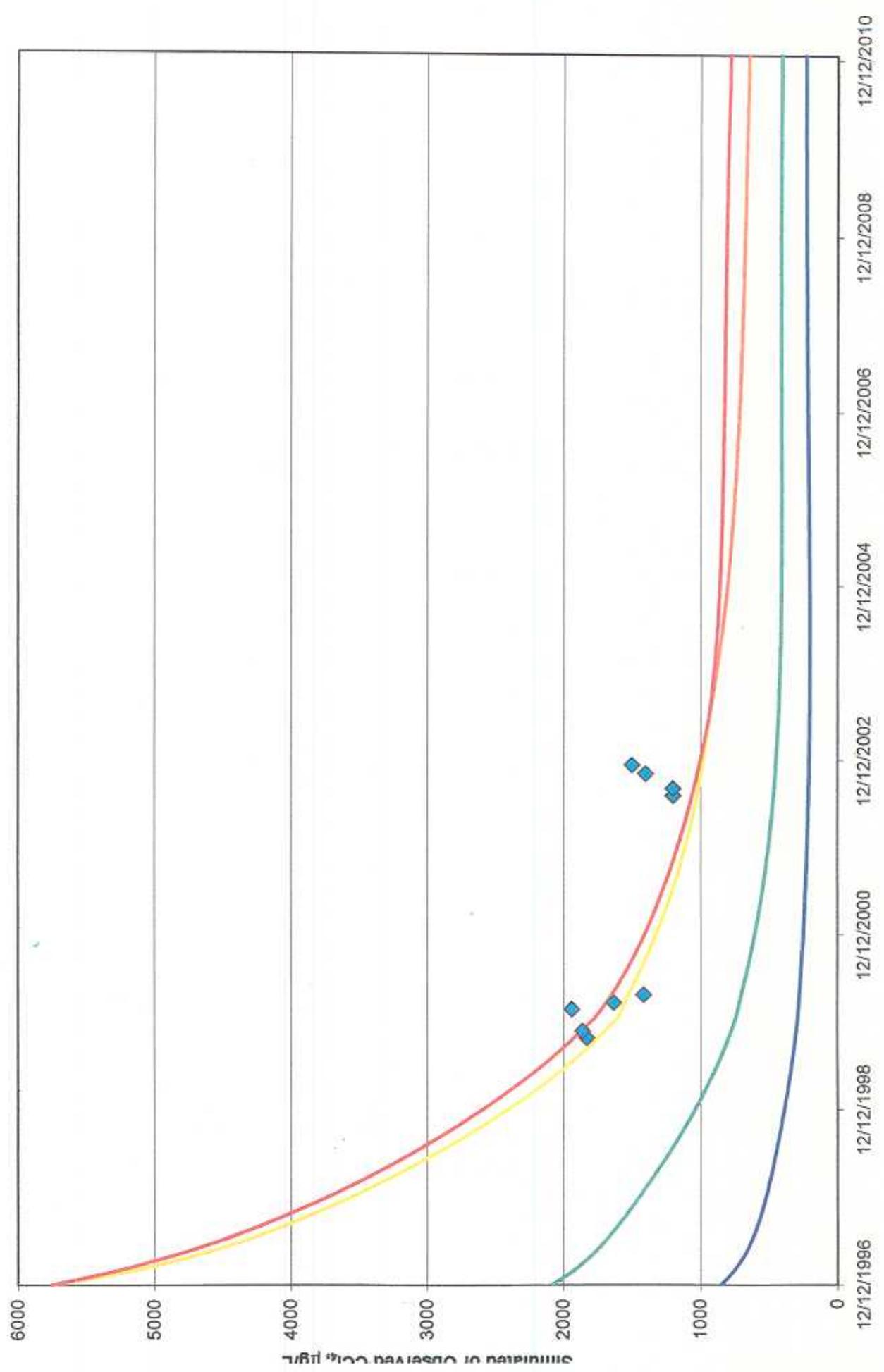
SB68S

Layer 2 Layer 3 Layer 4 Layer 5 Layer 6 Observed Concentrations Maximum of All Layers



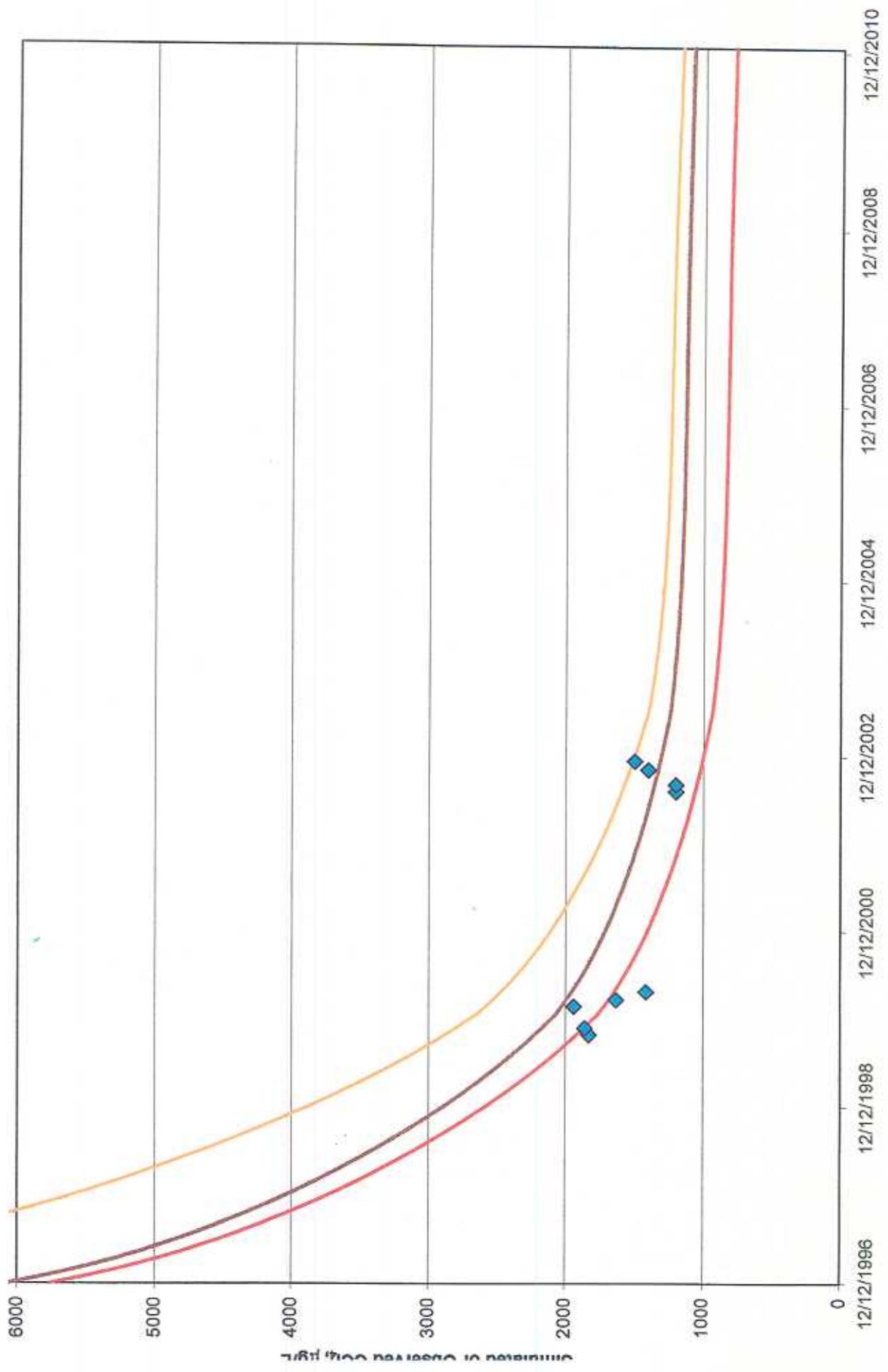
SB68M

Layer 7 Layer 8 Layer 9 Layer 10 Observed Concentrations Maximum of All Layers



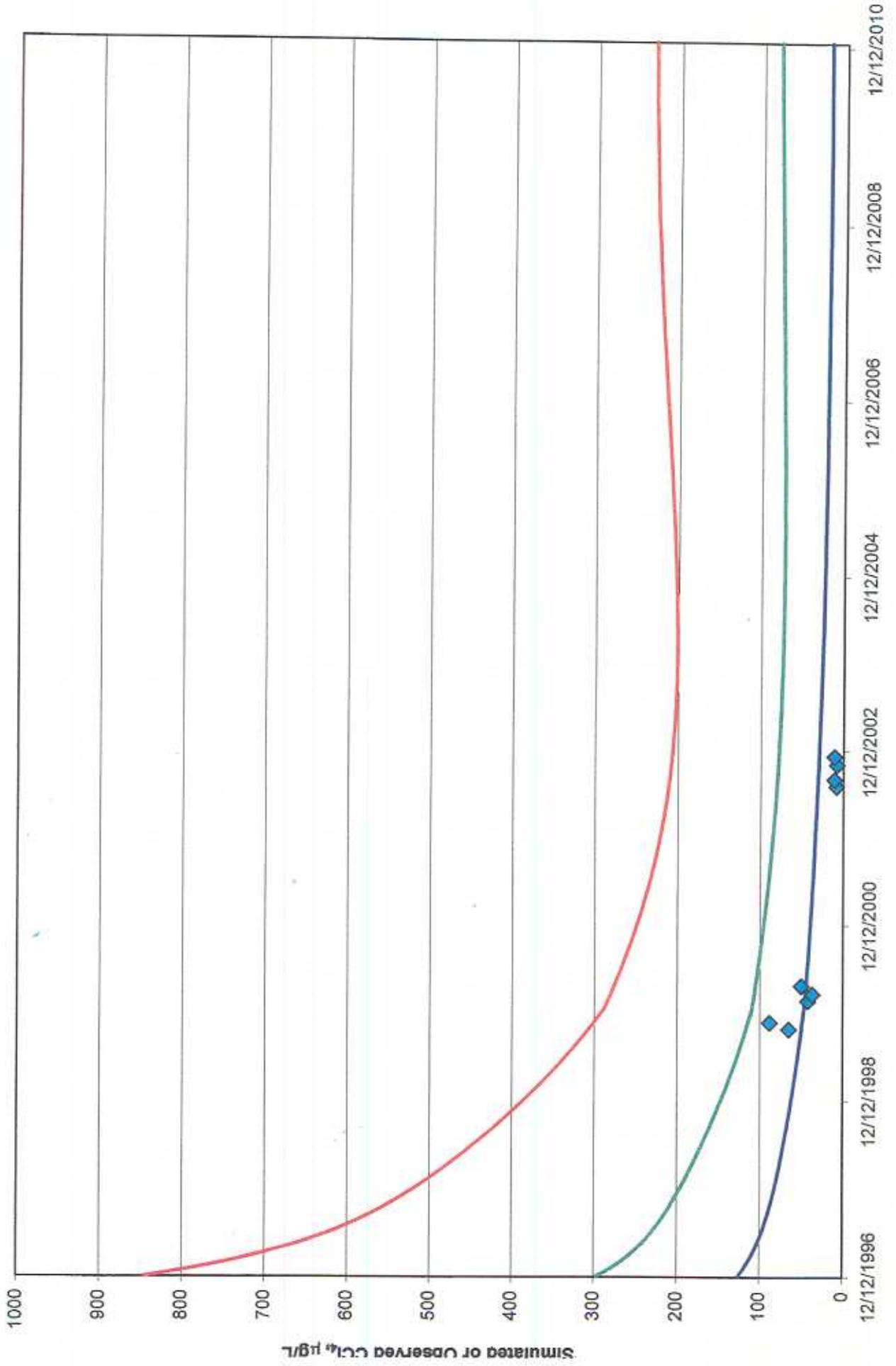
SB68M

◆ Observed Concentrations — Maximum of All Layers — 99.9% Confidence Limit — Maximum Conc. Plus 50%



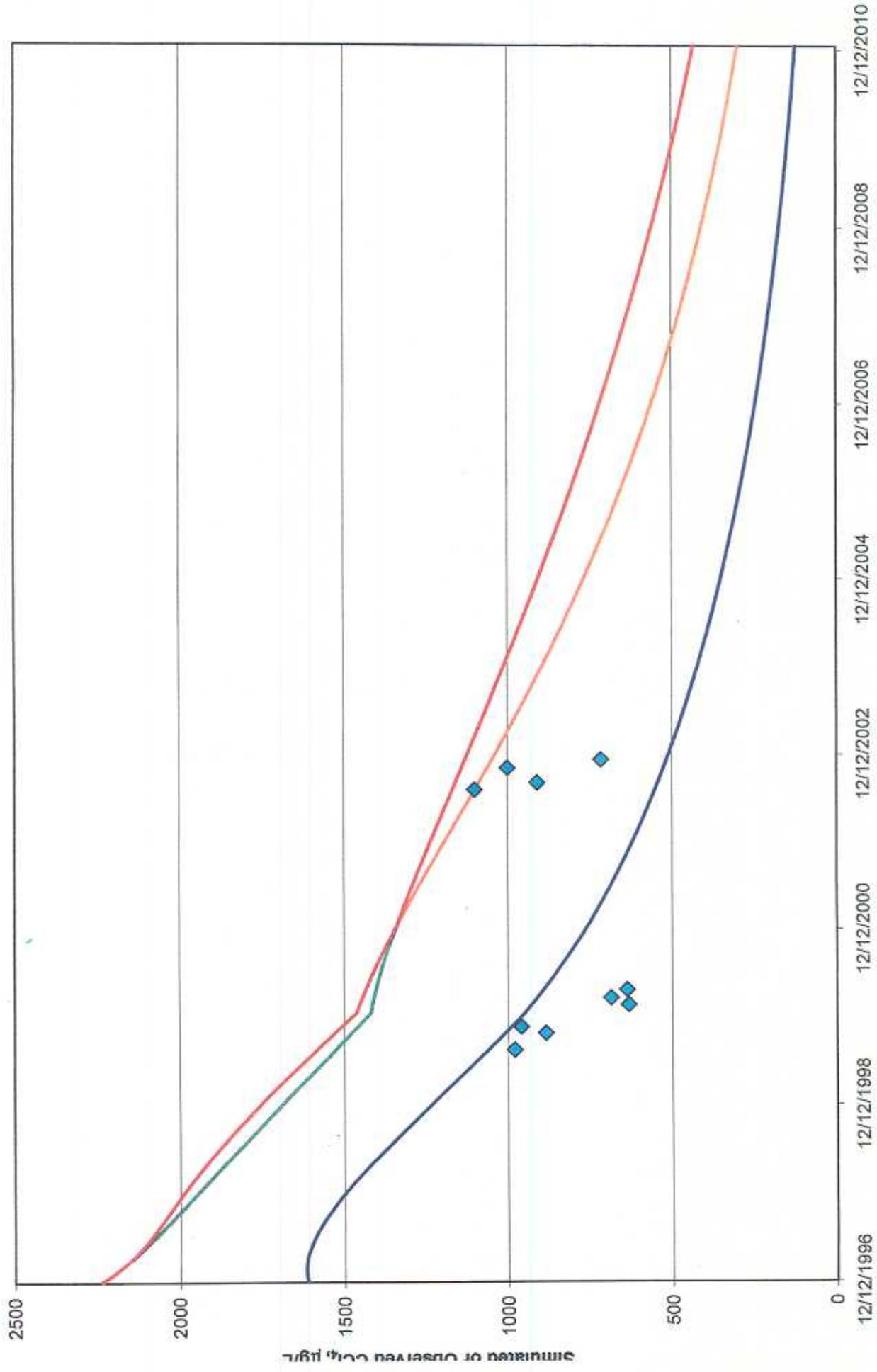
SB68D

Layer 10 Layer 11 Layer 12 Observed Concentrations Maximum of All Layers



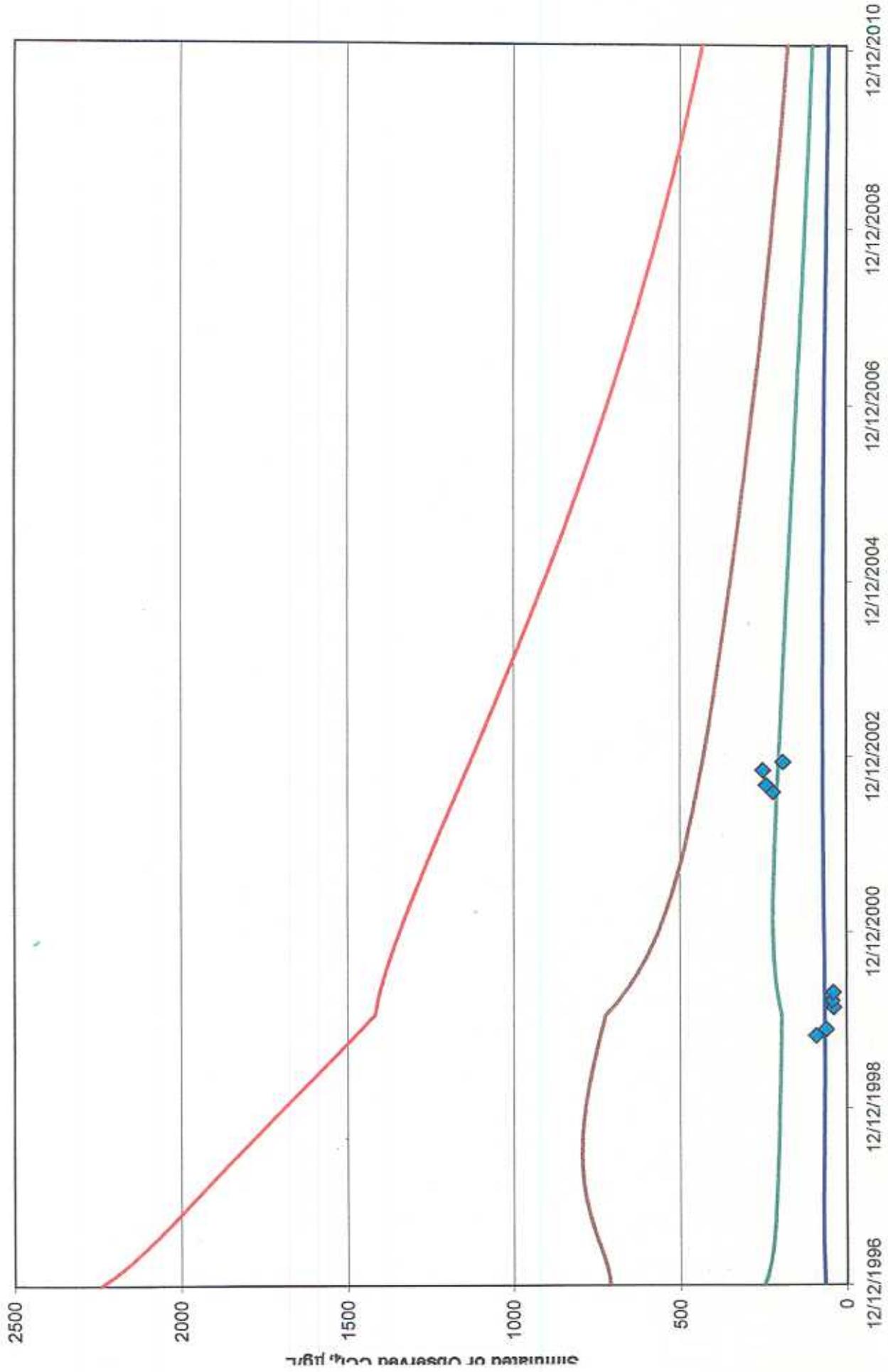
SB71S

- Layer 4
- Layer 5
- Layer 6
- Observed Concentrations
- Maximum of All Layers



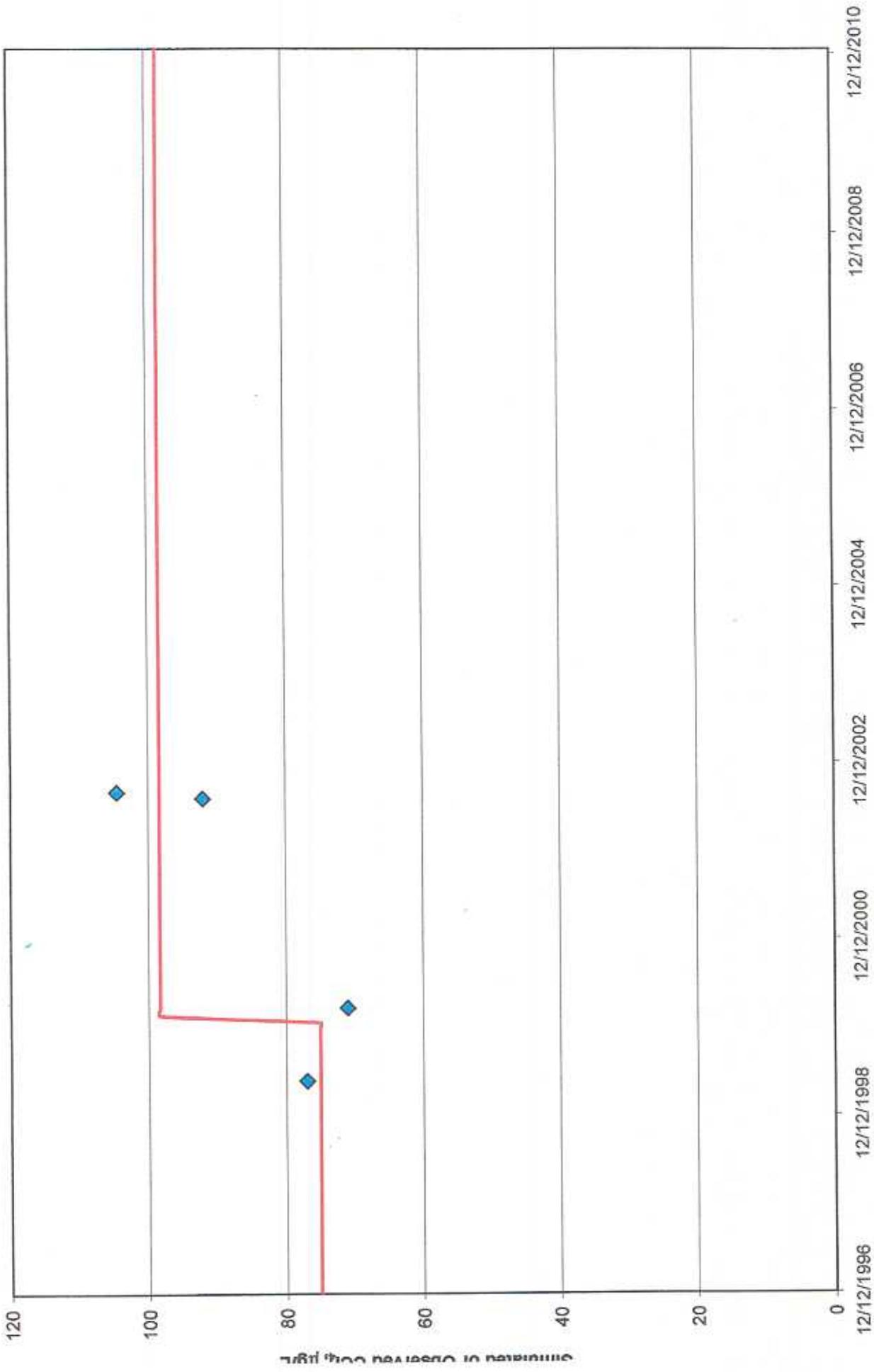
SB71M

Layer 6 Layer 7 Layer 8 Layer 9 Observed Concentrations Maximum of All Layers



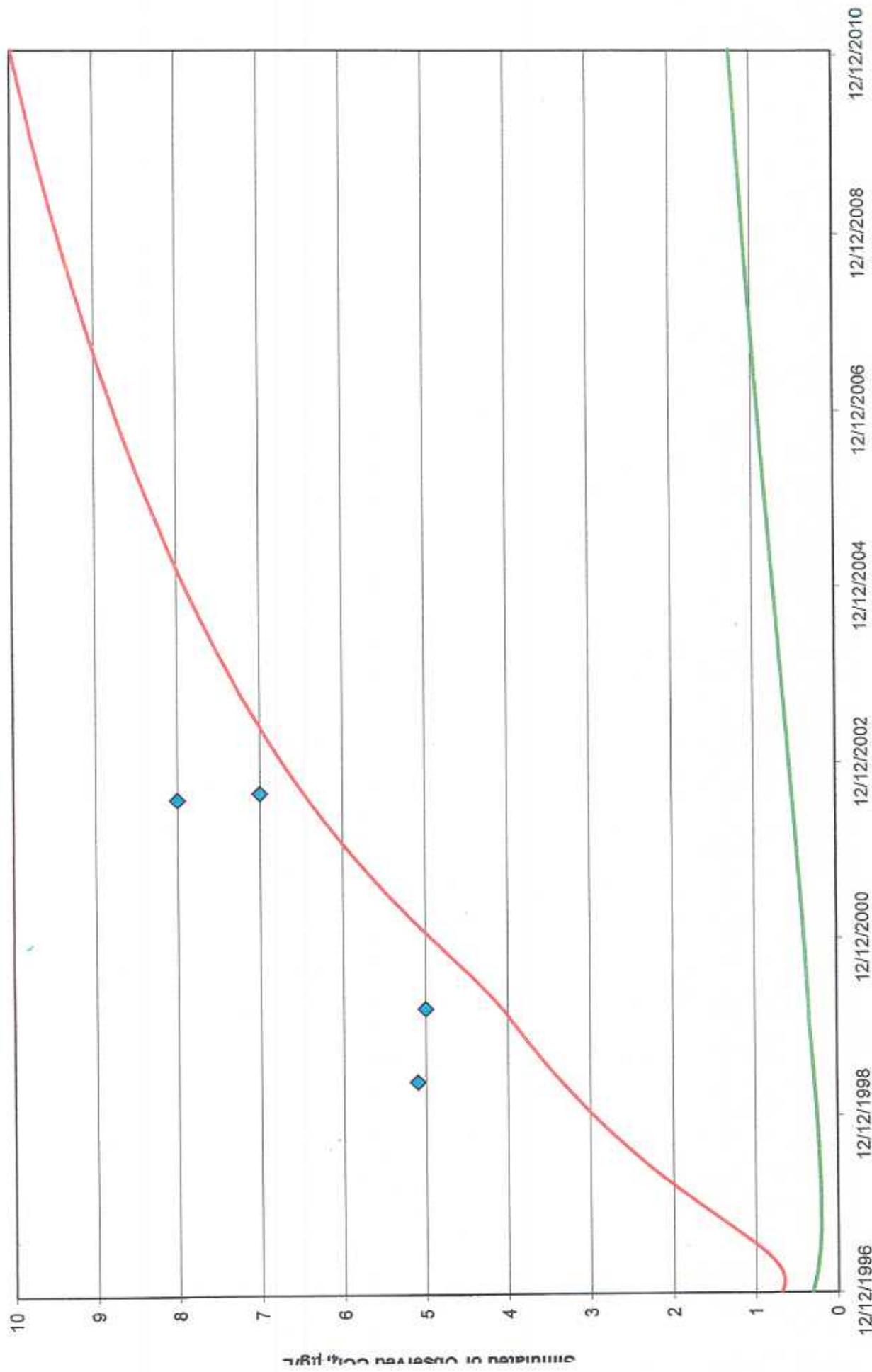
S2

— Constant Concentration
◆ Observed Concentrations



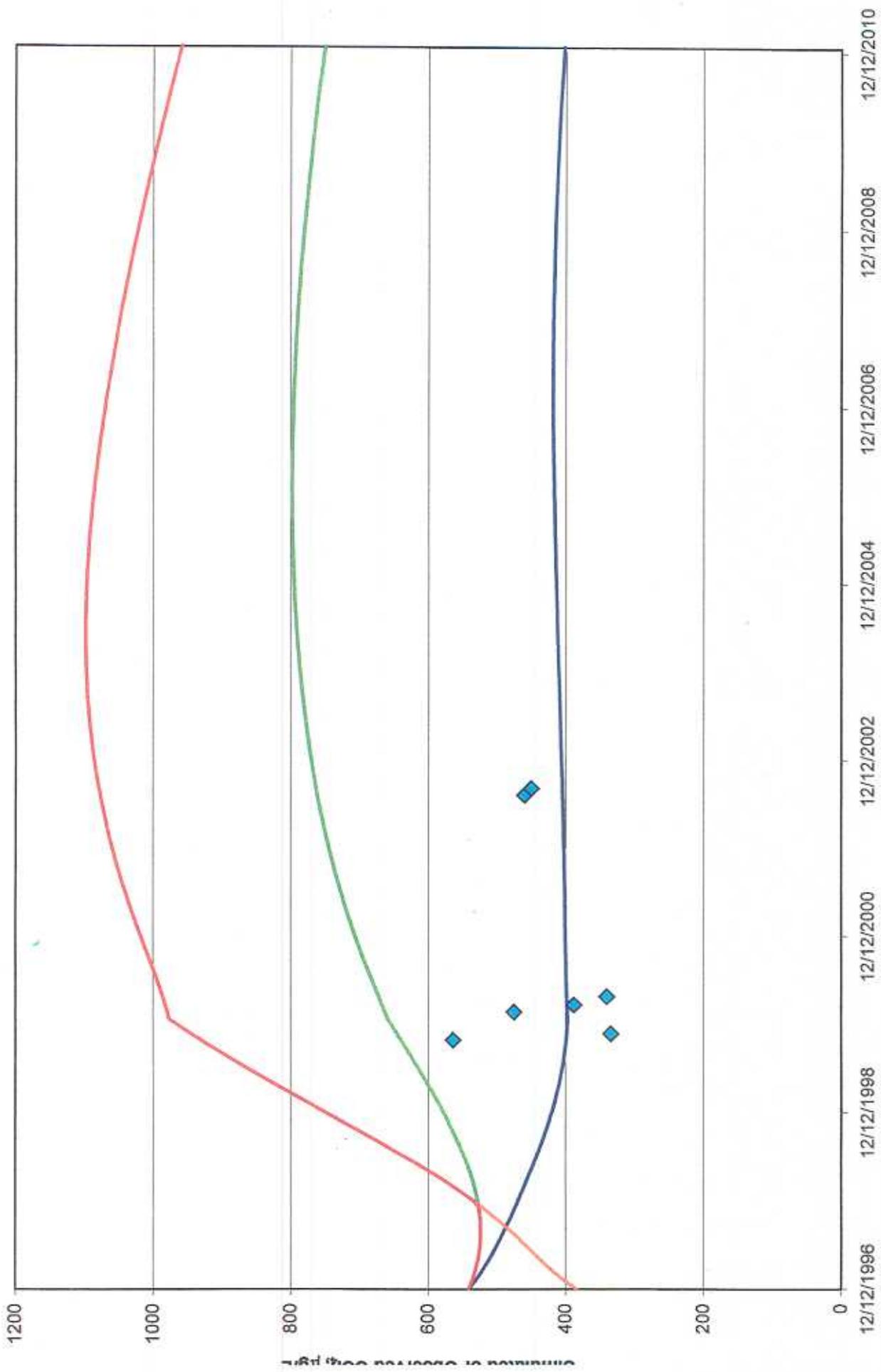
D2

Layer 11 Layer 12 Observed Concentrations Maximum of All Layers



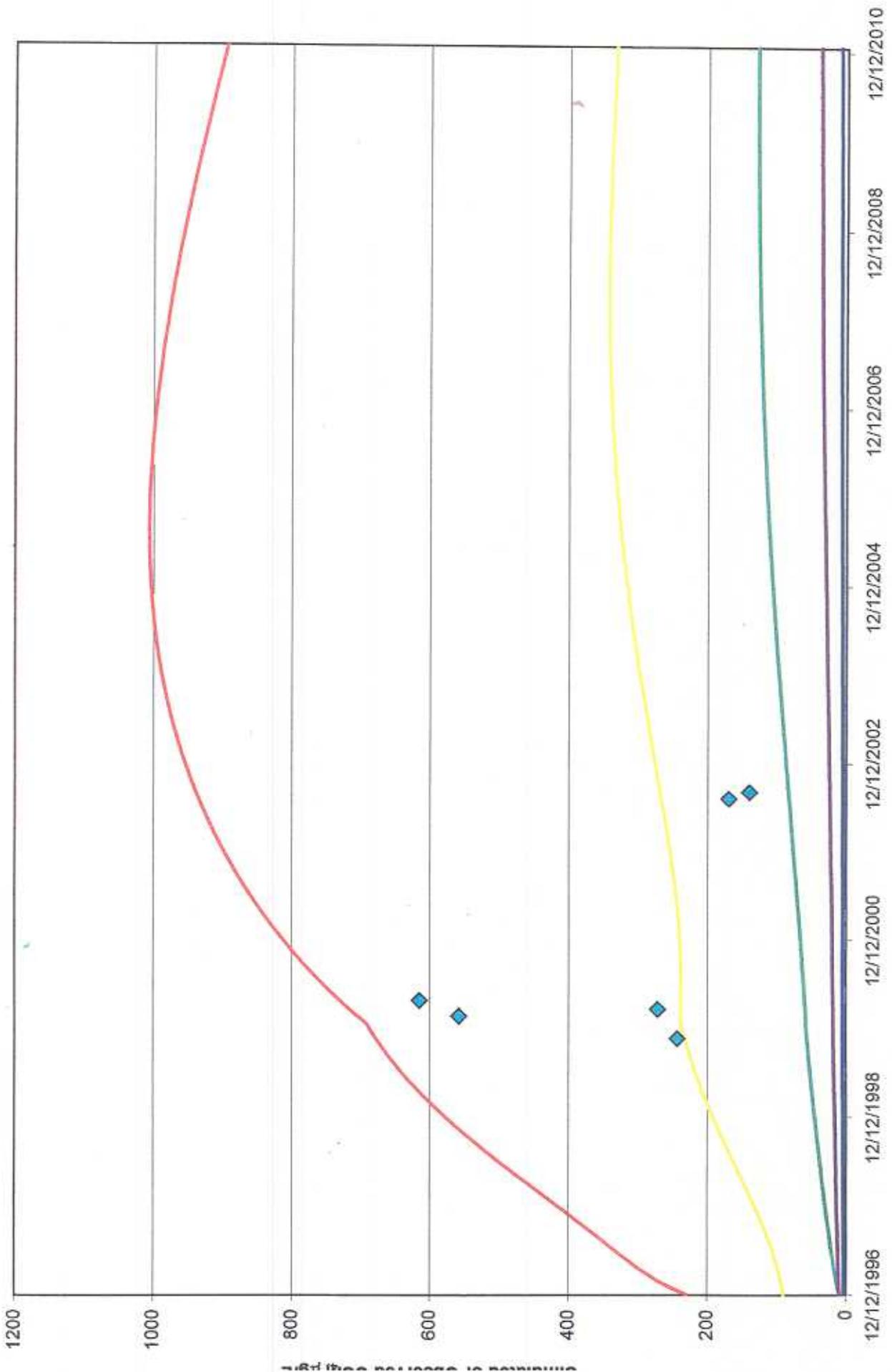
SB69M

- Layer 5
- Layer 6
- Layer 7
- Observed Concentrations
- Maximum of All Layers



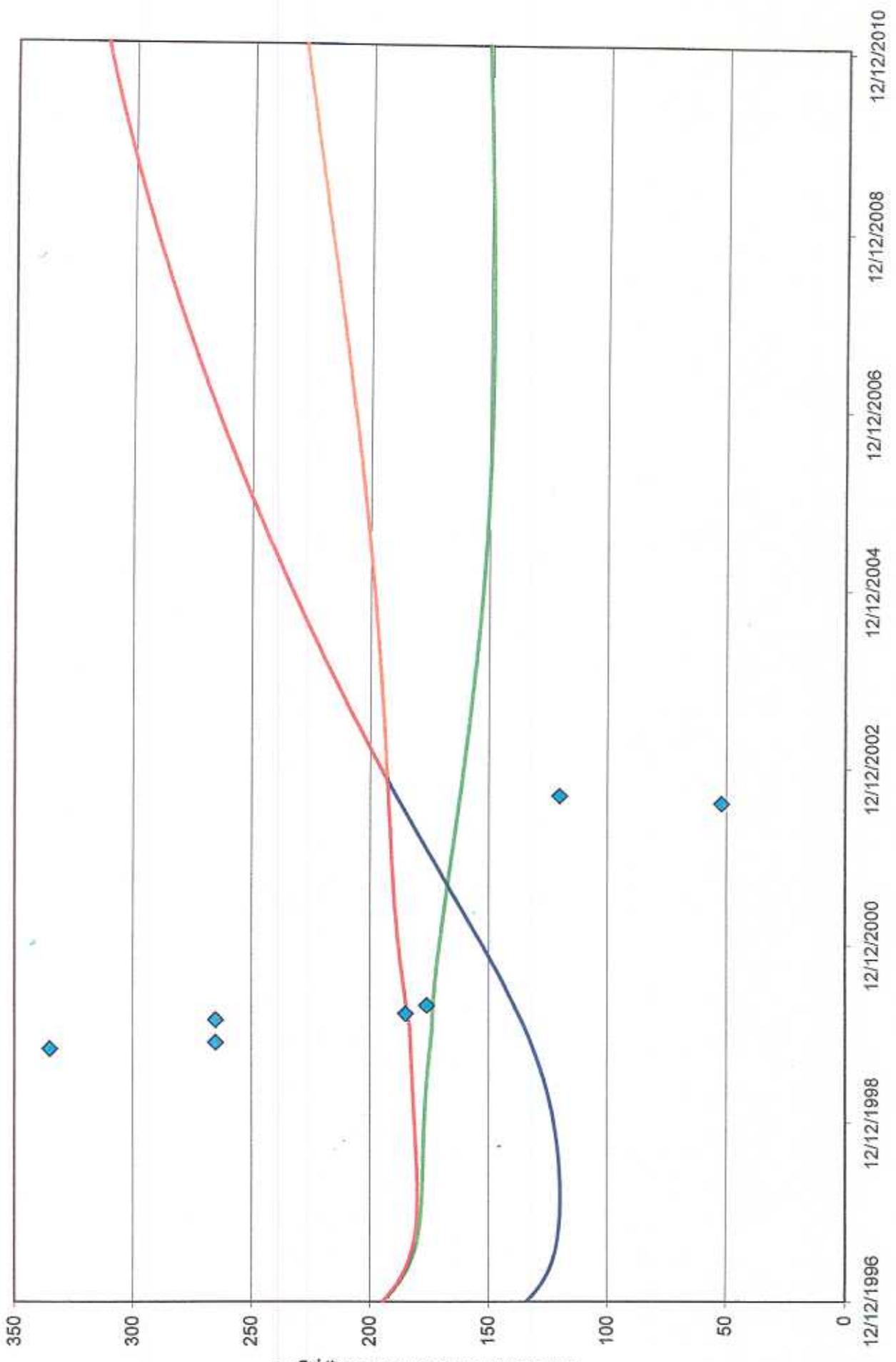
SB69D

Layer 8 Layer 9 Layer 10 Layer 11 Layer 12 Observed Concentrations Maximum of All Layers



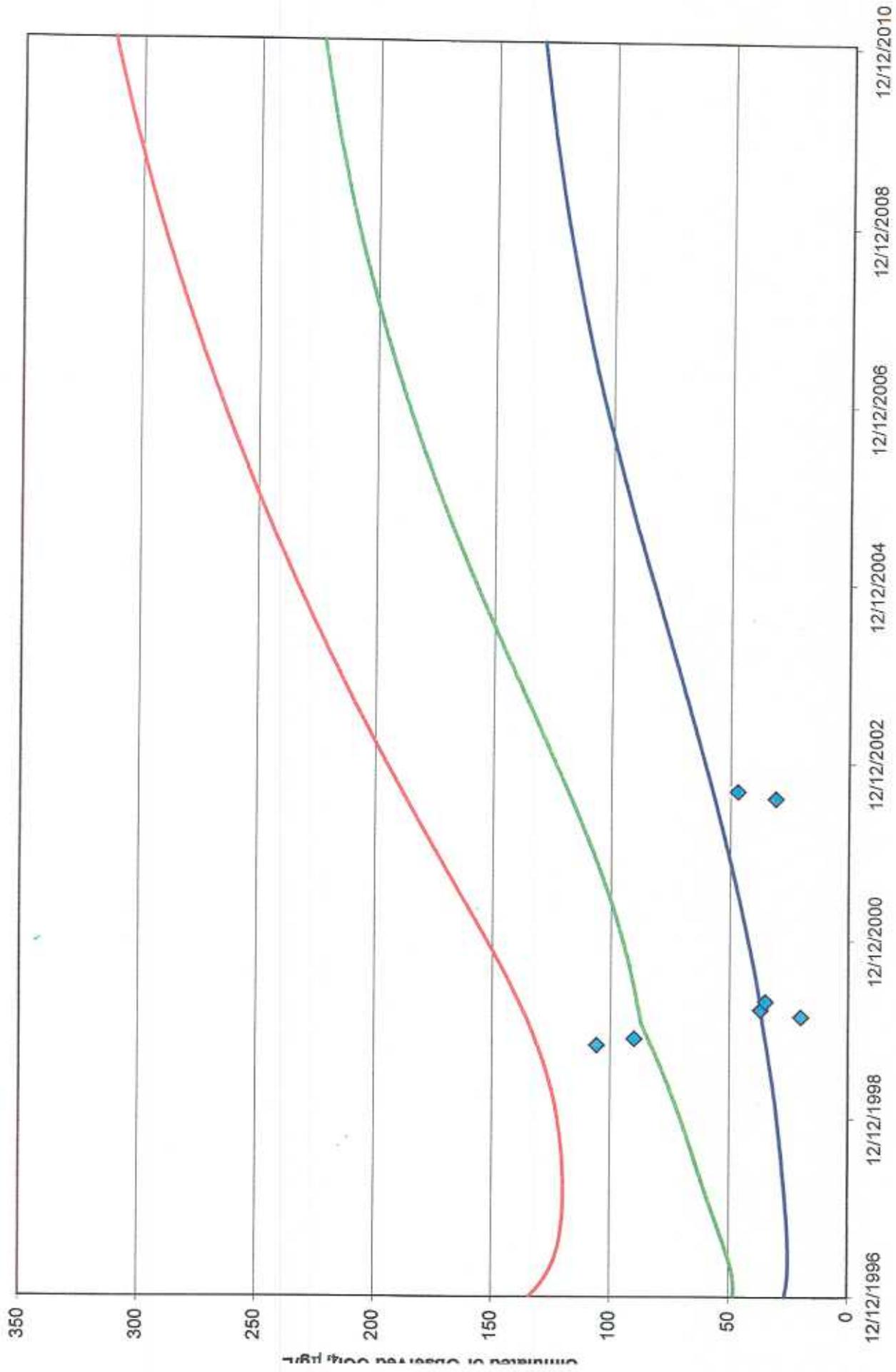
SB70S

— Layer 5 — Layer 6 — Layer 7 ◆ Observed Concentrations — Maximum of All Layers



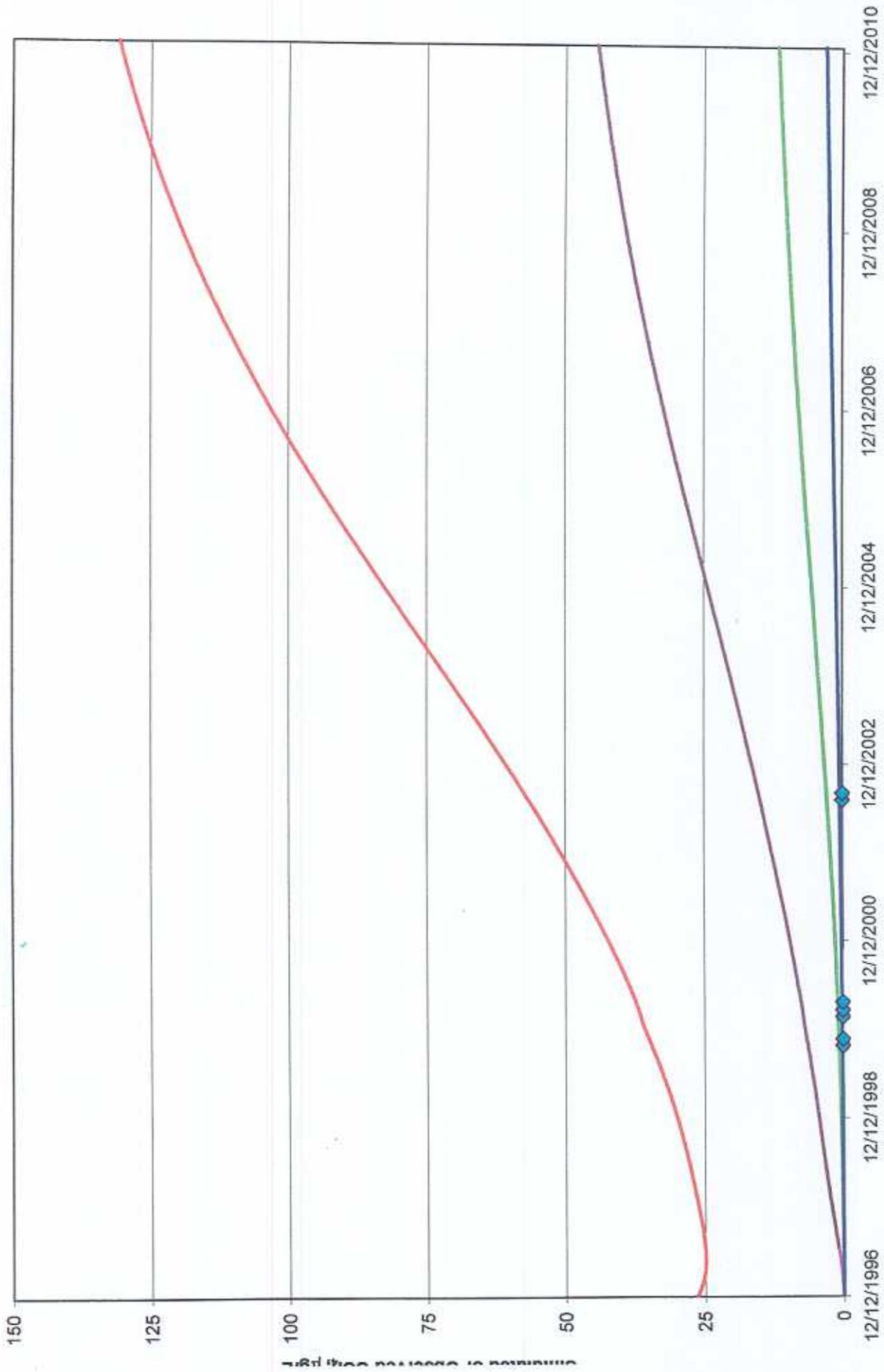
SB70M

— Layer 7 — Layer 8 — Layer 9 ◆ Observed Concentrations — Maximum of All Layers



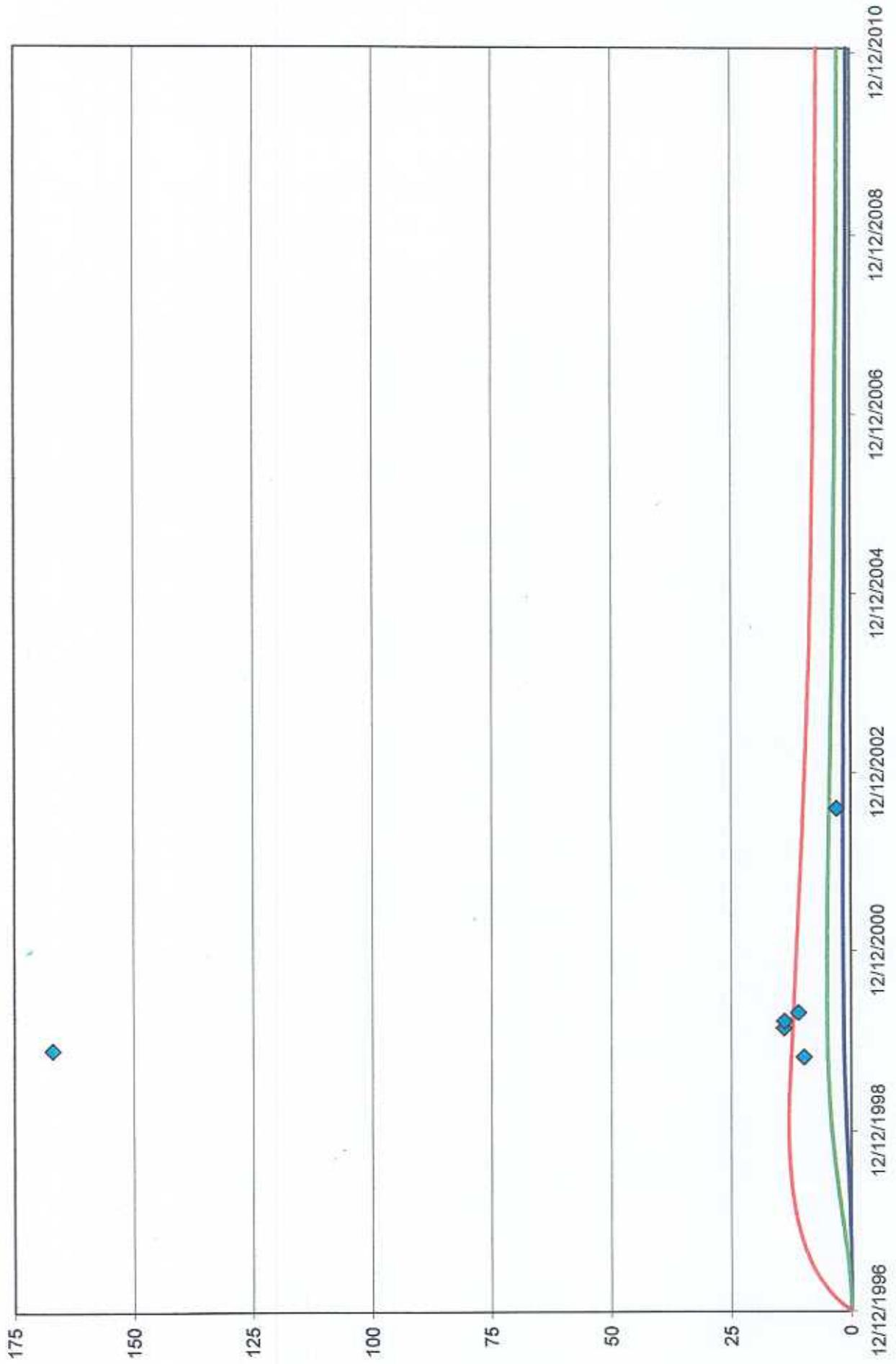
SB70D

Layer 9 Layer 10 Layer 11 Layer 12 Observed Concentrations Maximum of All Layers



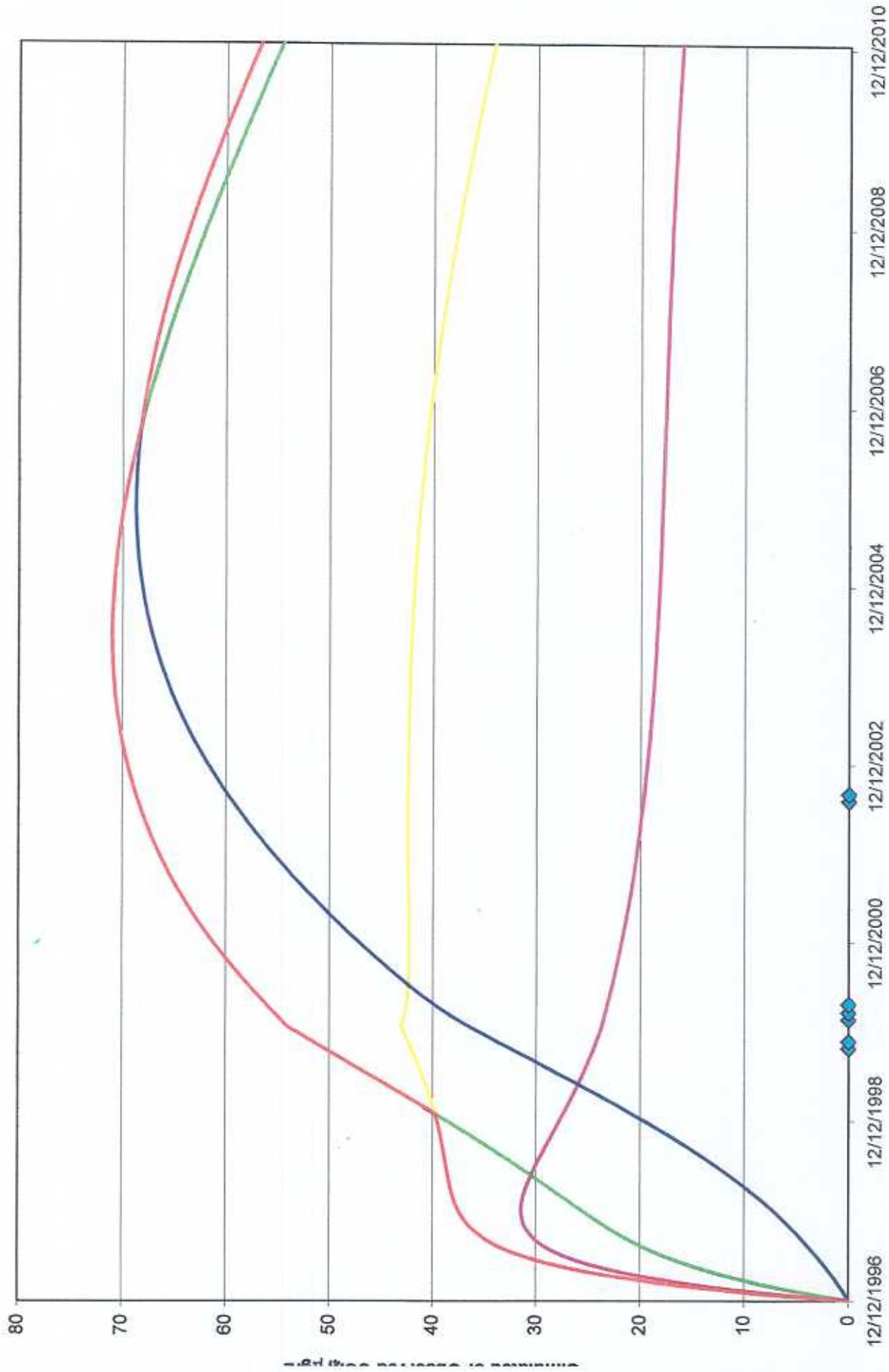
SB72S

— Layer 3 — Layer 4 — Layer 5 ◆ Observed Concentrations — Maximum of All Layers



SB72M

— Layer 6 — Layer 7 — Layer 8 — Layer 9 ◆ Observed Concentrations — Maximum of All Layers



SB72D

— Layer 10 — Layer 11 — Layer 12 ◆ Observed Concentrations — Maximum of All Layers

