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

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

ANL/ER/RP-116457

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

January 2003

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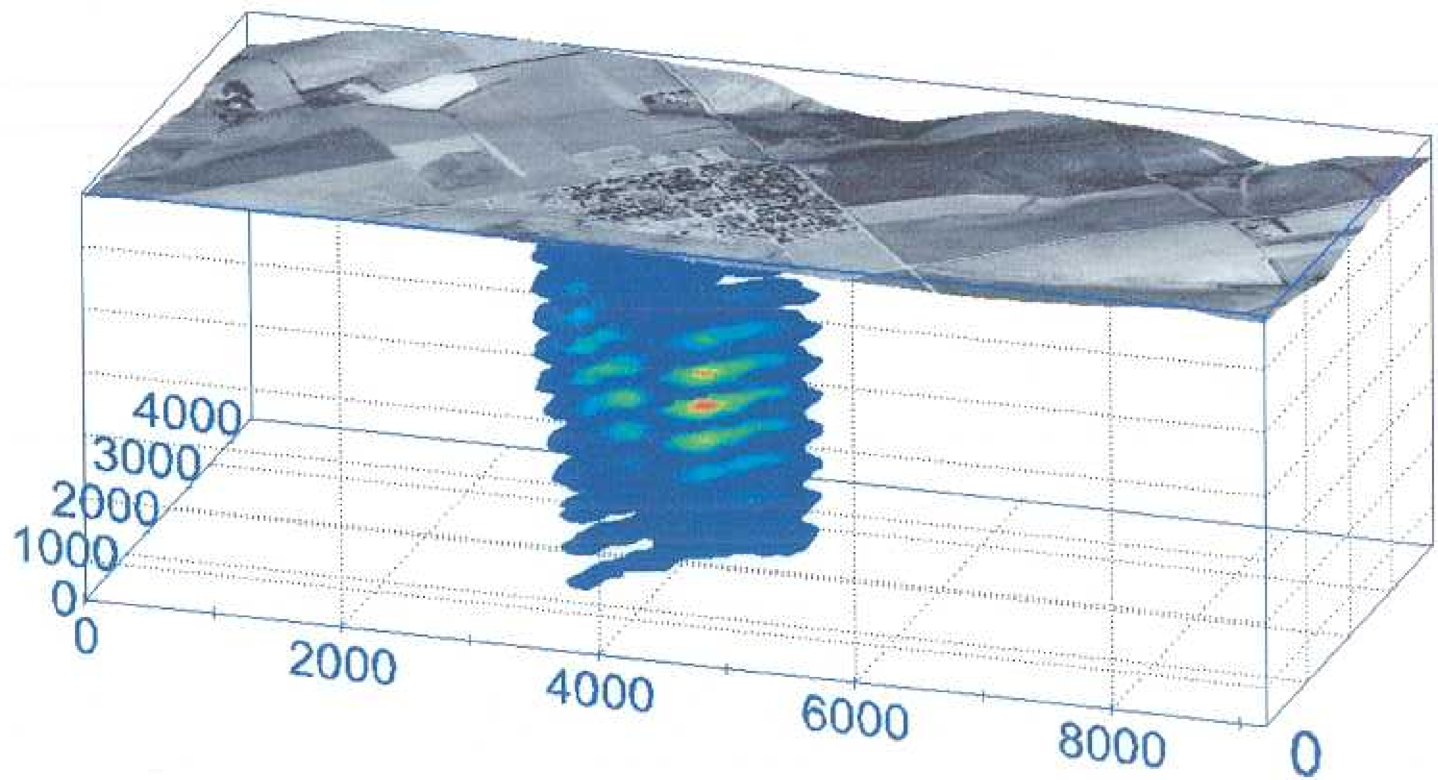
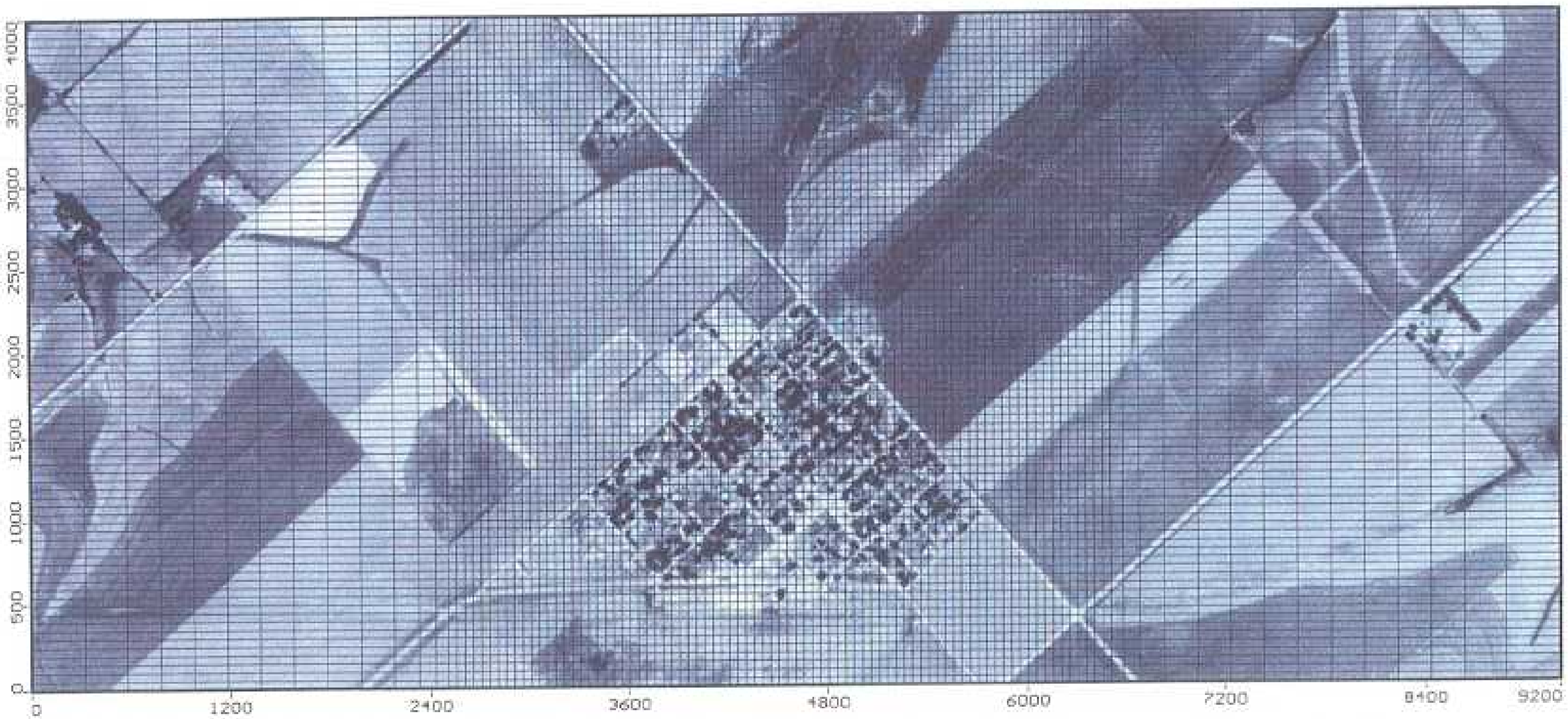


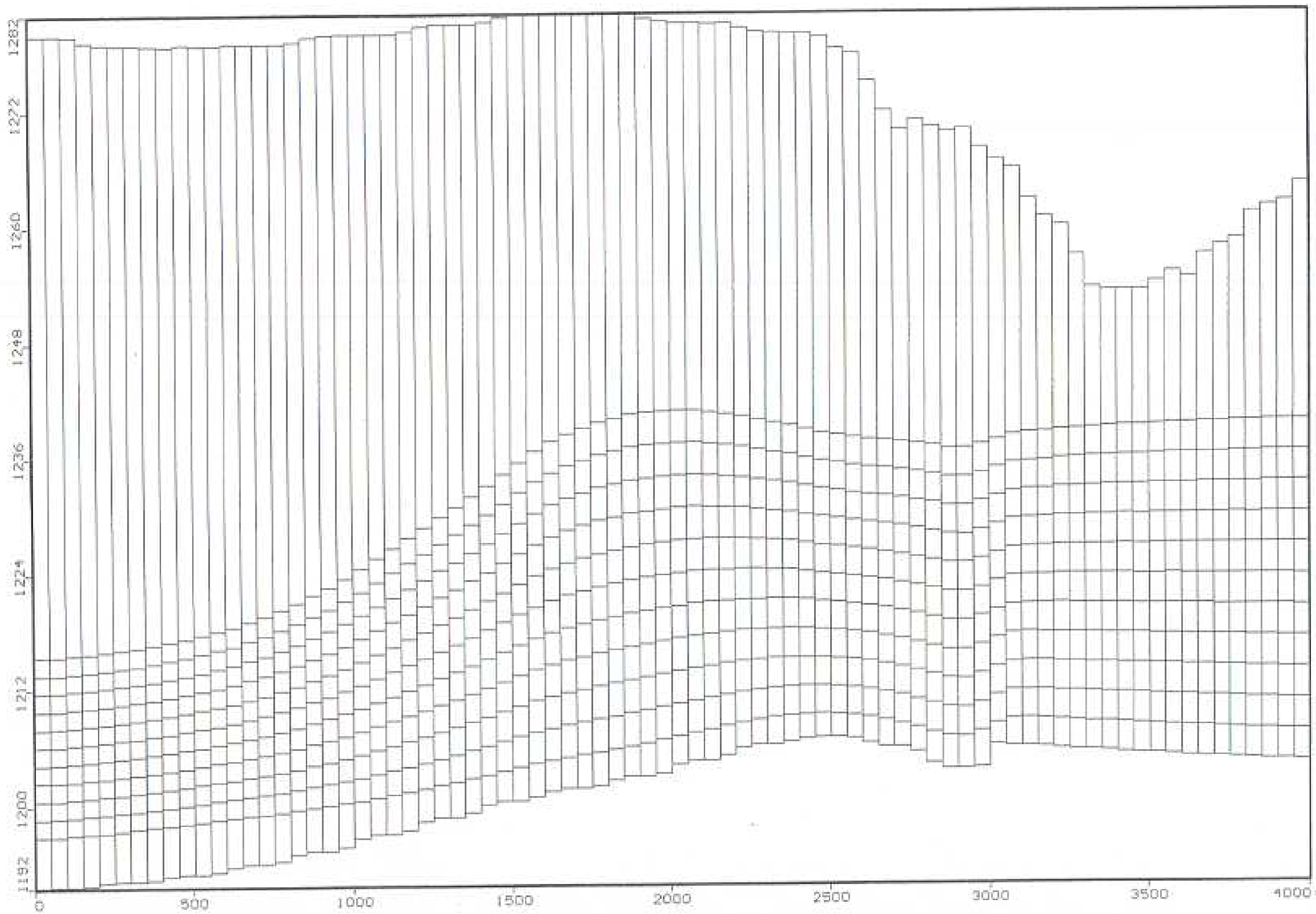
January 2003

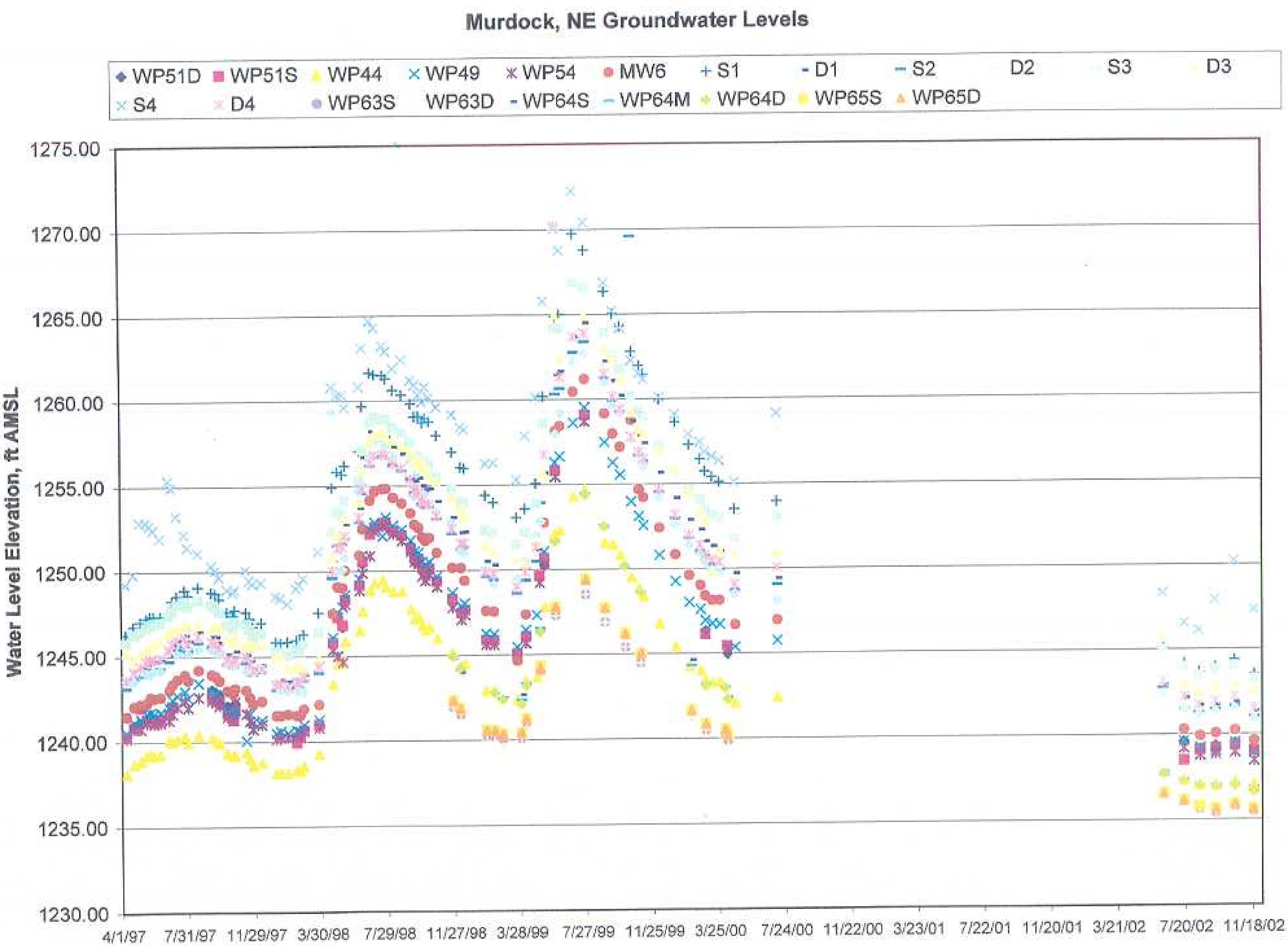
MURDOCK, NEBRASKA GROUNDWATER FLOW AND TRANSPORT MODELING AND LONG-TERM GROUNDWATER QUALITY MONITORING RECOMMENDATIONS

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

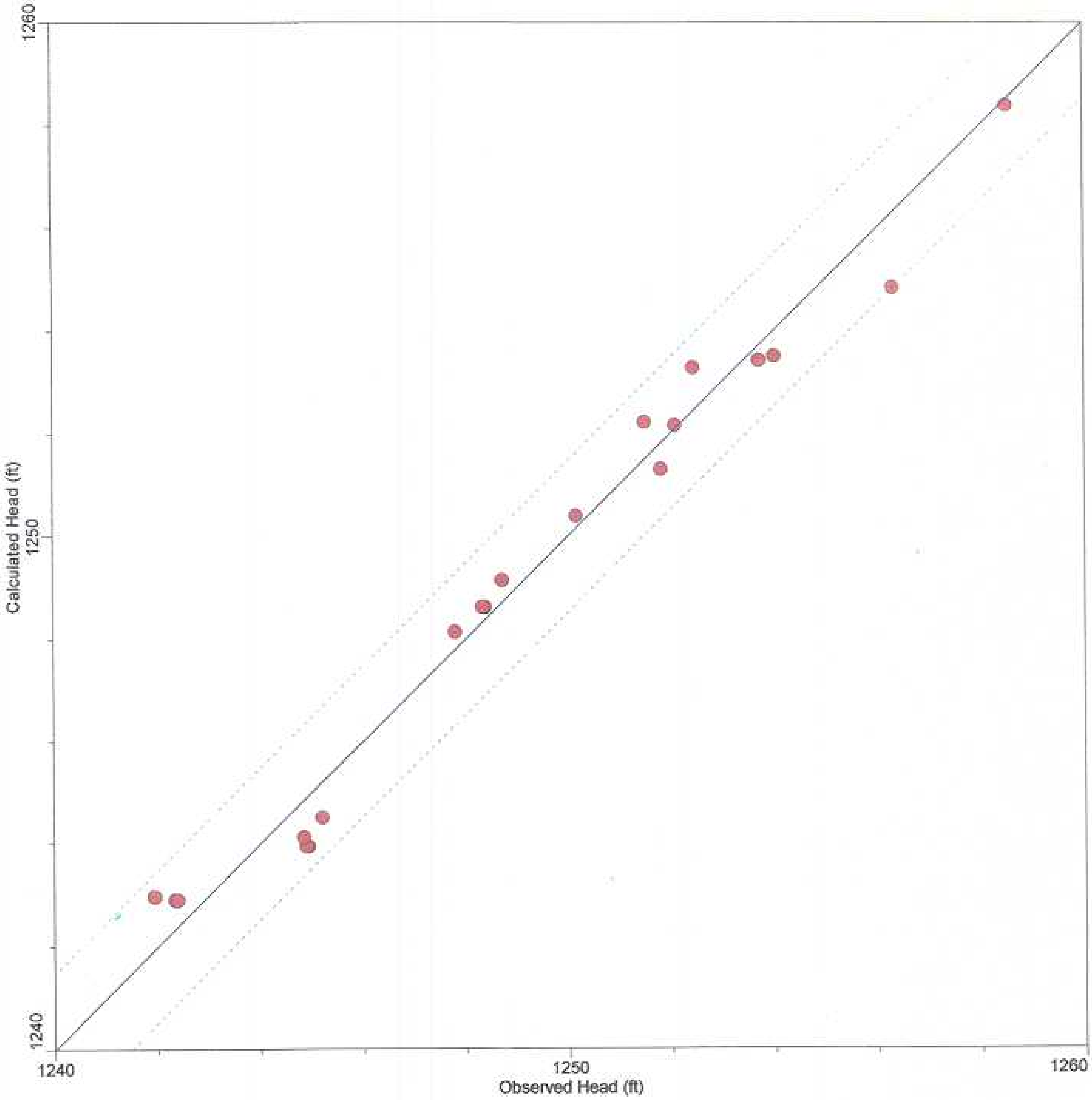

4000
3500
3000
2500
2000
1500
1000
500
0
0
1200
2400
3600
4800
6000
7200
8400
9200


1282
1272
1260
1248
1236
1224
1212
1200
1192
0
500
1000
1500
2000
2500
3000
3500
4000


Murdock, NE Groundwater Levels
WP51D
WP51S
WP44
WP49
WP54
MW6
S1
D1
S2
D2
S3
D3
S4
D4
WP63S
WP63D
WP64S
WP64M
WP64D
WP65S
WP65D
Water Level Elevation, ft AMSL
1275.00
1270.00
1265.00
1260.00
1255.00
1250.00
1245.00
1240.00
1235.00
1230.00
4/1/97
7/31/97
11/29/97
3/30/98
7/29/98
11/27/98
3/28/99
7/27/99
11/25/99
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

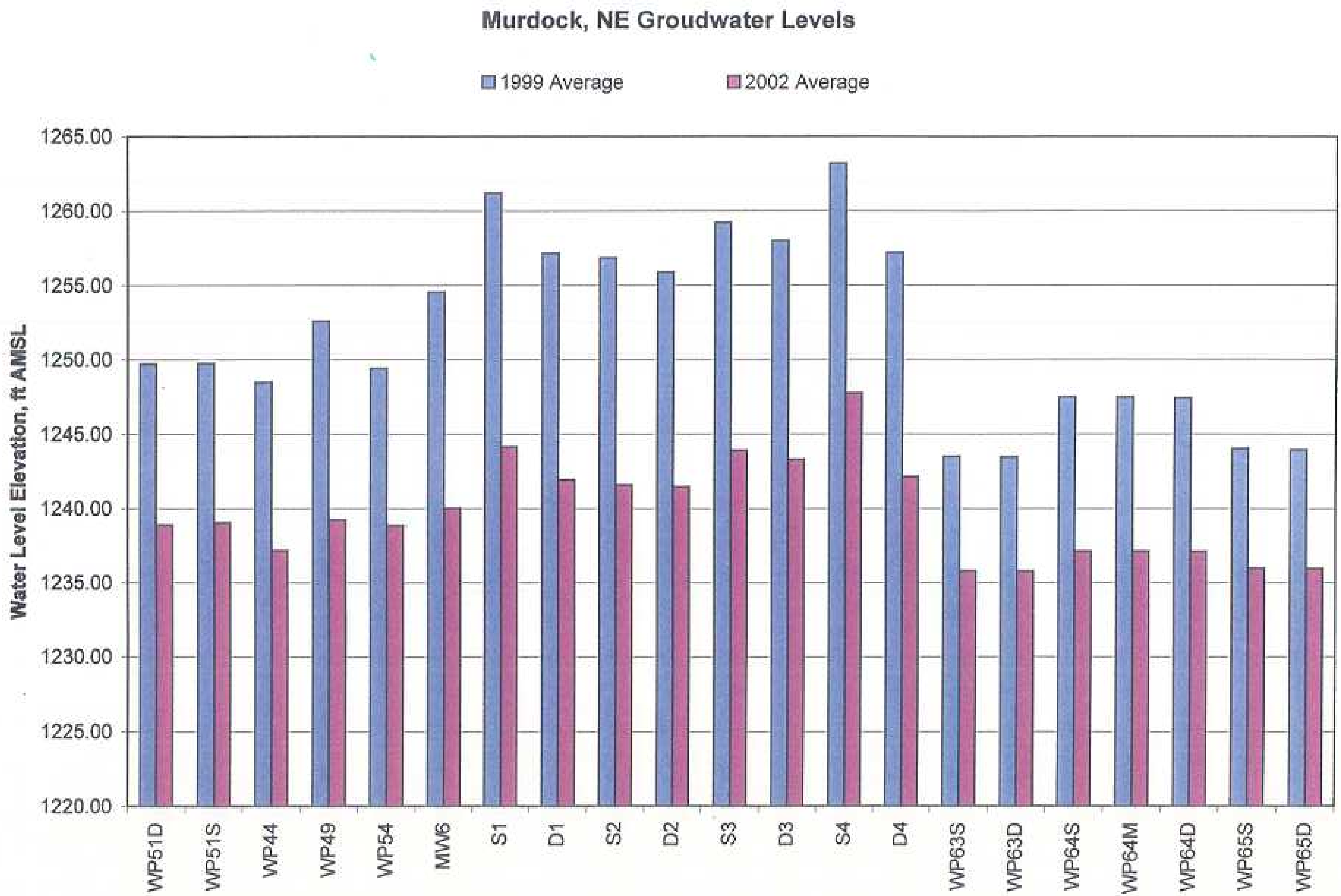
Calculated vs. Observed Head : Steady state

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

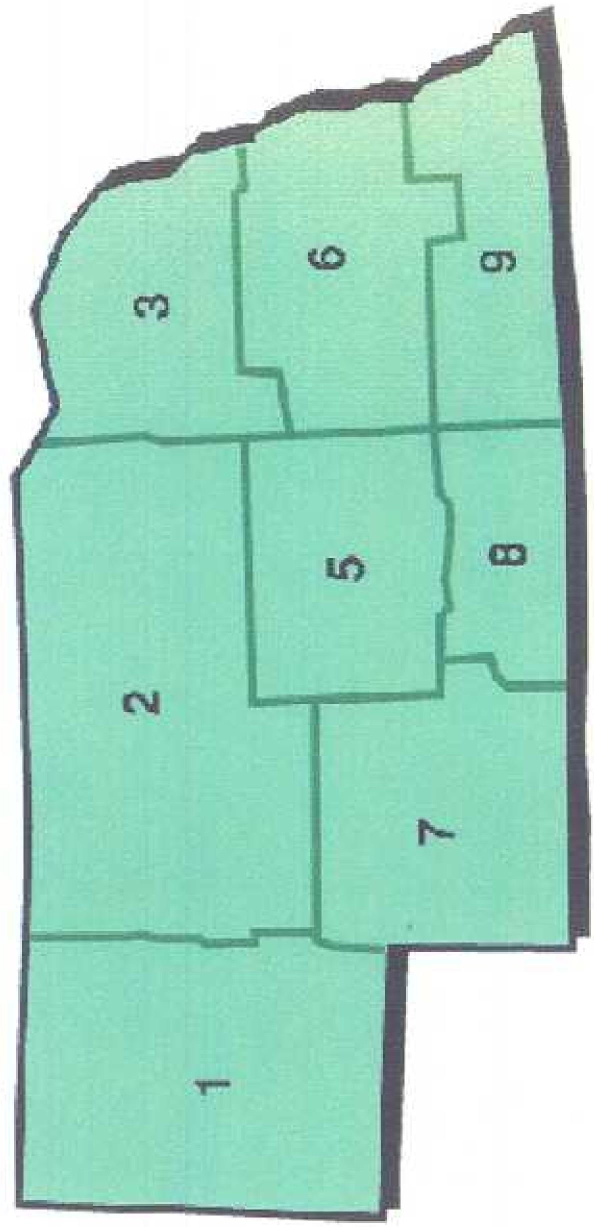


Num.Points : 21
Max. Residual: -1.462842 (ft) at S1/S1
Min. Residual: 0.06526367 (ft) at D2/D2
Residual Mean : 0.004922805 (ft)
Absolute Residual Mean : 0.5984584 (ft)

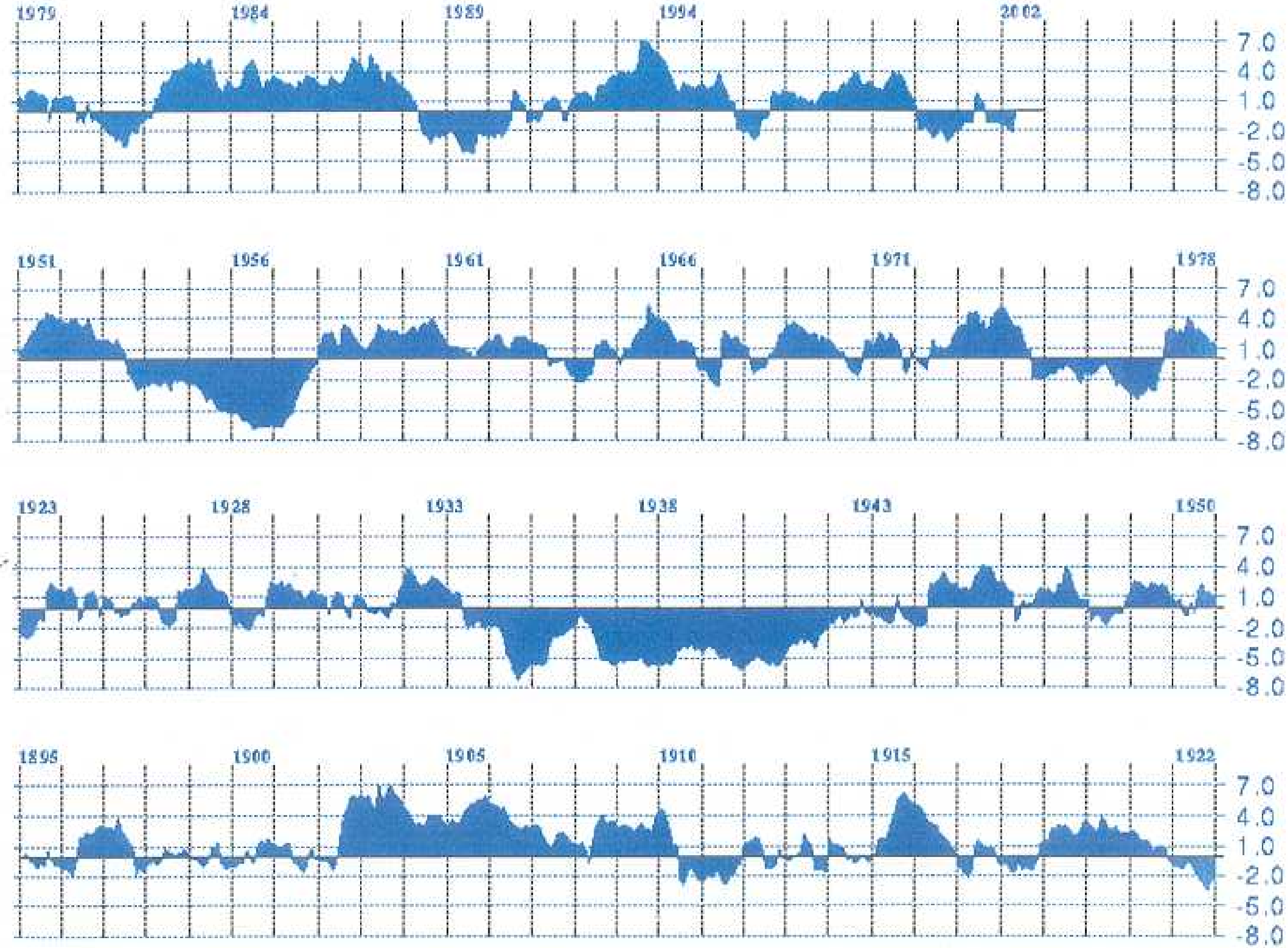
Standard Error of the Estimate : 0.1549392 (ft)
Root mean squared : 0.6929269 (ft)
Normalized RMS : 4.181816 (%)


Murdock, NE Groudwater Levels
1999 Average
2002 Average
Water Level Elevation, ft AMSL
1265.00
1260.00
1255.00
1250.00
1245.00
1240.00
1235.00
1230.00
1225.00
1220.00
WP51D
WP51S
WP44
WP49
WP54
MW6
S1
D1
S2
D2
S3
D3
S4
D4
WP63S
WP63D
WP64S
WP64M
WP64D
WP65S
WP65D

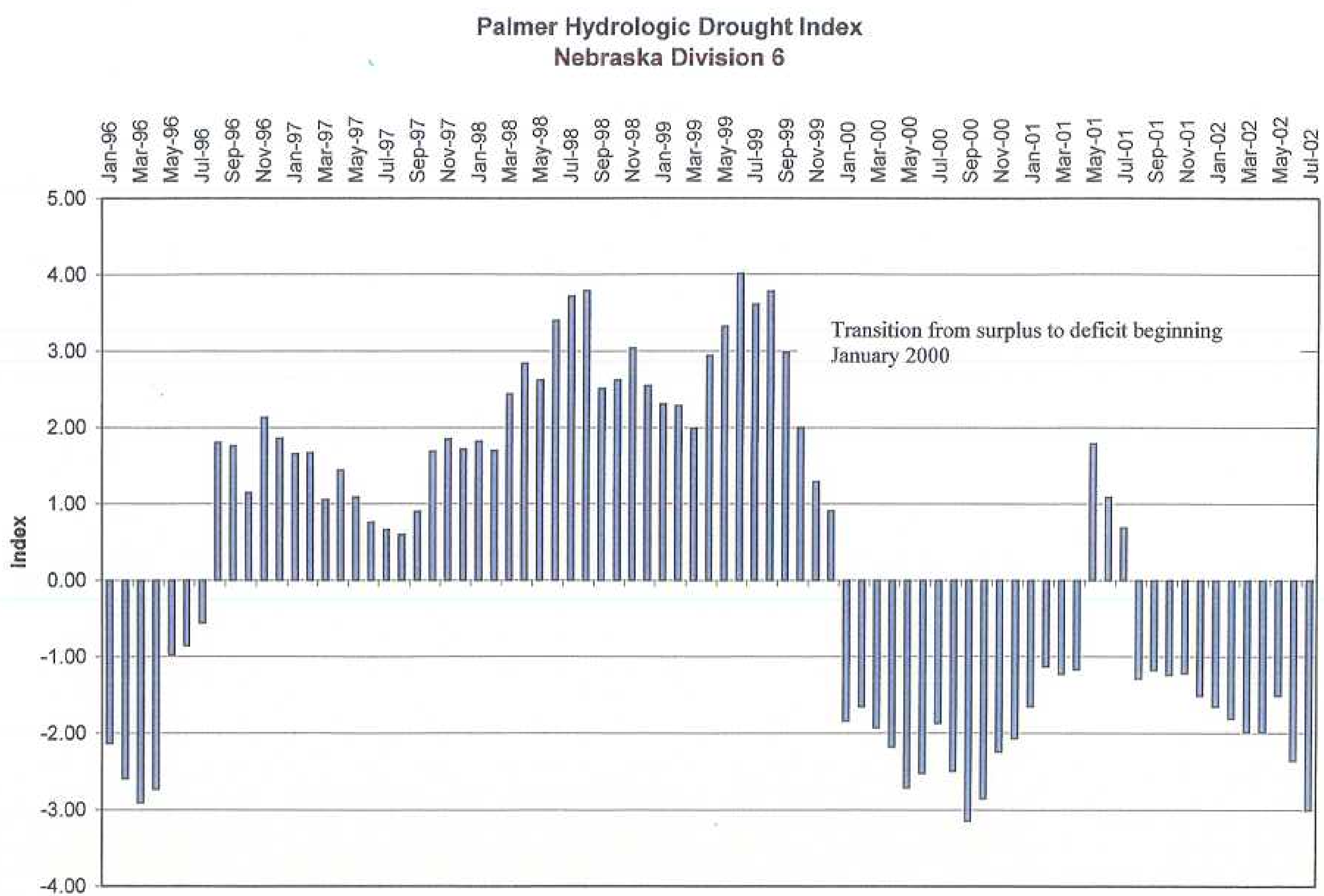
Agricultural Divisions in Nebraska – Murdock is in Division 6



Palmer Hydrological Drought Index



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



Palmer Hydrologic Drought Index
Nebraska Division 6
Transition from surplus to deficit beginning January 2000
Index
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
-4.00
Jan-96
Mar-96
May-96
Jul-96
Sep-96
Nov-96
Jan-97
Mar-97
May-97
Jul-97
Sep-97
Nov-97
Jan-98
Mar-98
May-98
Jul-98
Sep-98
Nov-98
Jan-99
Mar-99
May-99
Jul-99
Sep-99
Nov-99
Jan-00
Mar-00
May-00
Jul-00
Sep-00
Nov-00
Jan-01
Mar-01
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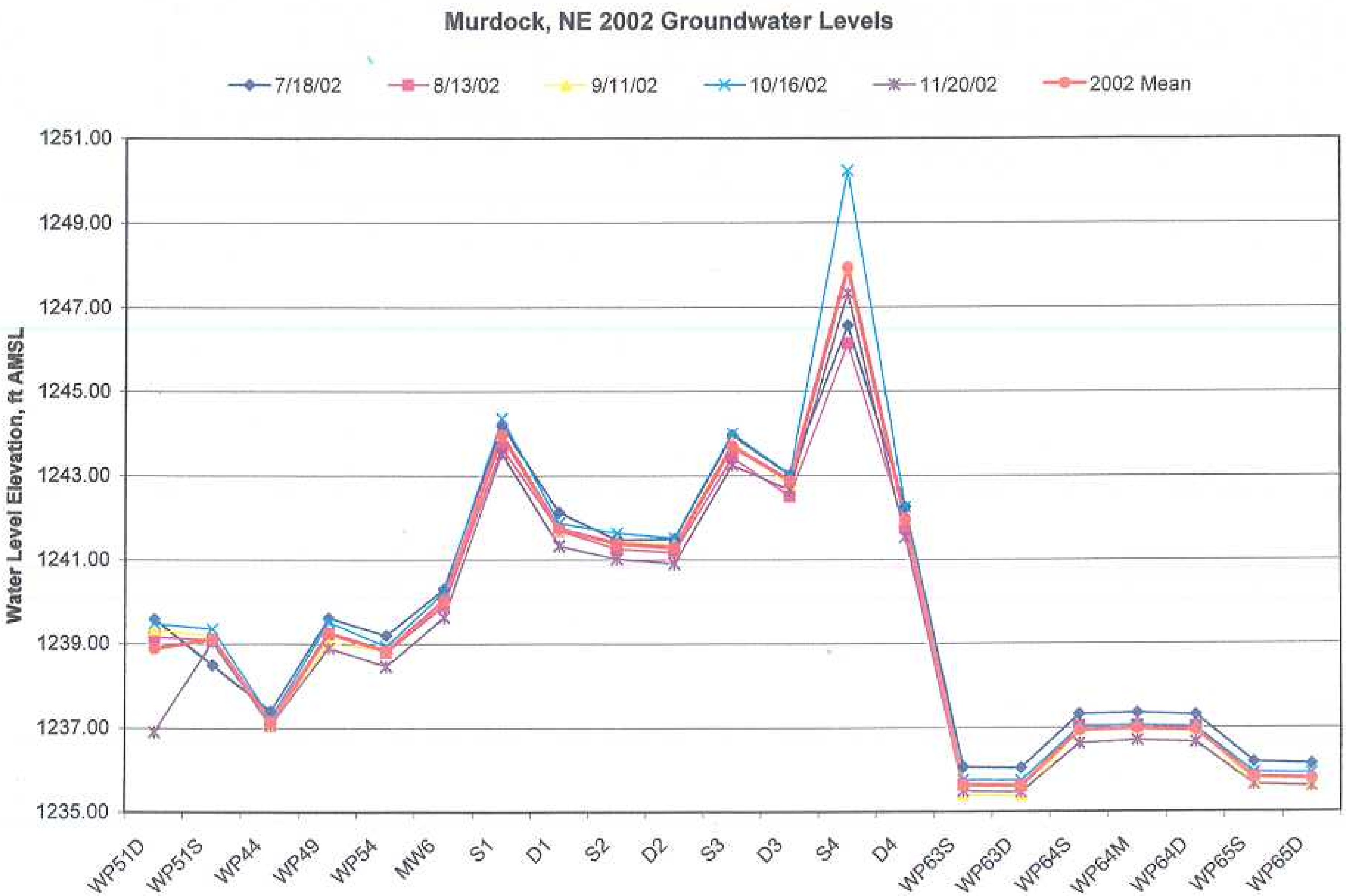
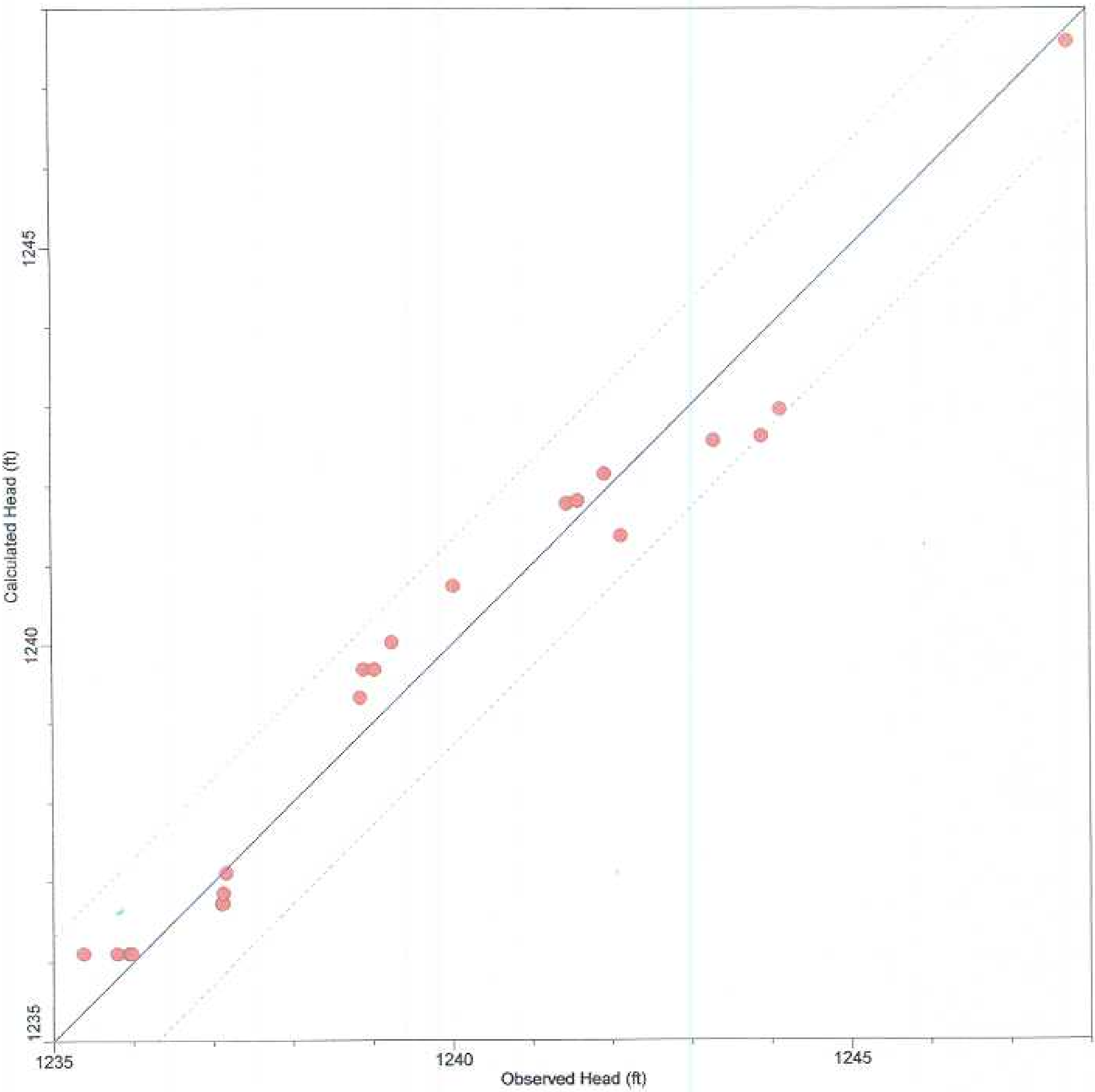
Jul-01
Sep-01
Nov-01
Jan-02
Mar-02
May-02
Jul-02


Murdock, NE 2002 Groundwater Levels
7/18/02
8/13/02
9/11/02
10/16/02
11/20/02
2002 Mean
Water Level Elevation, ft AMSL
1251.00
1249.00
1247.00
1245.00
1243.00
1241.00
1239.00
1237.00
1235.00
WP51D
WP51S
WP44
WP49
WP54
MW6
S1
D1
S2
D2
S3
D3
S4
D4
WP63S
WP63D
WP64S
WP64M
WP64D
WP65S
WP65D

Calculated vs. Observed Head : Steady state

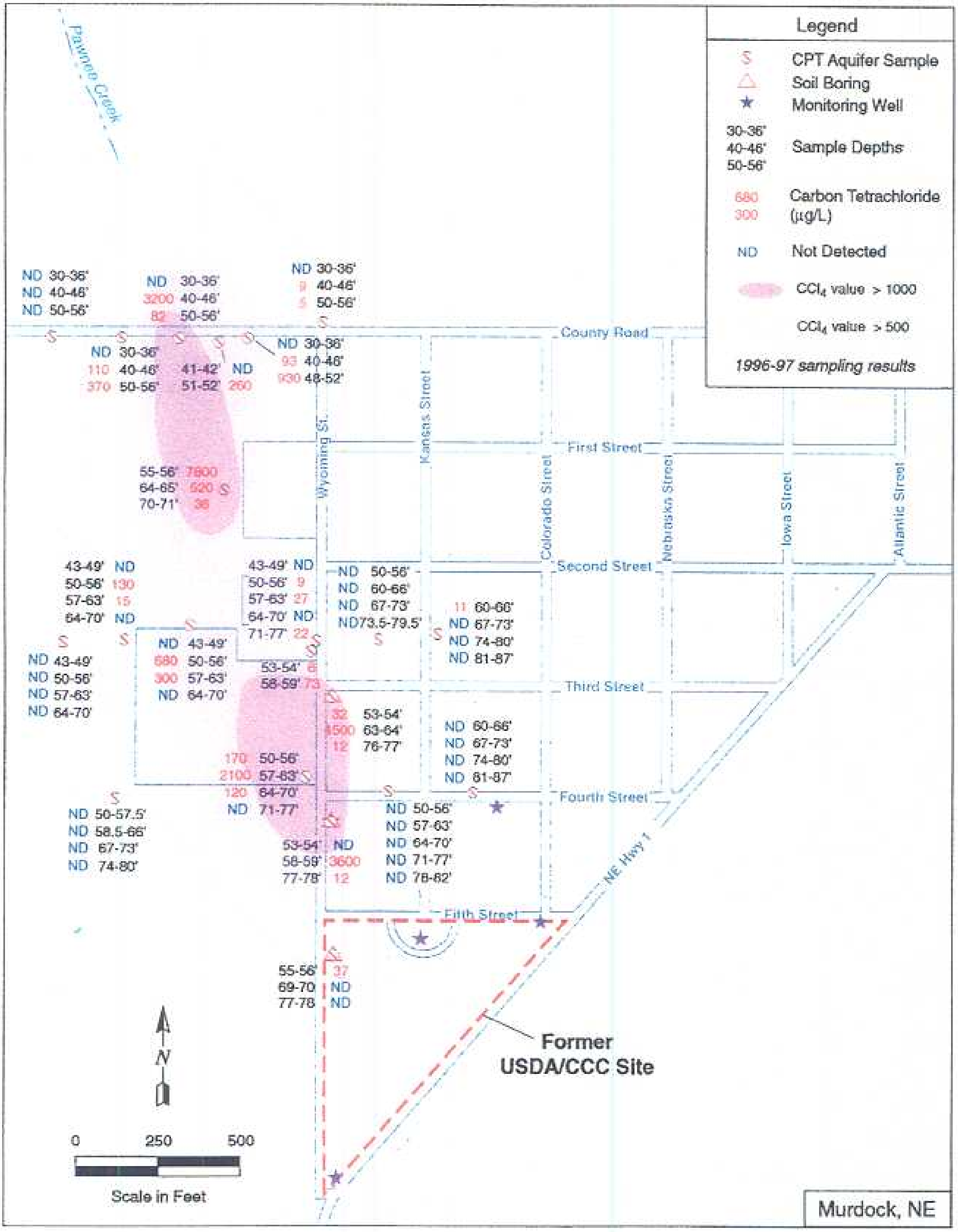
Calibration to average observed 2002 groundwater levels



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 (%)

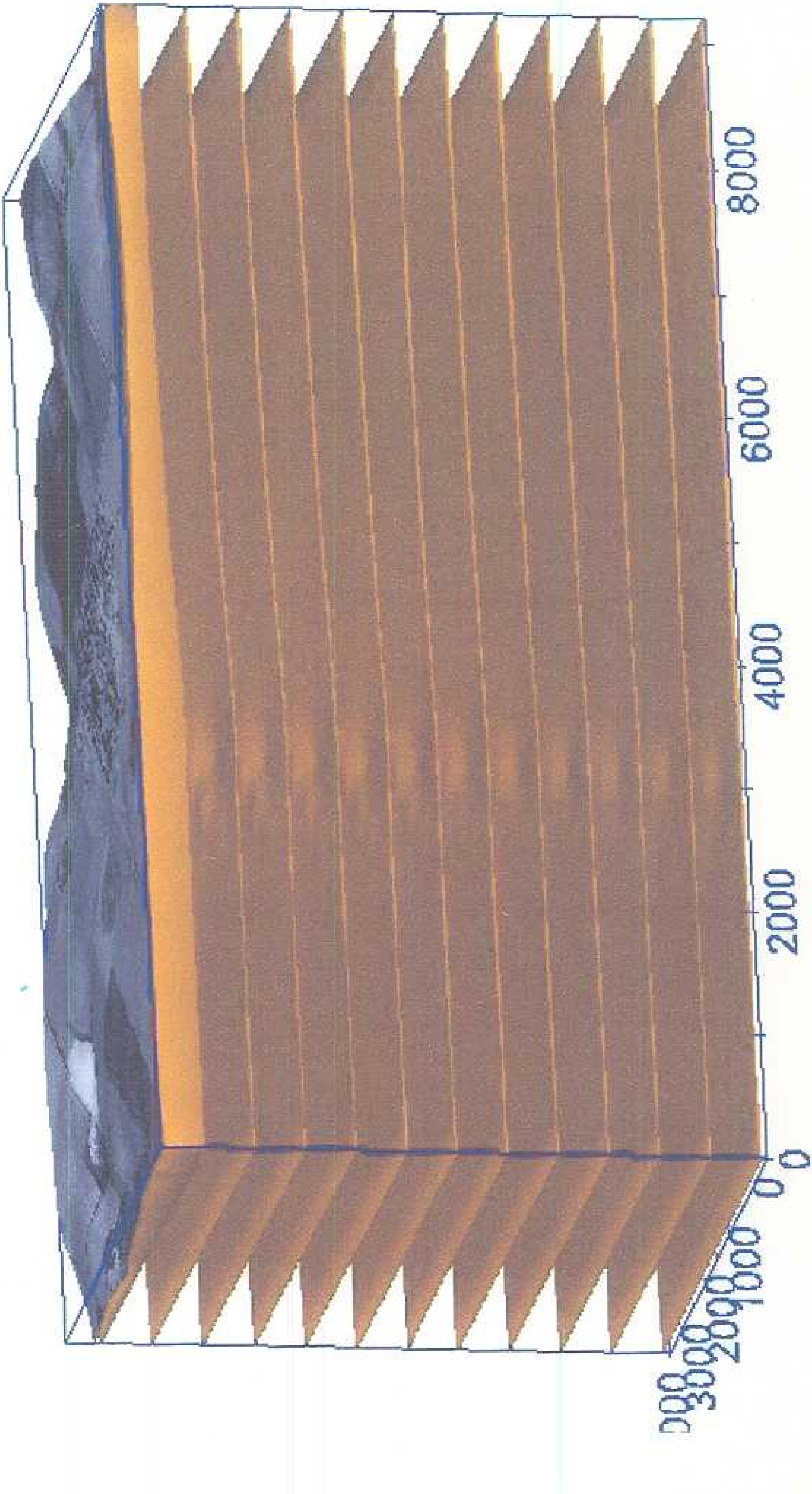
Initial CCl_4 concentration distribution for transport model calibration



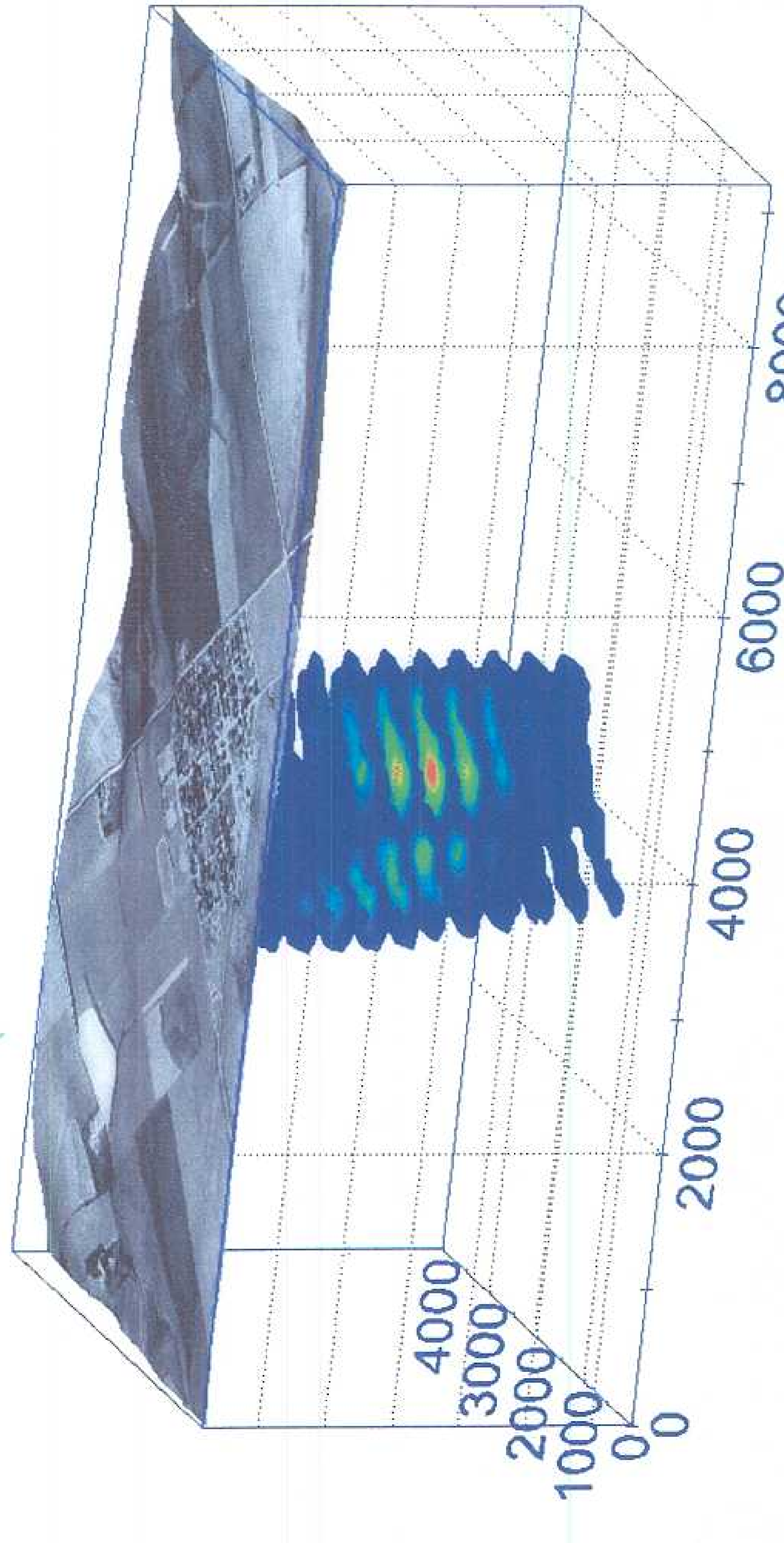
Murdock Monitoring Program -- CCl4 and ChCl3

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	CCl4 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	3904.41	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

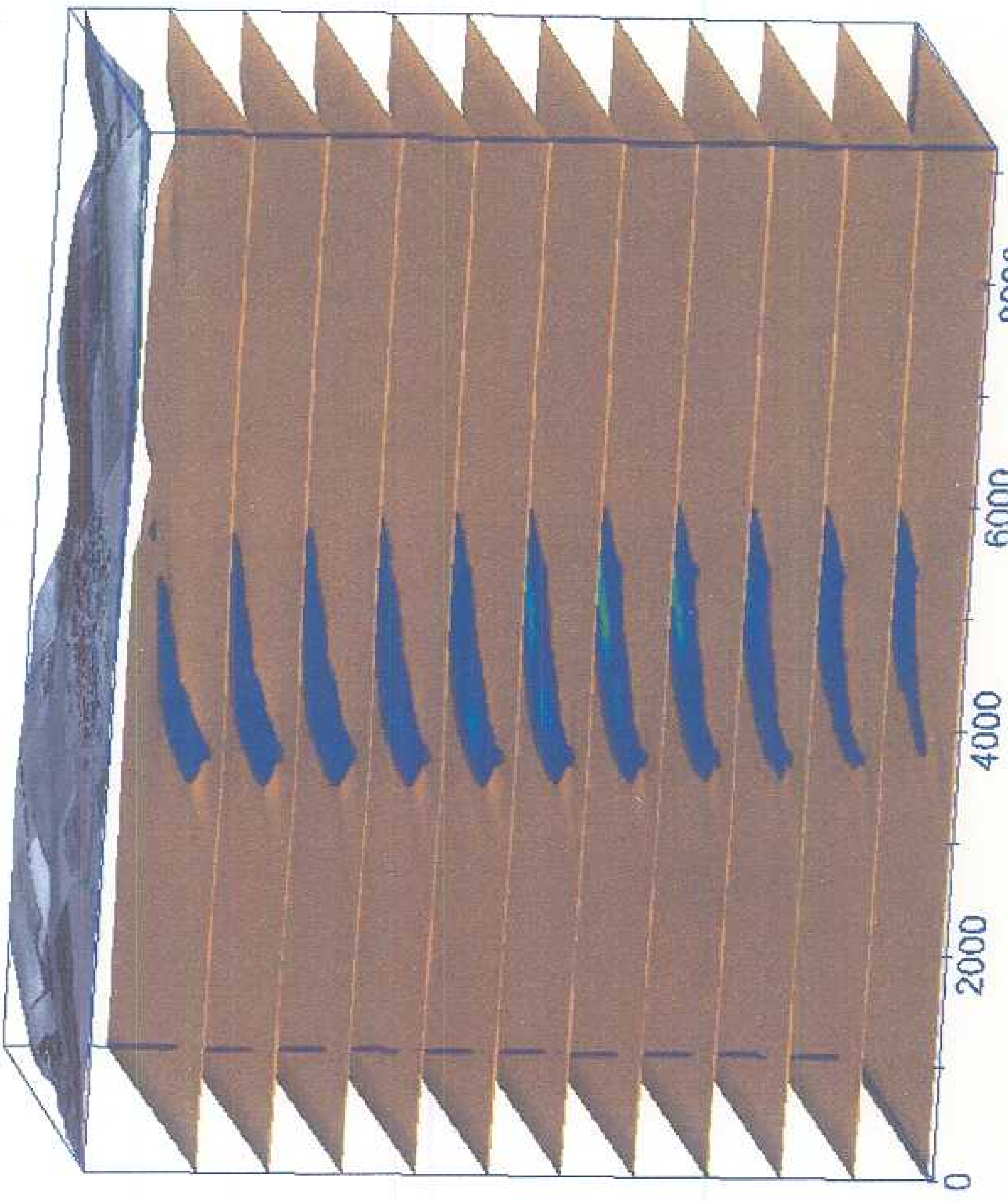
Murdock groundwater model layer structure



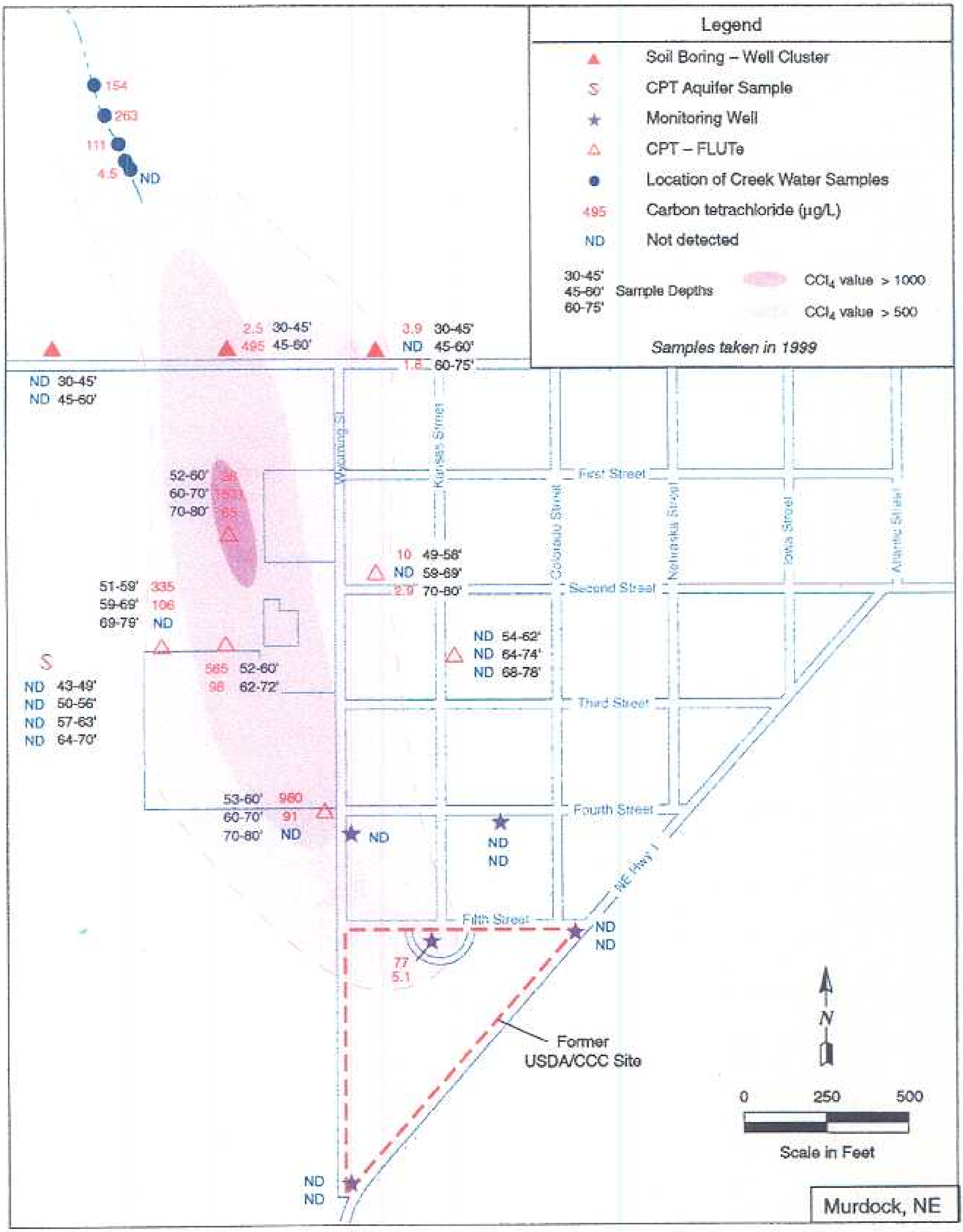
Initial CCl_4 concentrations for MT3D-99 transport modeling by model layer

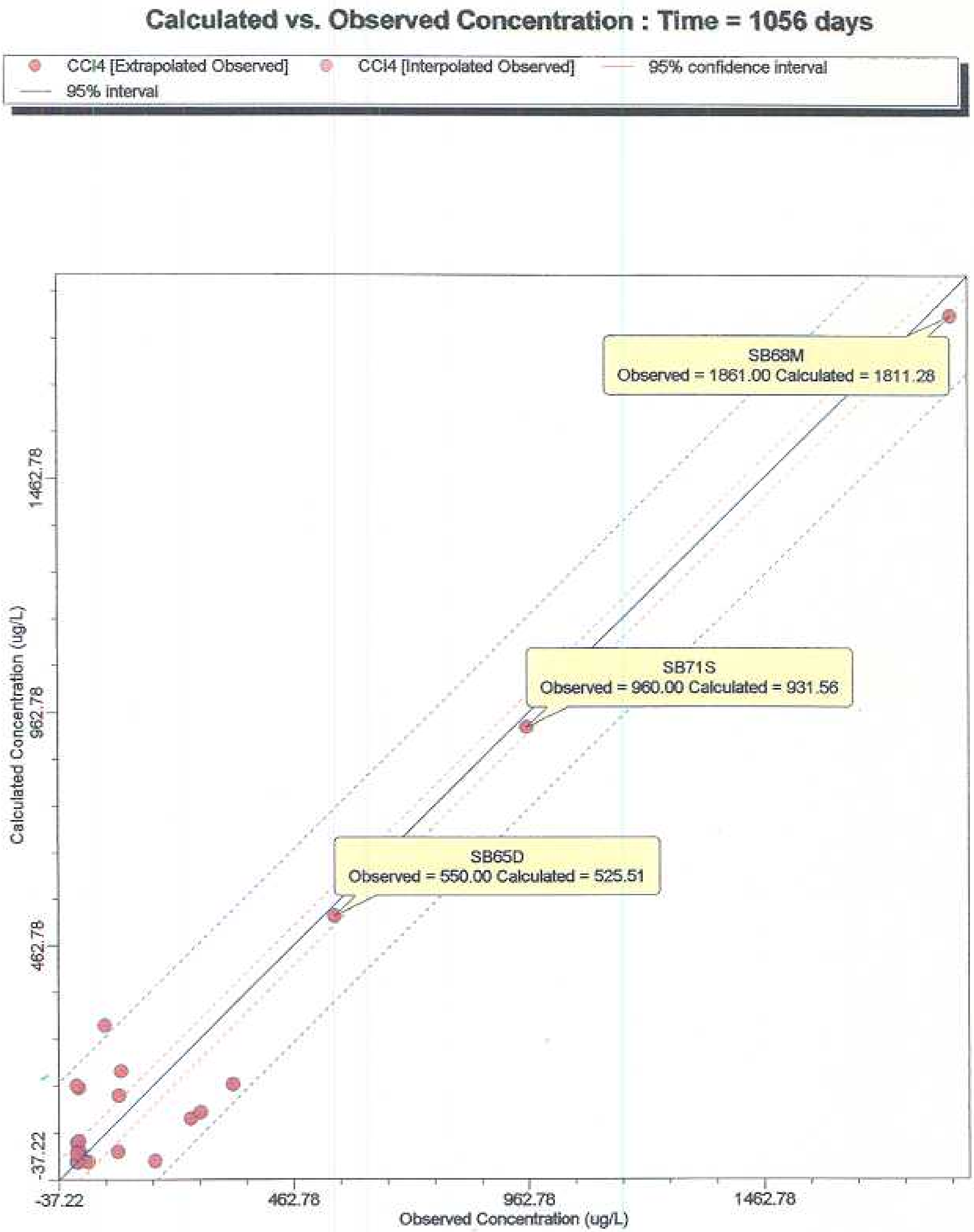


1996/97 CCl_4 concentrations mapped to model grid structure for initial conditions



November 1999 transport model calibration target concentrations

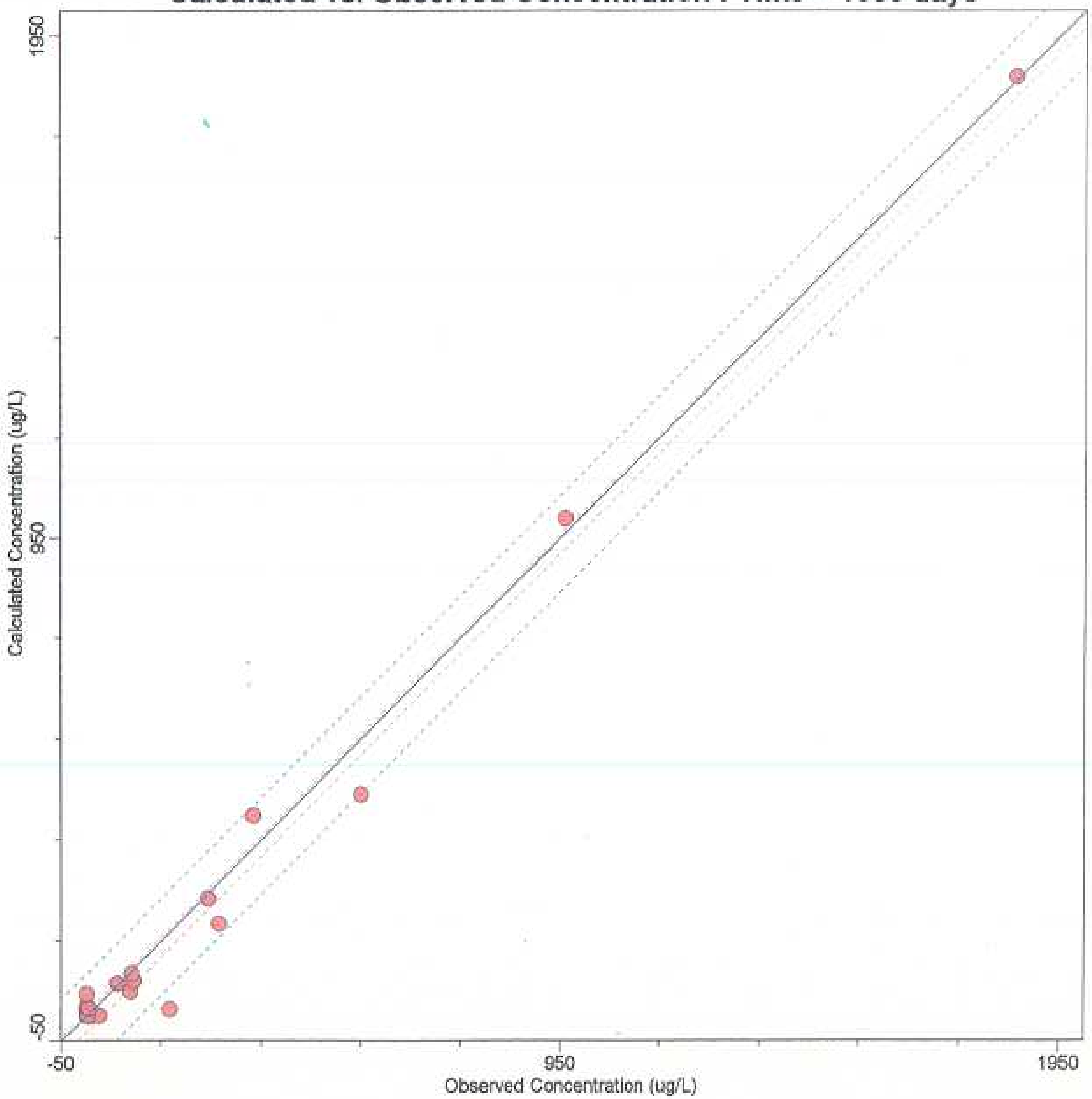




Num.Points : 24
Max. Residual: 230.3179 (ug/L) at SB71M/SB71M
Min. Residual: 0.07512894 (ug/L) at SB63S/SB63S
Residual Mean : -0.5727512 (ug/L)
Absolute Residual Mean : 69.42724 (ug/L)

Standard Error of the Estimate : 20.49186 (ug/L)
Root mean squared : 98.27717 (ug/L)
Normalized RMS : 5.280879 (%)

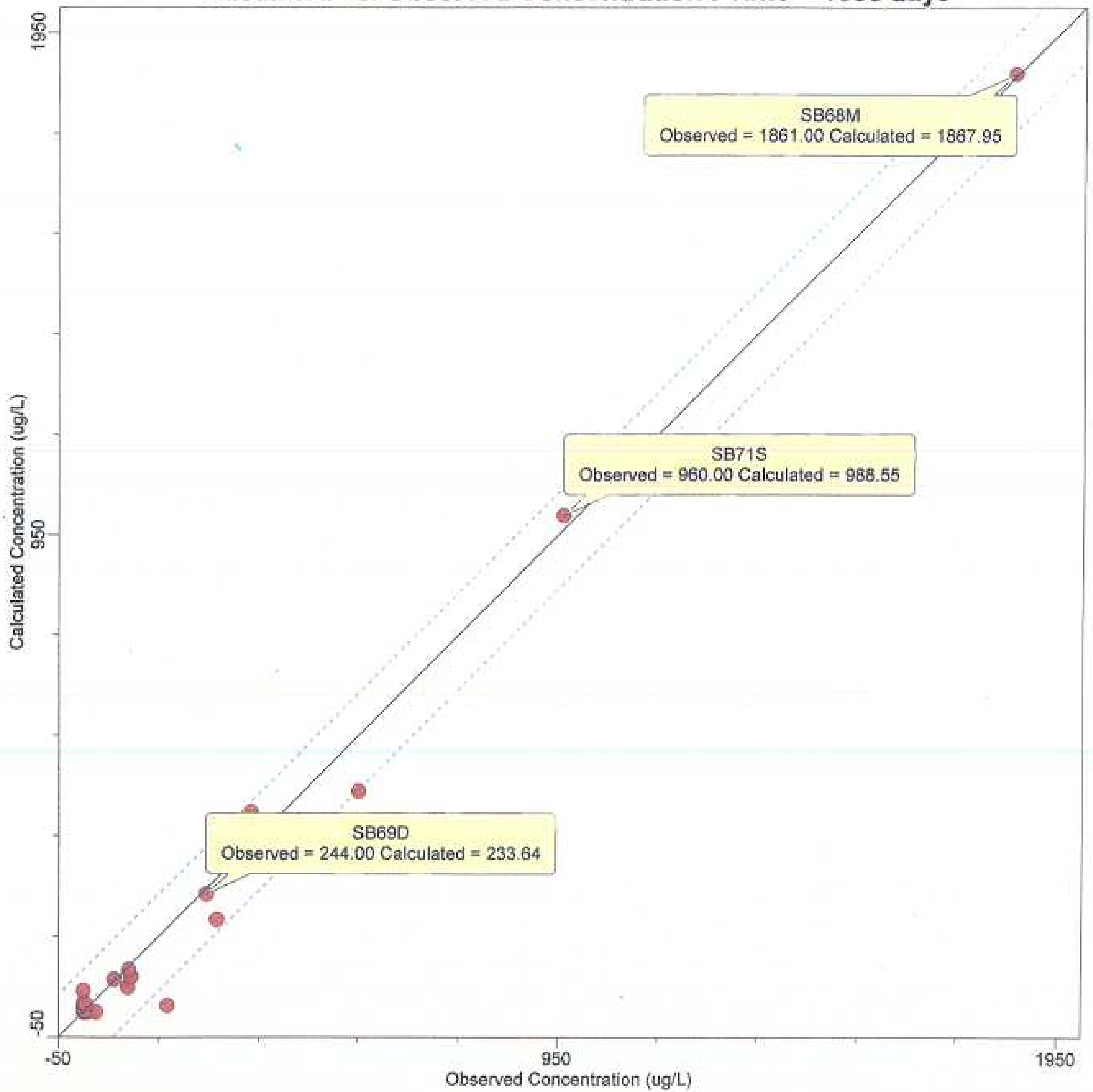
Calculated vs. Observed Concentration : Time = 1056 days



Num.Points : 24
Max. Residual: -154.5781 (ug/L) at SB72S/SB72S
Min. Residual: -0.009305454 (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 (%)

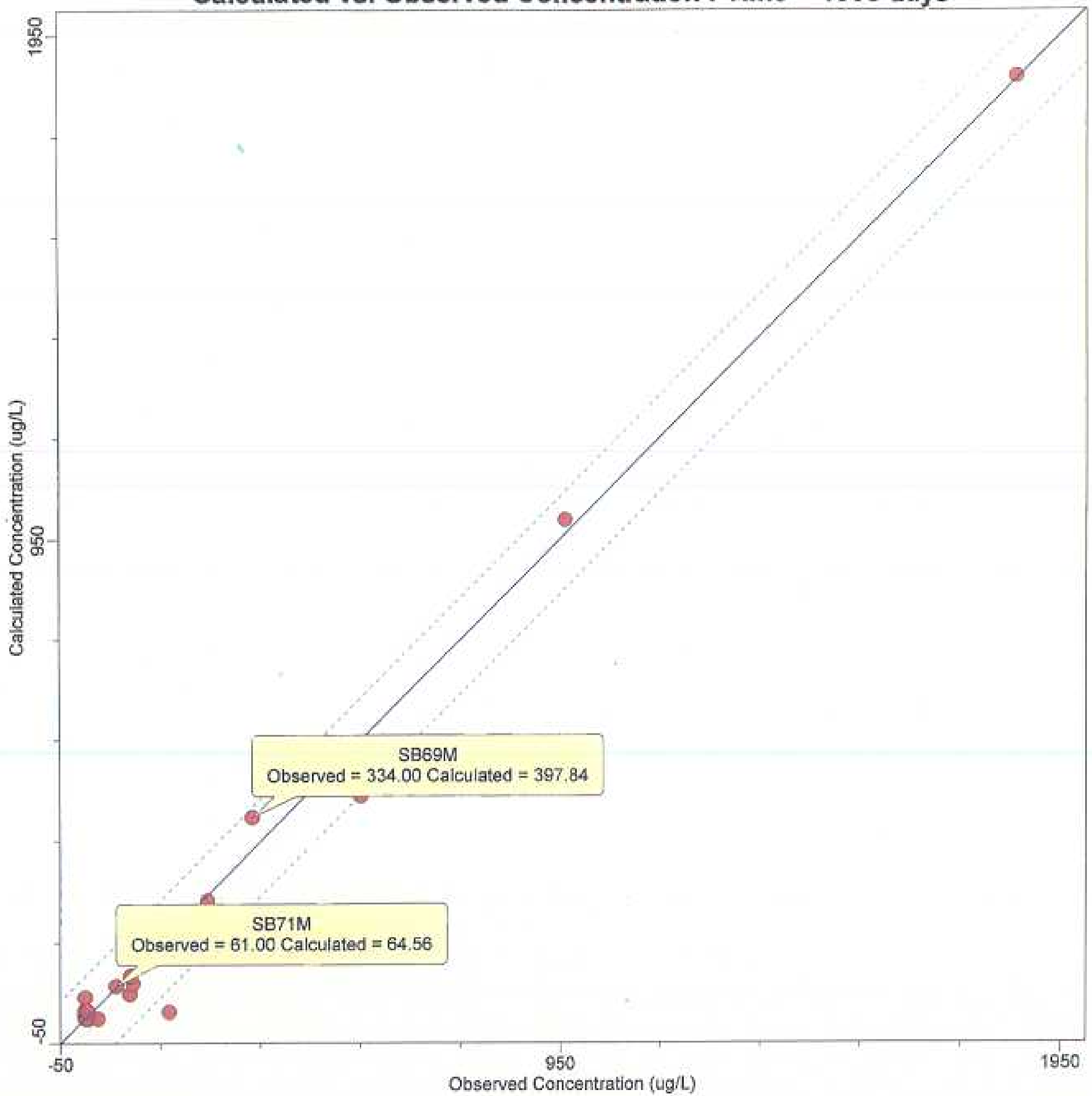
Calculated vs. Observed Concentration : Time = 1056 days



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 (%)

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)

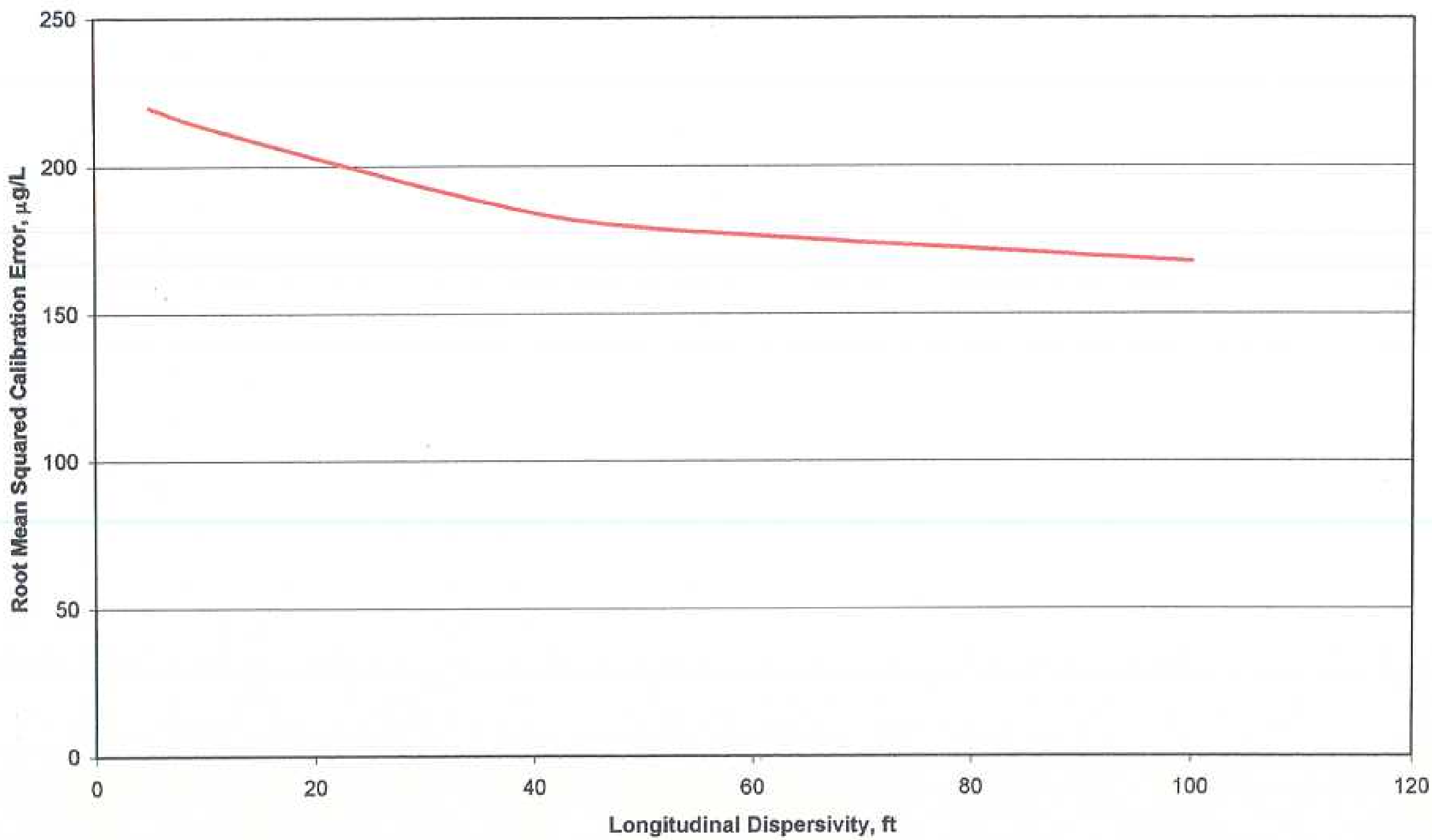
Standard Error of the Estimate : 9.522373 (ug/L)
Root mean squared : 47.14297 (ug/L)
Normalized RMS : 2.533207 (%)

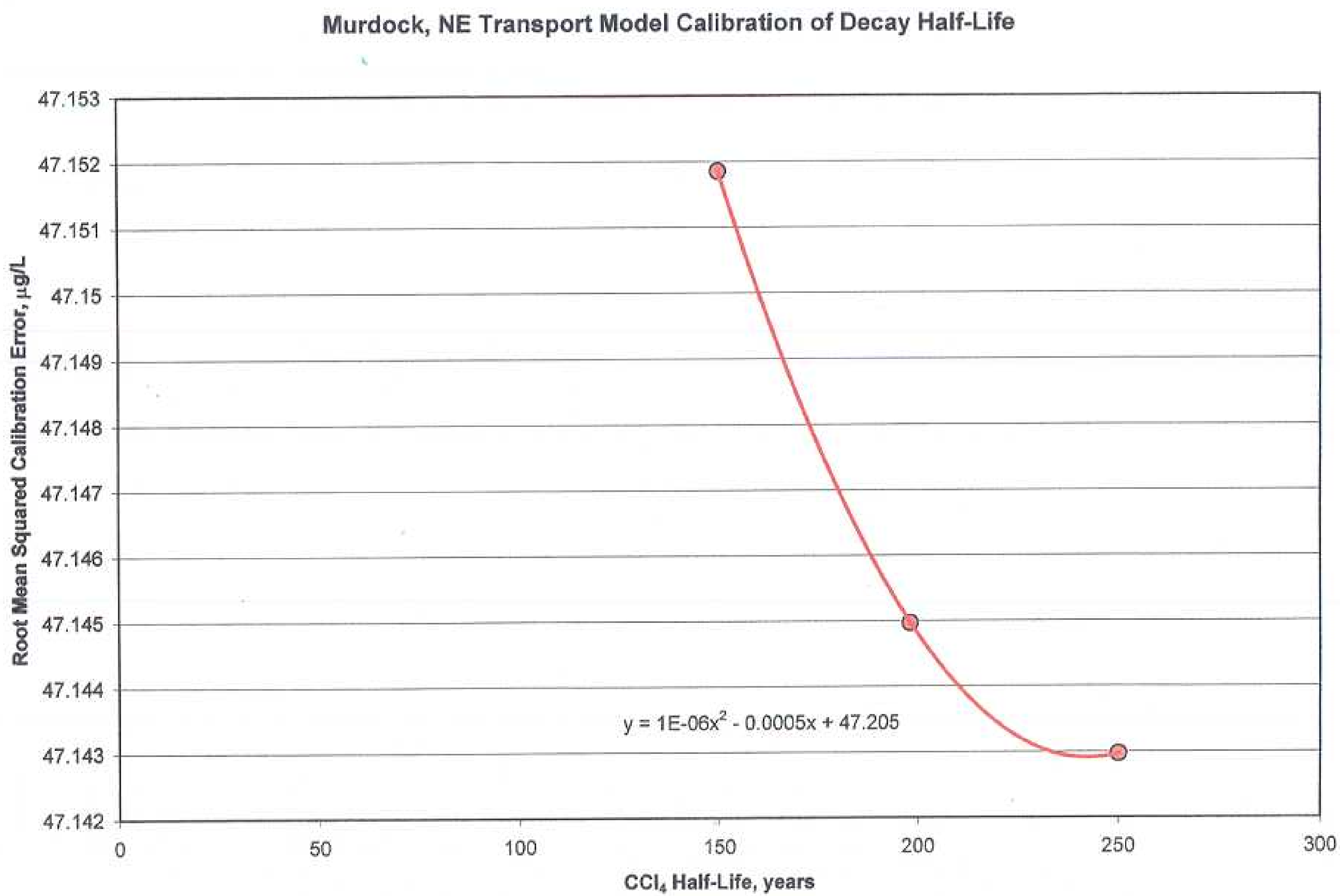
Model	Stratigraphic Unit	Effective Porosity[1]	Total Porosity[2]	Longitudinal Dispersivity ft	Transverse Dispersivity ft	Vertical Dispersivity ft	Bulk Density lb/ft^3	K_d ft^3/lb	K_d L/μg	Retardation Factor
Layer 1	Silt/Clay	0.32	0.39	34.8	1.0	0.0	101.0	7.337E-03	4.580E-10	2.90
Layer 2	Sand	0.25	0.40	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	5.166E-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

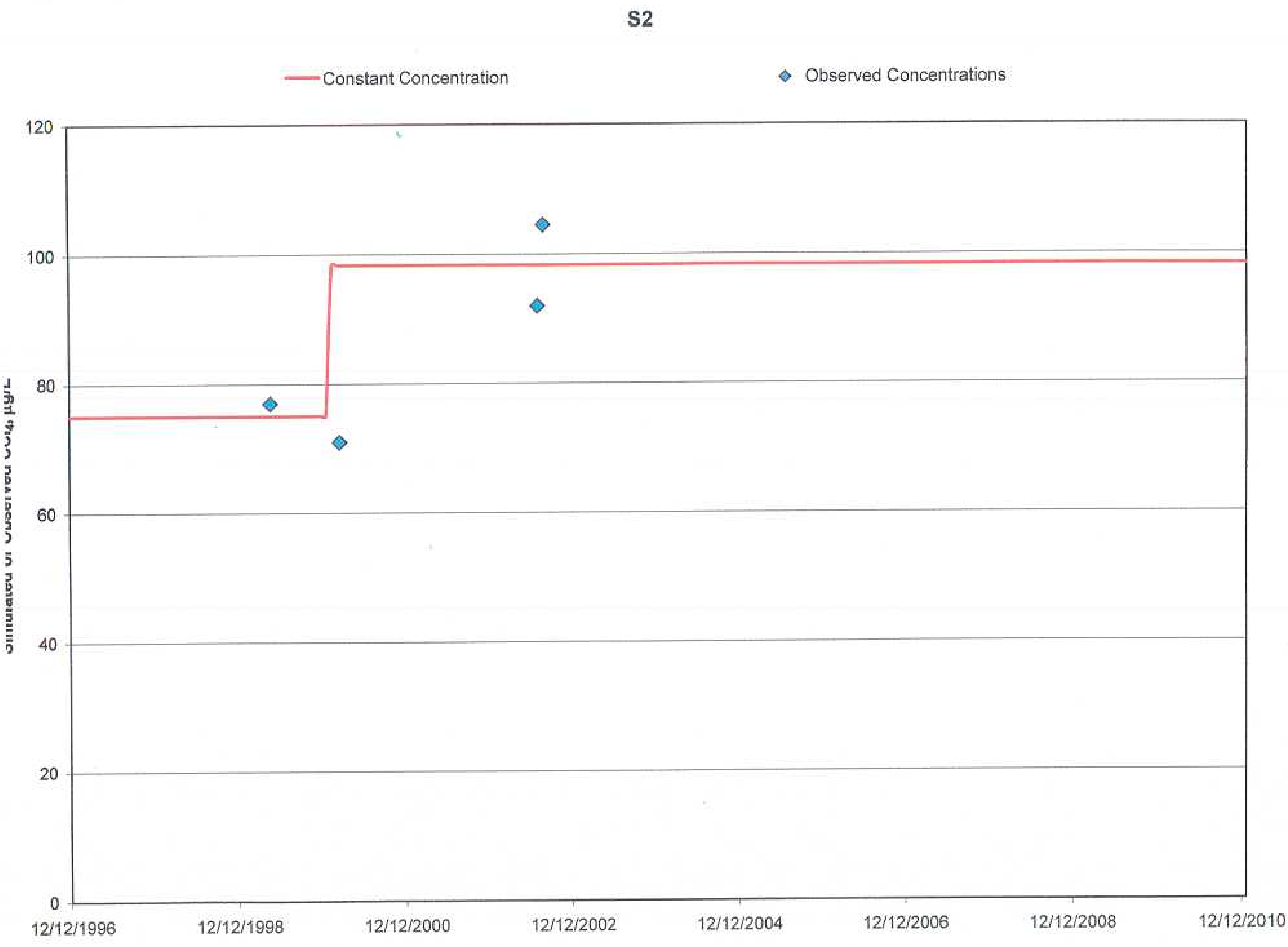
[1]Estimated from de Marsily, G., 1986, *Quantitative Hydrogeology*, Academic Press, Inc., Orlando, FL, p. 36.
[2]$n = (1 - \rho_b/\rho_d)$; assume ρ_d = 165.0857 lb/ft^3

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	1st 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	98.5	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



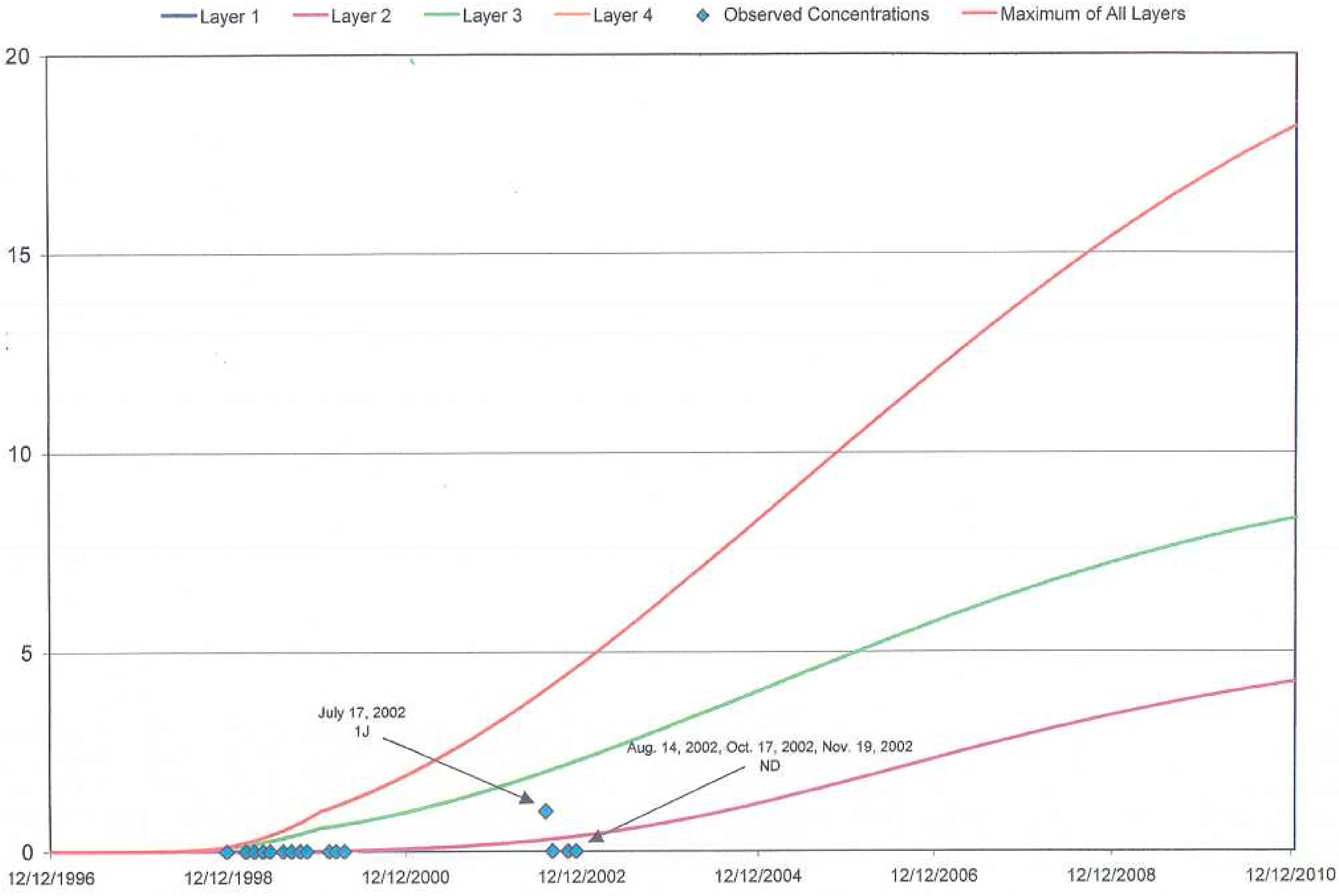

Murdock, NE Transport Model Calibration of Decay Half-Life
Root Mean Squared Calibration Error, µg/L
47.153
47.152
47.151
47.15
47.149
47.148
47.147
47.146
47.145
47.144
47.143
47.142
0
50
100
150
200
250
300
CCl4 Half-Life, years
y = 1E-06x2 - 0.0005x + 47.205


S2
Constant Concentration
Observed Concentrations
120
100
80
60
40
20
0
12/12/1996
12/12/1998
12/12/2000
12/12/2002
12/12/2004
12/12/2006
12/12/2008
12/12/2010

1/17/2003

SB71S
0
46.80005
49.90002
53
56.20007
59.30005
62.40002
65.5
68.6001
71.80005
74.90002
78
81.20007
SB71M
0
46.80005
49.90002
53
56.20007
59.30005
62.40002
65.5
68.6001
71.80005
74.90002
78
81.20007
SB71D
0
46.80005
49.90002
53
56.20007
59.30005
62.40002
65.5
68.6001
71.80005
74.90002
78
81.20007

SB63S



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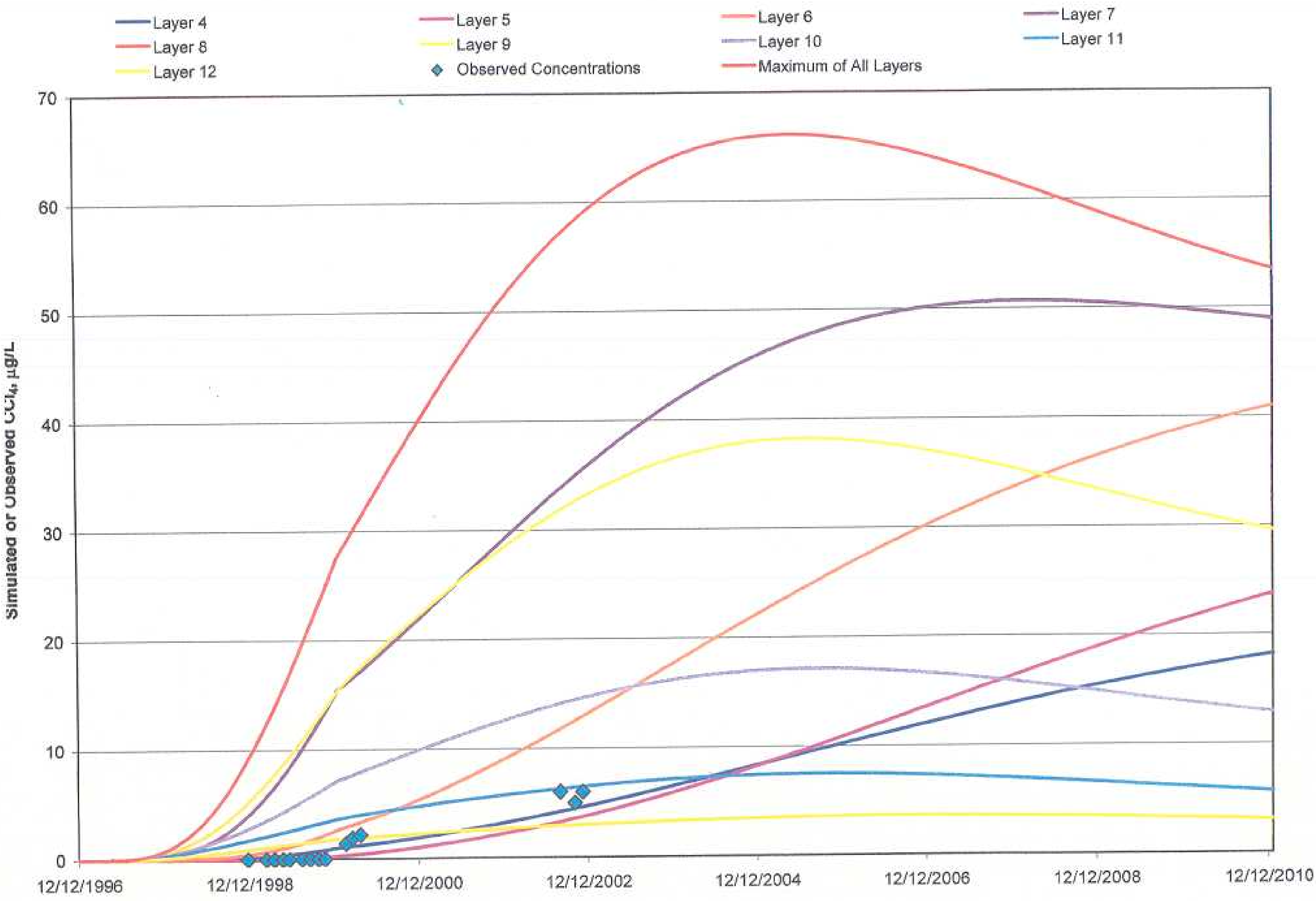
SB63D



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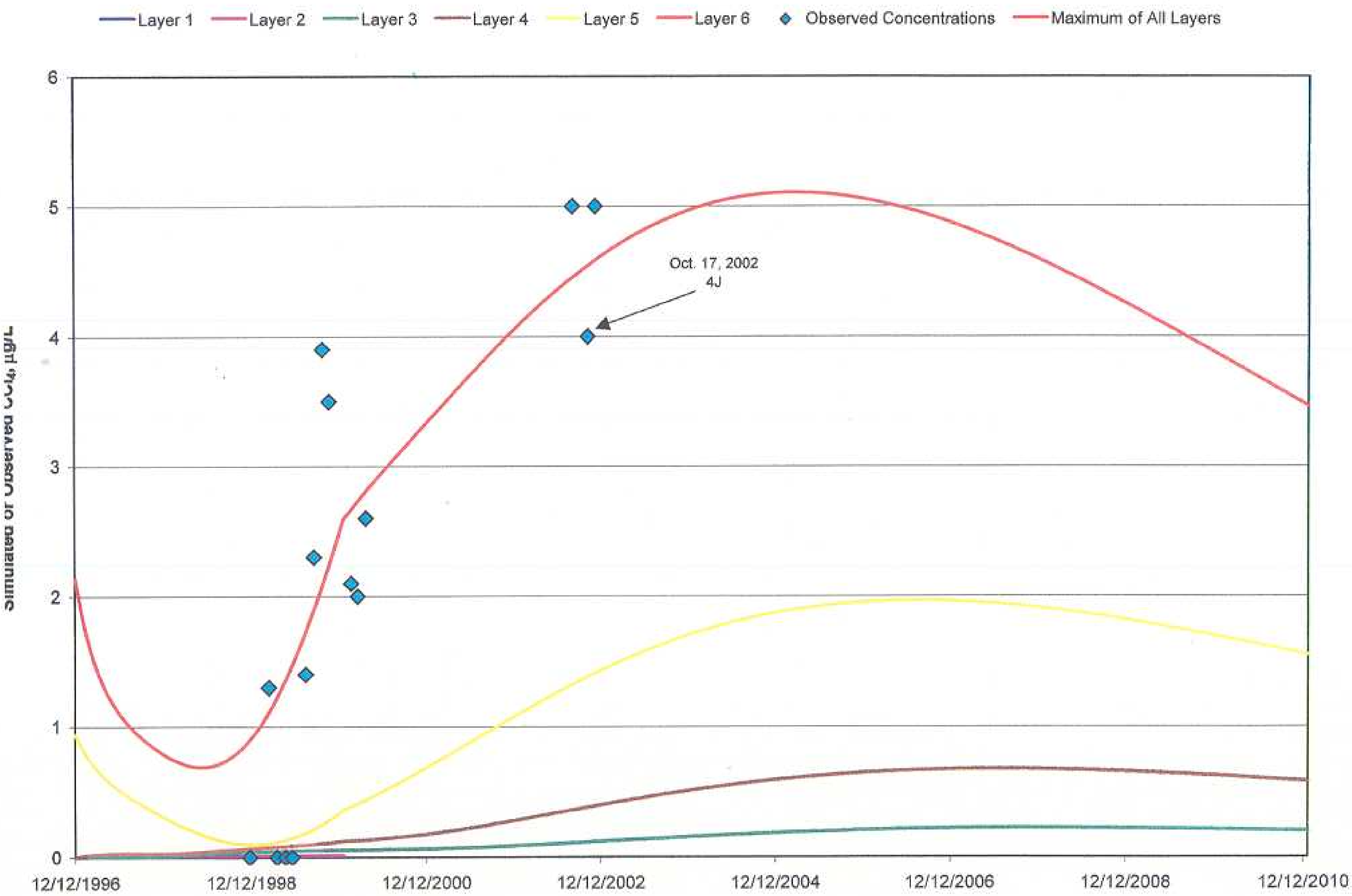
SB64S



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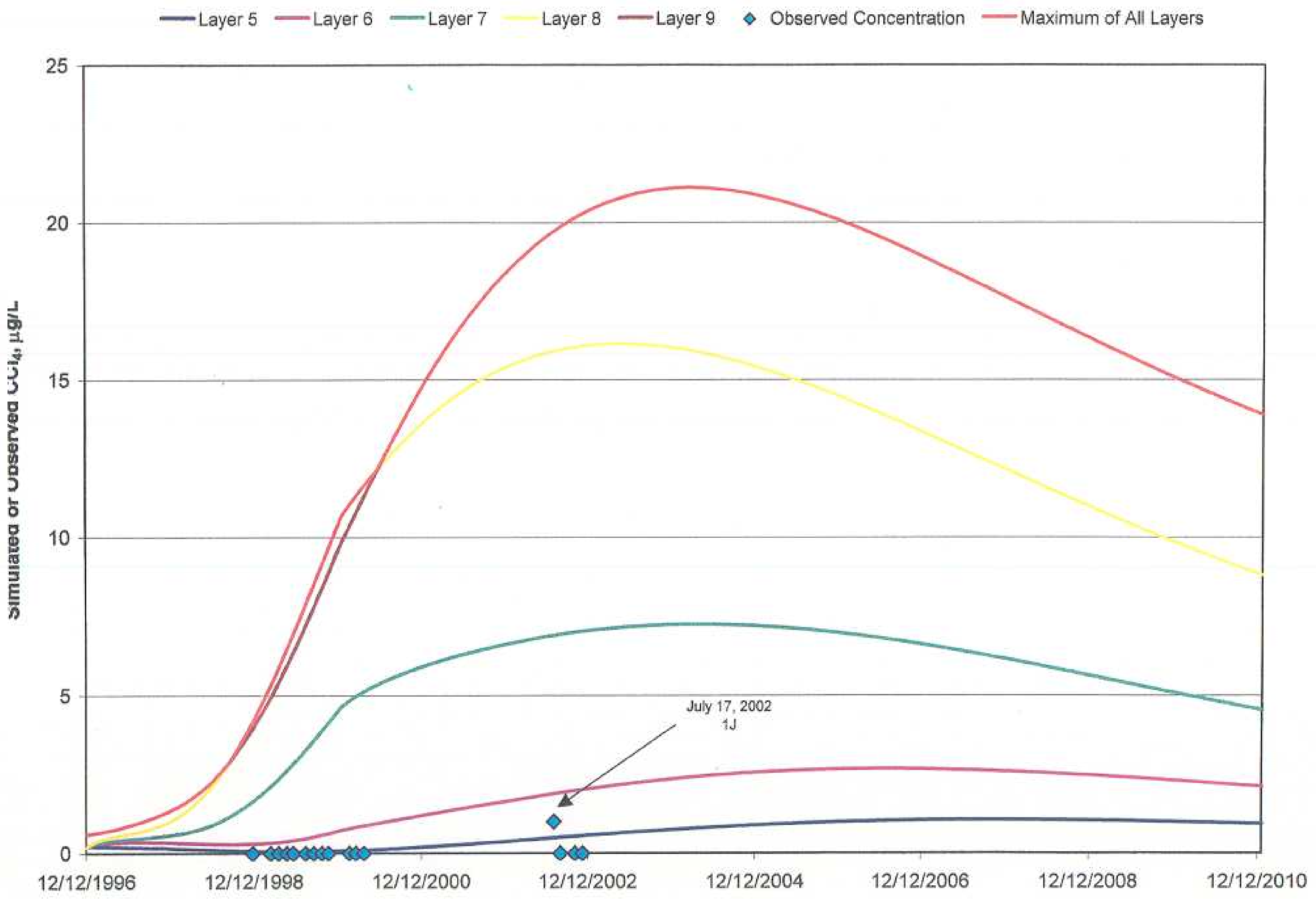
SB64M



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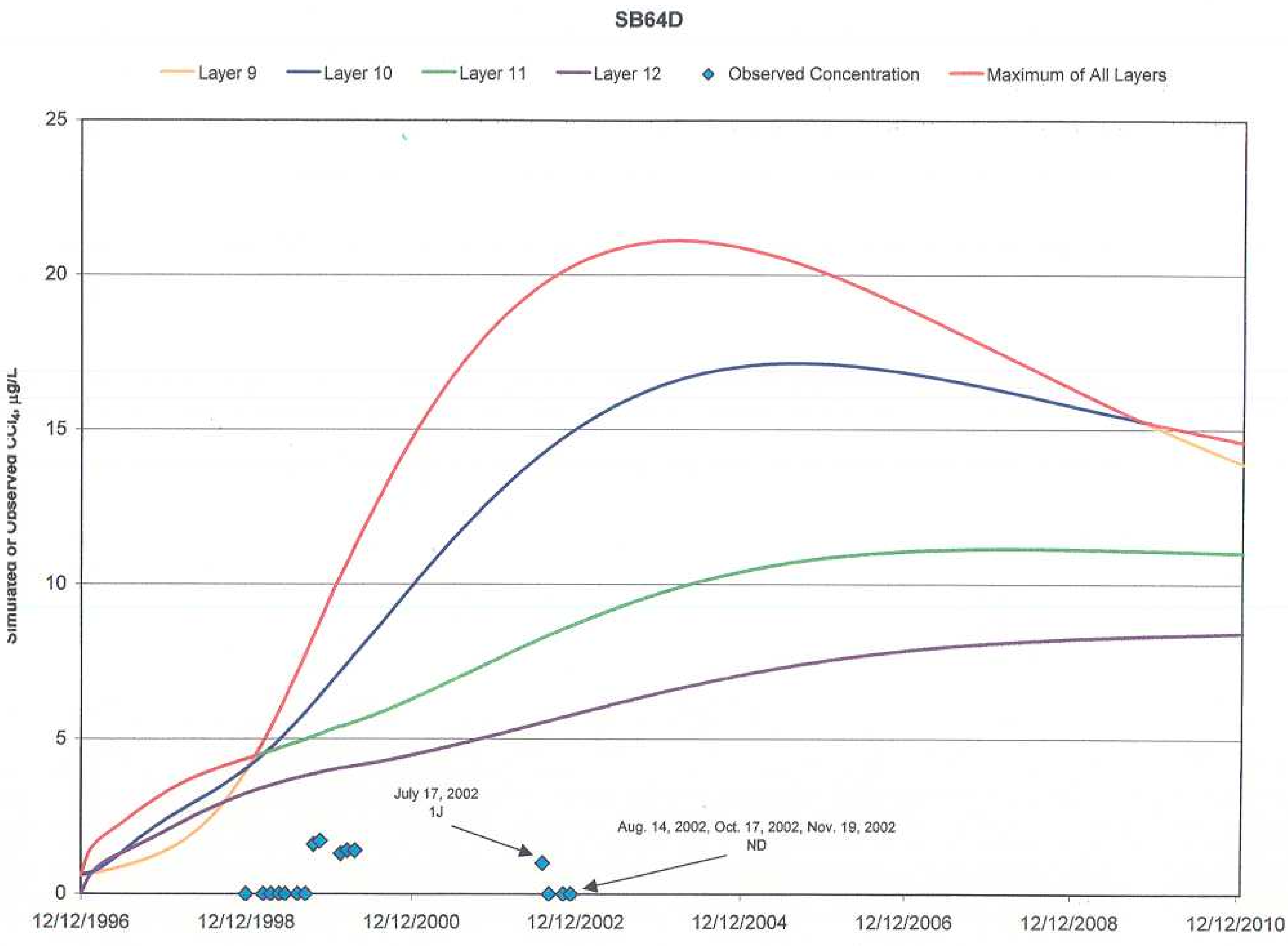
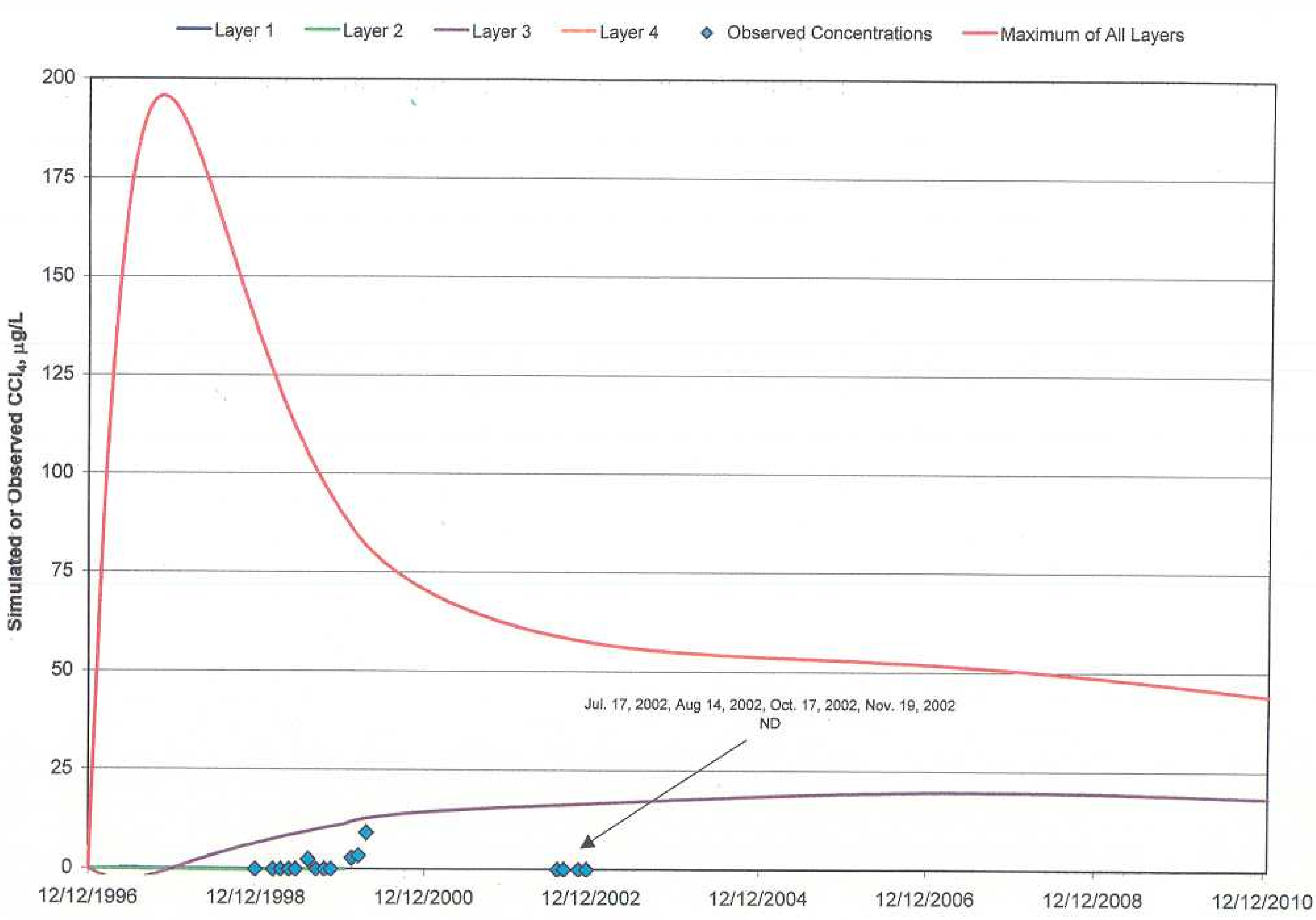

SB64D
Layer 9
Layer 10
Layer 11
Layer 12
Observed Concentration
Maximum of All Layers
Simulated or Observed CCl_4, µg/L
25
20
15
10
5
0
12/12/1996
12/12/1998
12/12/2000
12/12/2002
12/12/2004
12/12/2006
12/12/2008
12/12/2010
July 17, 2002
1J
Aug. 14, 2002, Oct. 17, 2002, Nov. 19, 2002
ND

1/17/2003

SB65S



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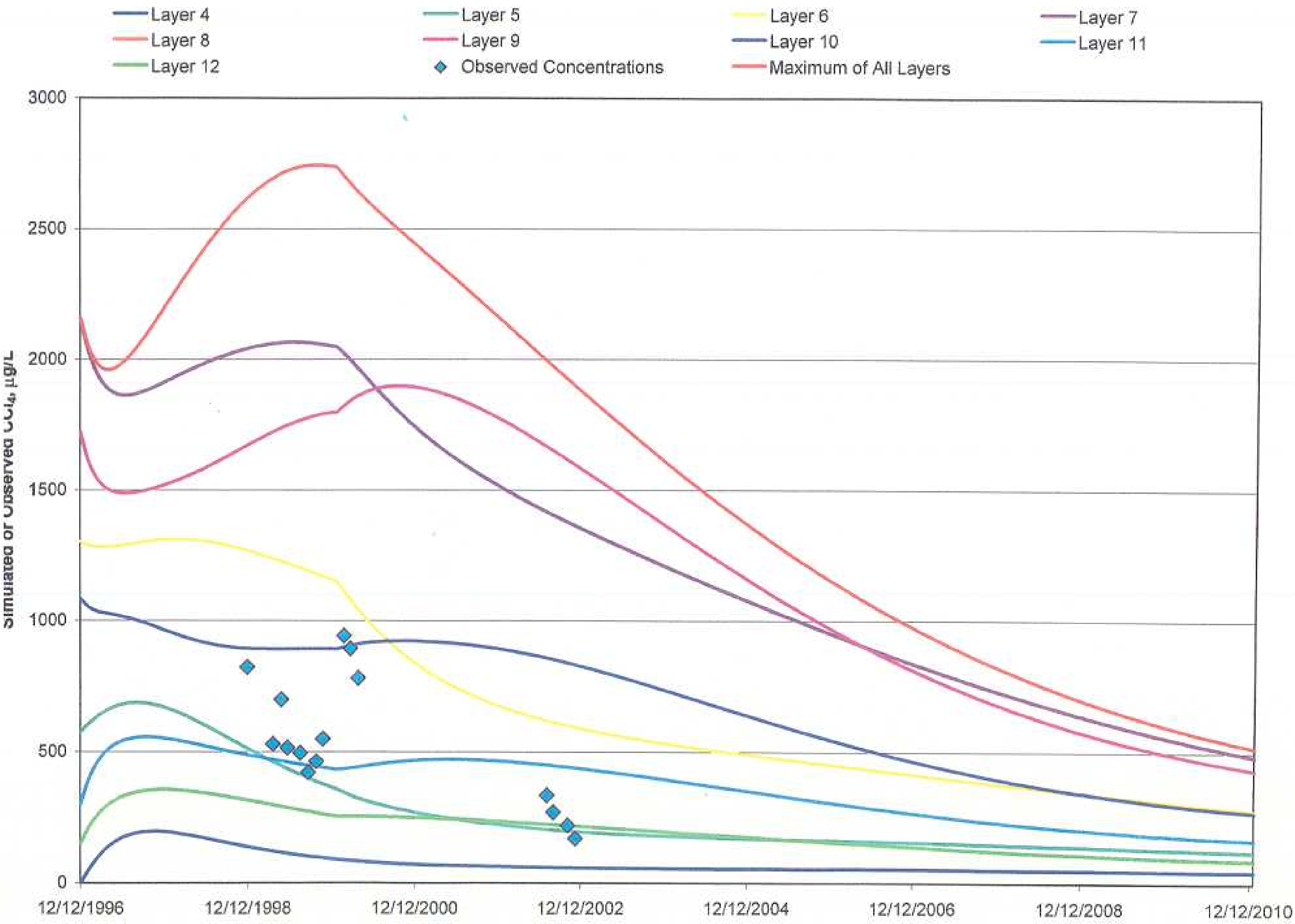
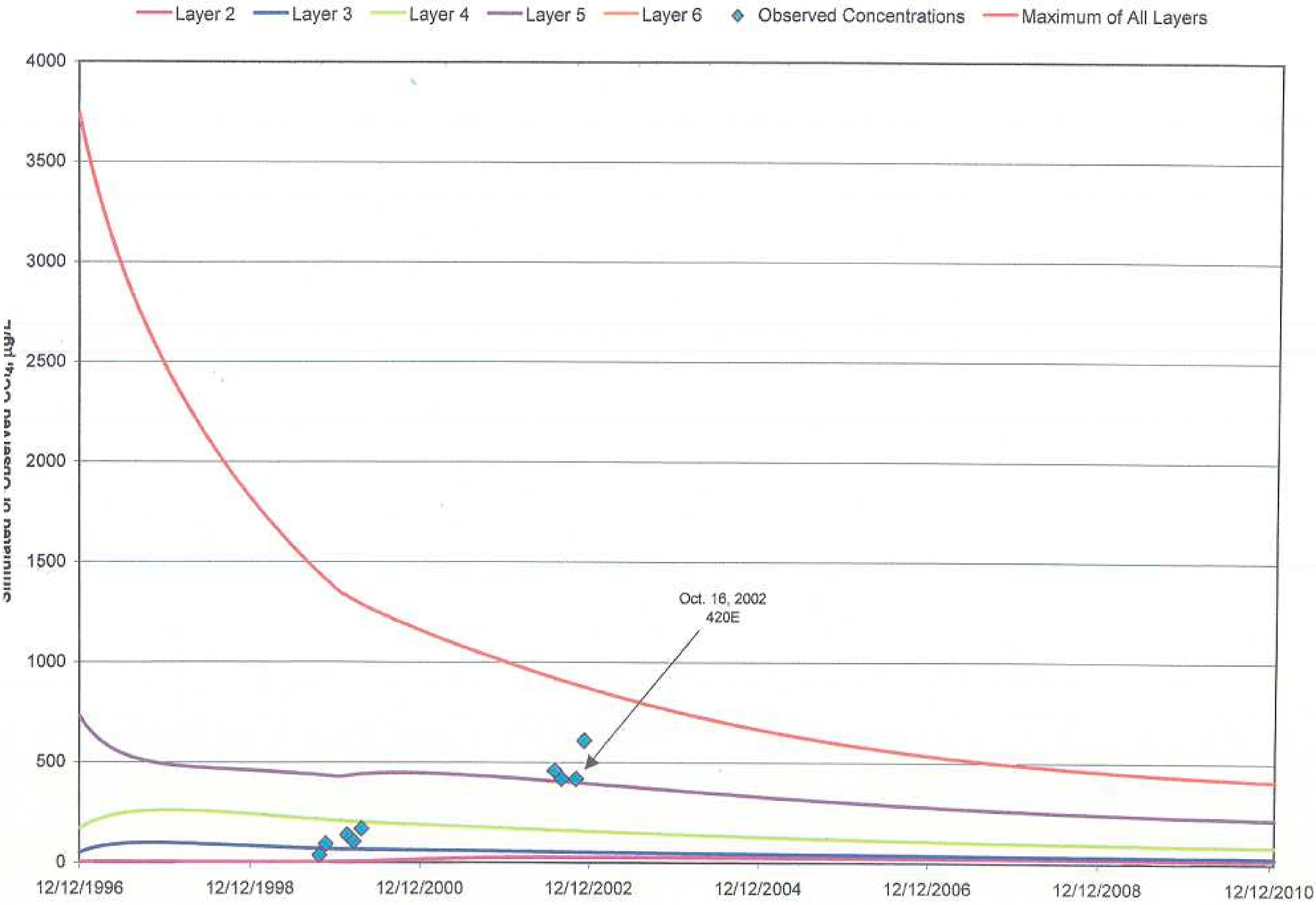
SB65D



1/17/2003

SB68S



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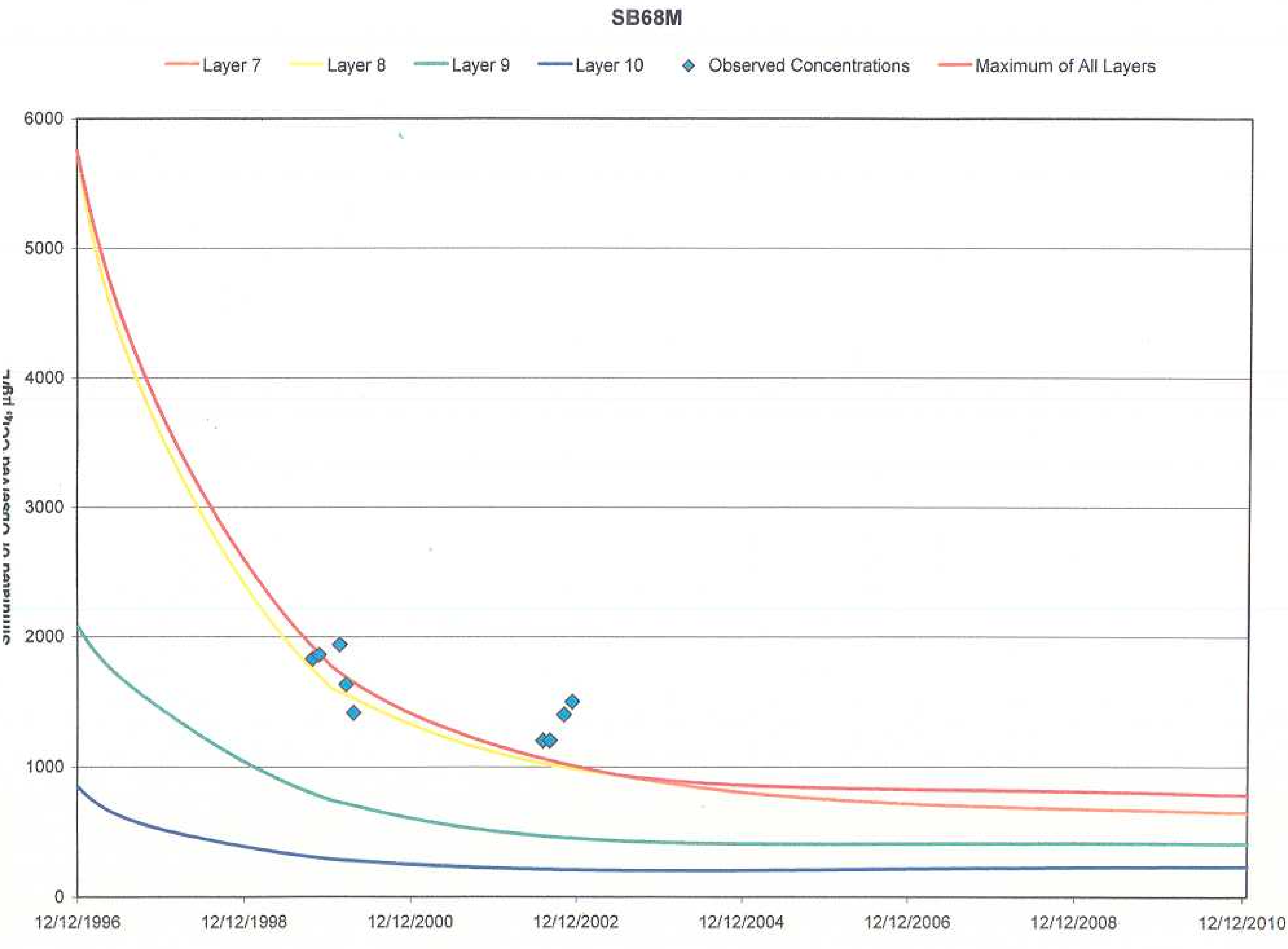
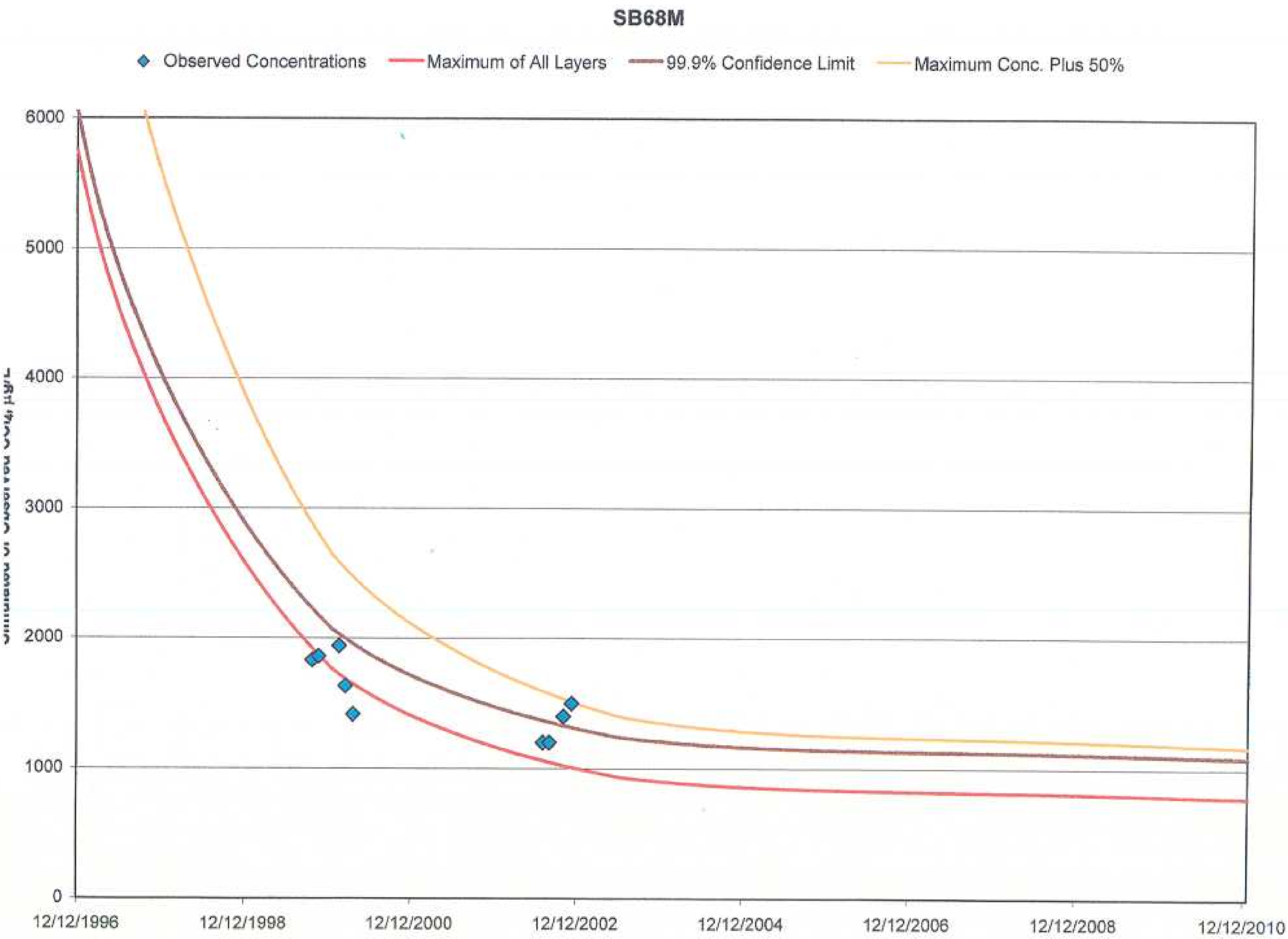
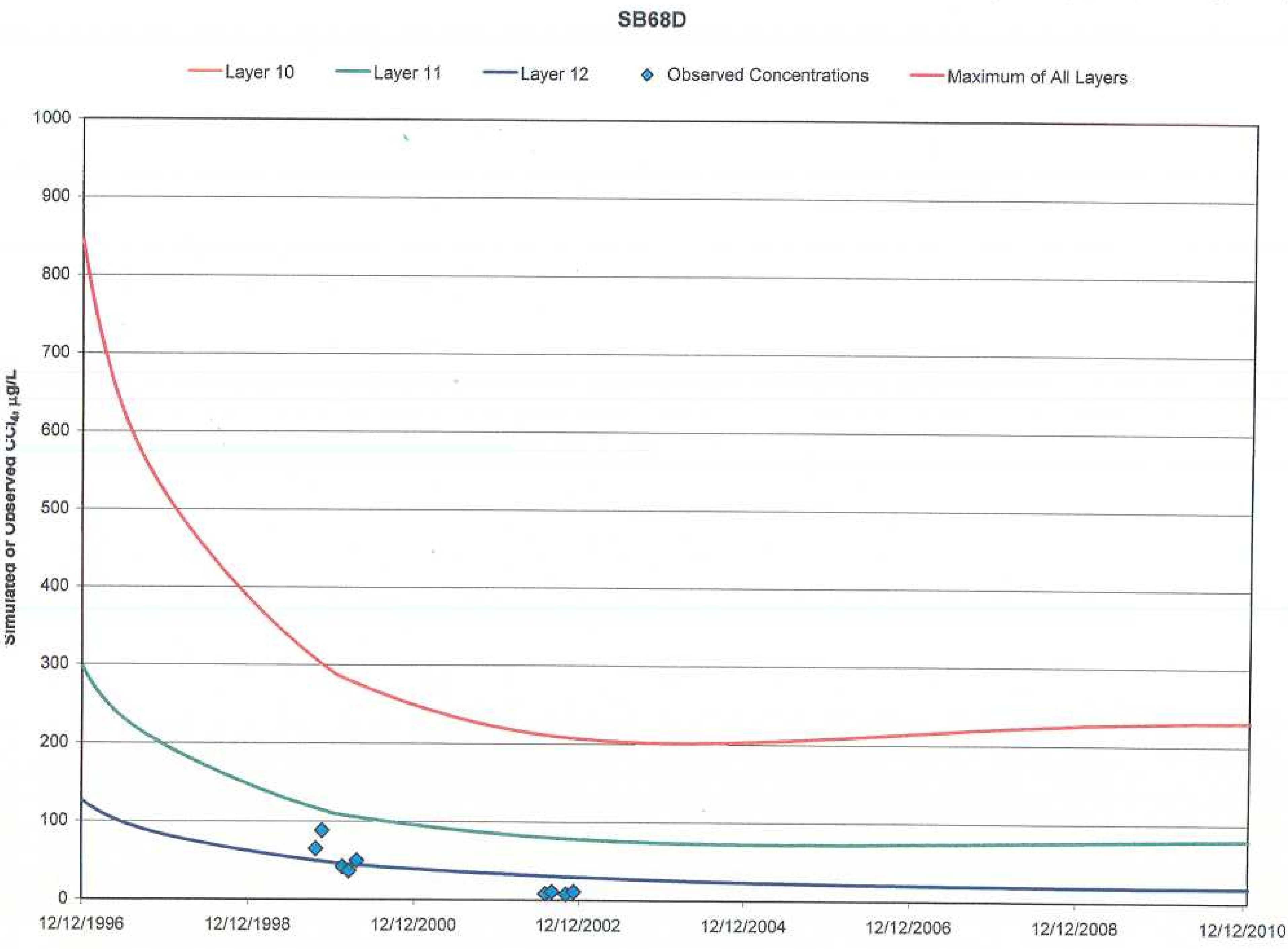

SB68M
Layer 7
Layer 8
Layer 9
Layer 10
Observed Concentrations
Maximum of All Layers
6000
5000
4000
3000
2000
1000
0
12/12/1996
12/12/1998
12/12/2000
12/12/2002
12/12/2004
12/12/2006
12/12/2008
12/12/2010

1/17/2003

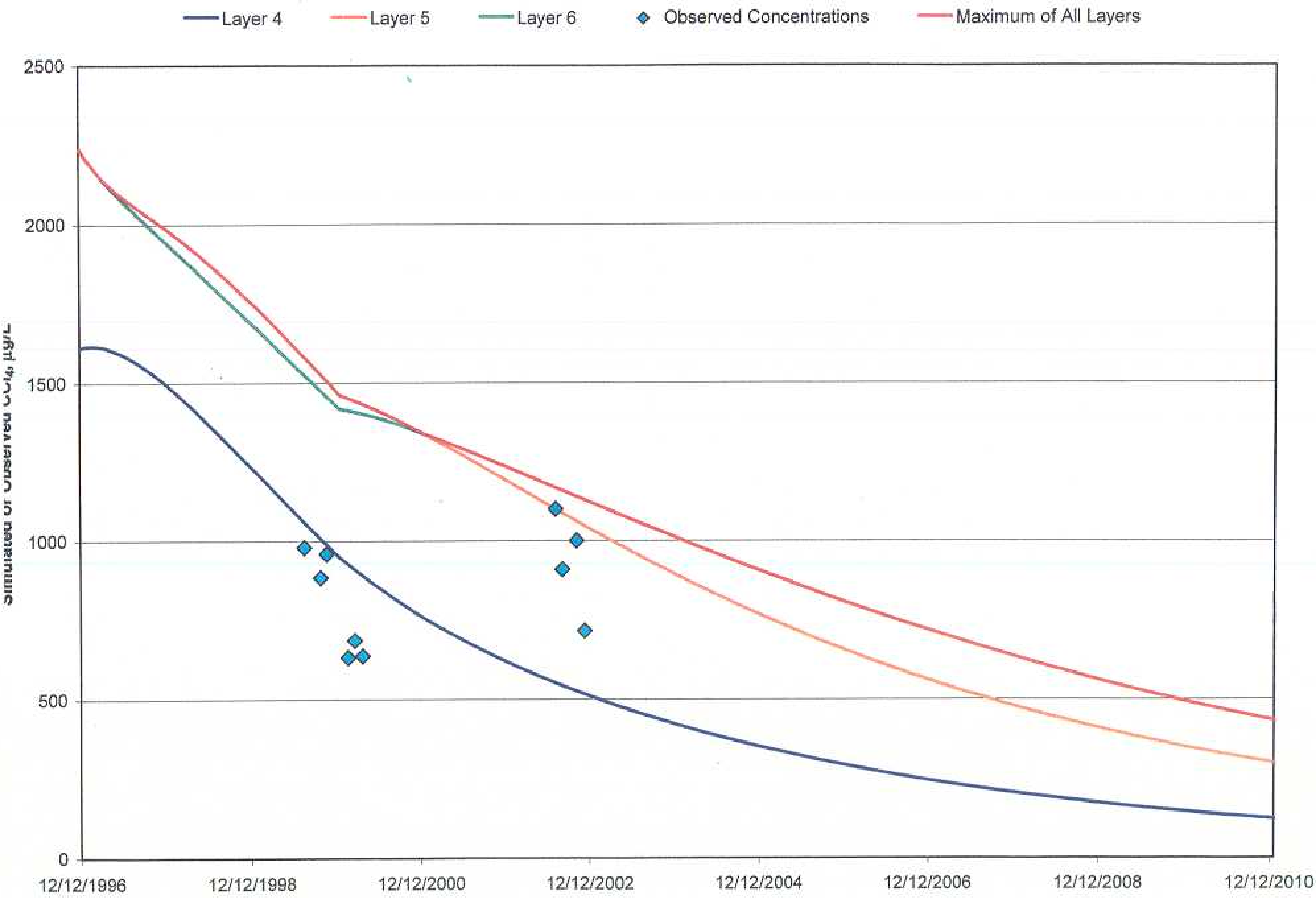

SB68M
Observed Concentrations
Maximum of All Layers
99.9% Confidence Limit
Maximum Conc. Plus 50%
6000
5000
4000
3000
2000
1000
0
12/12/1996
12/12/1998
12/12/2000
12/12/2002
12/12/2004
12/12/2006
12/12/2008
12/12/2010

1/17/2003


SB68D
Layer 10
Layer 11
Layer 12
Observed Concentrations
Maximum of All Layers
Simulated or Observed CCl4, µg/L
1000
900
800
700
600
500
400
300
200
100
0
12/12/1996
12/12/1998
12/12/2000
12/12/2002
12/12/2004
12/12/2006
12/12/2008
12/12/2010

1/17/2003

SB71S



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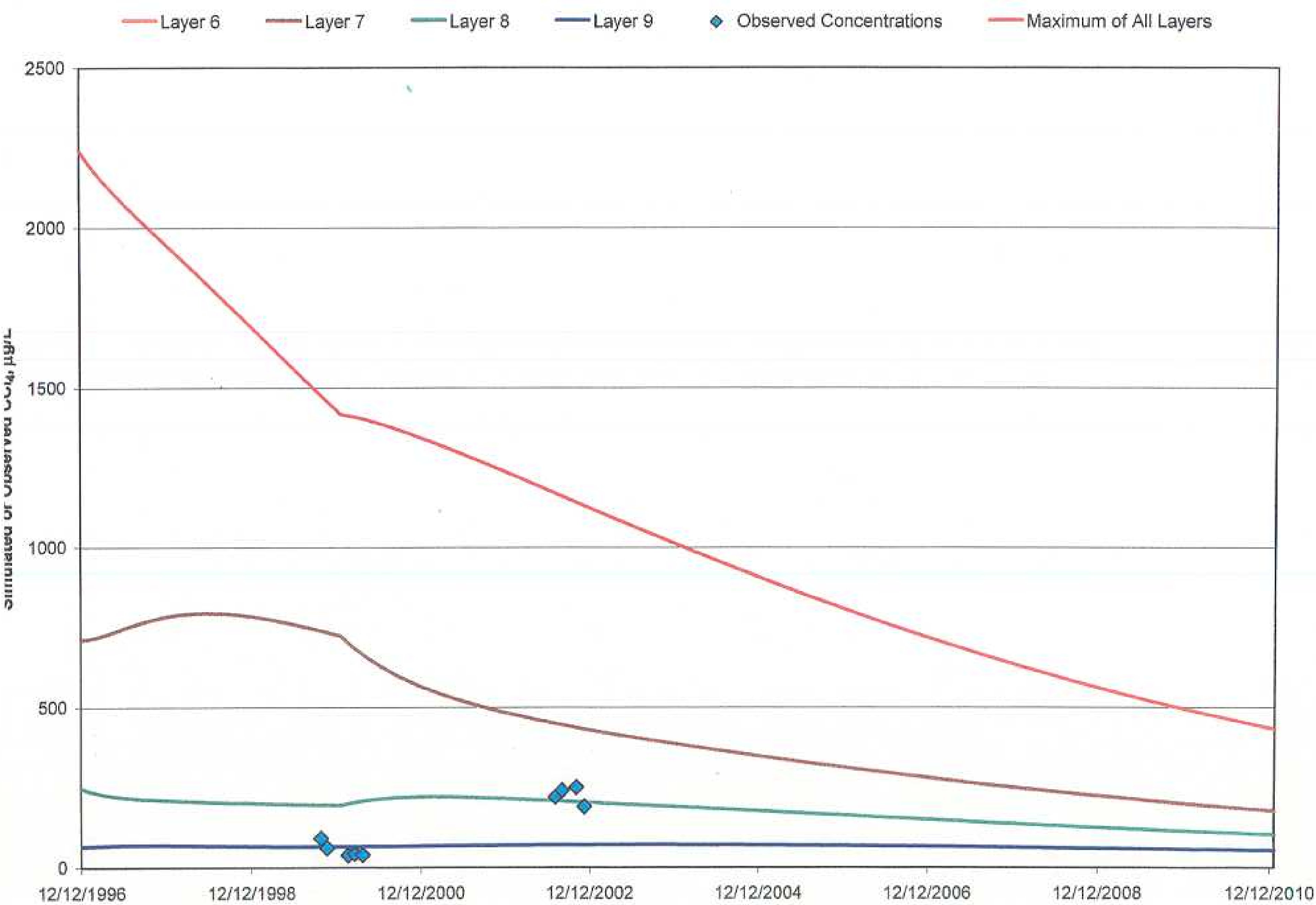
SB71M



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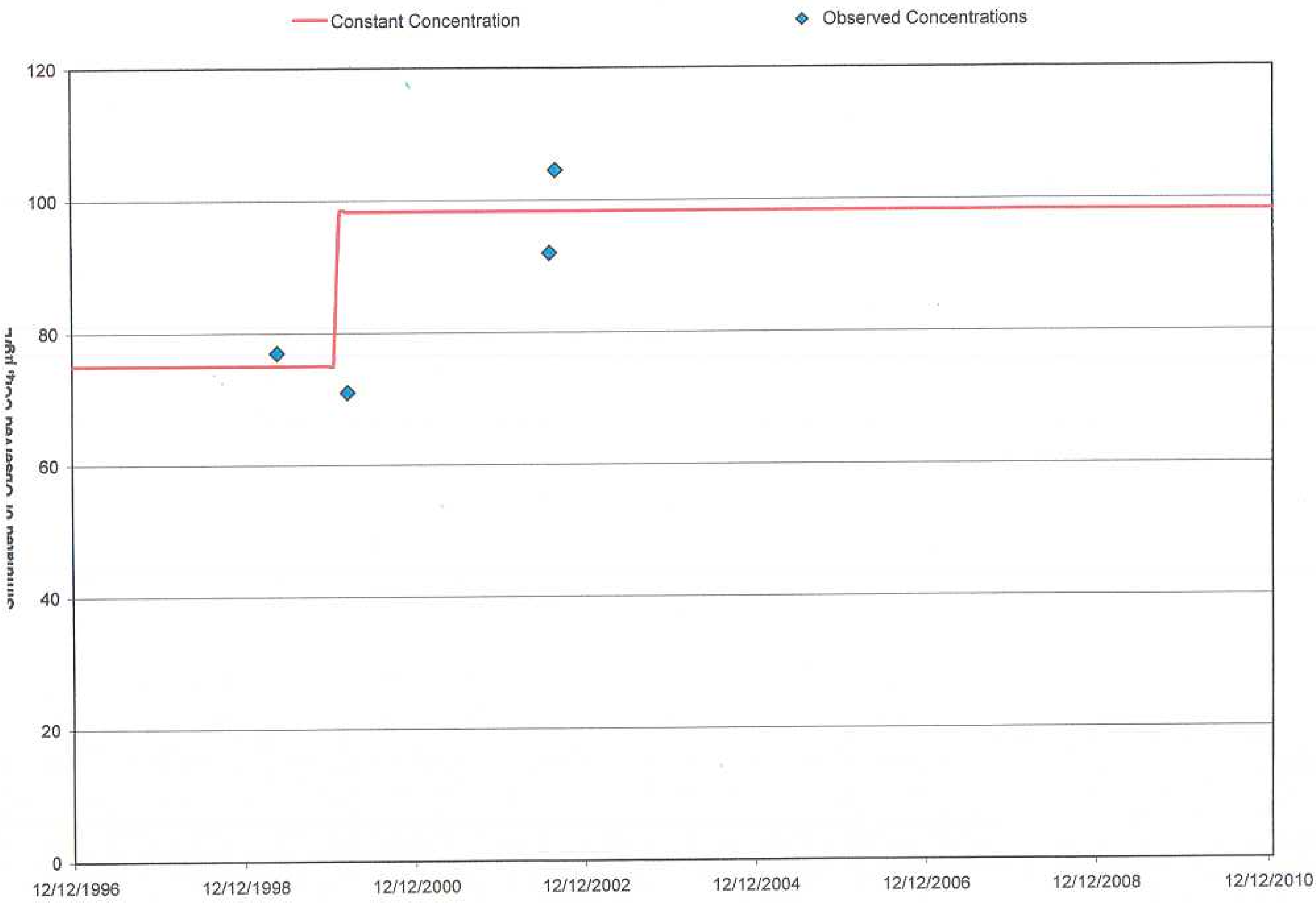
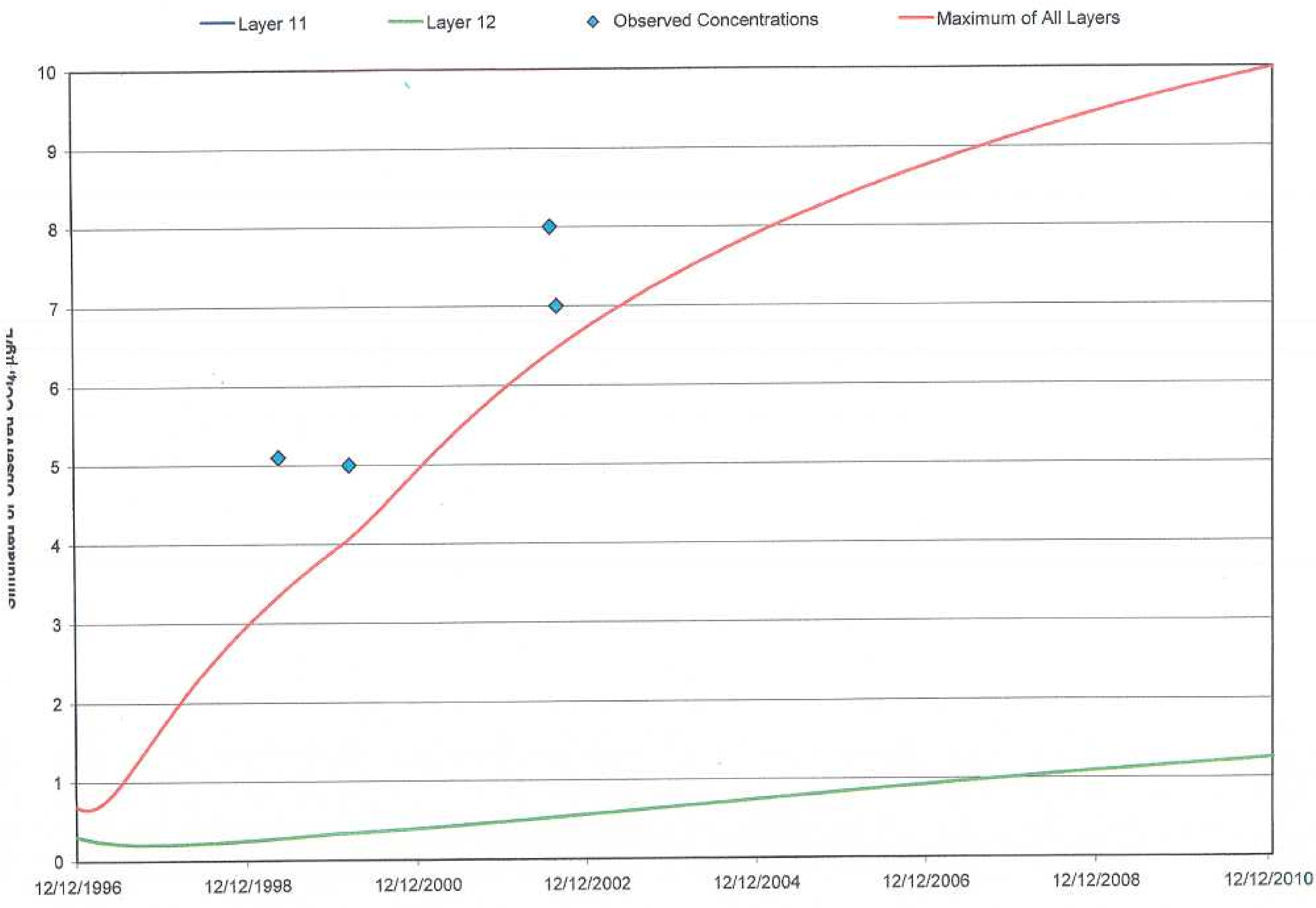
S2



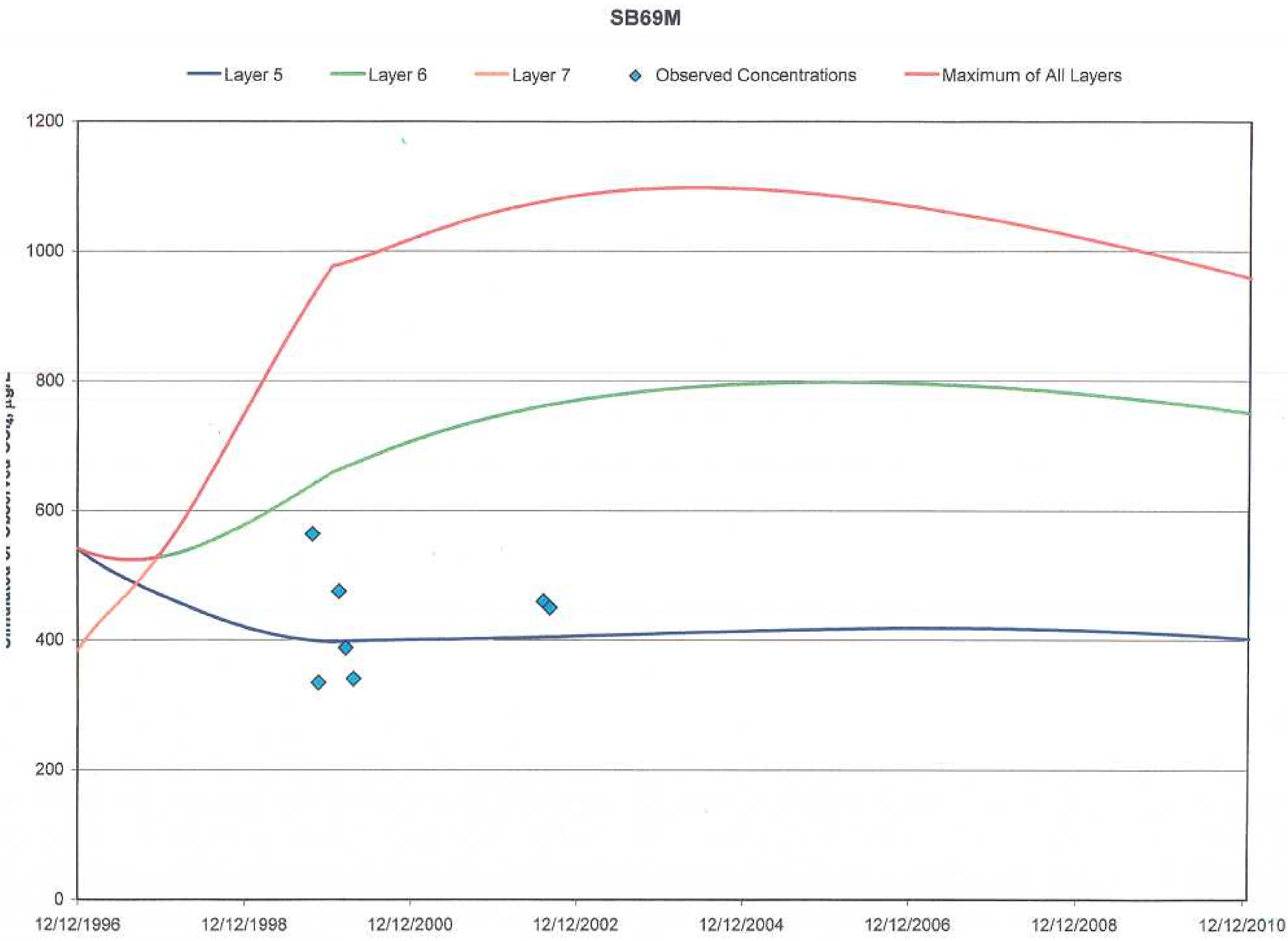
Constant Concentration
Observed Concentrations
120
100
80
60
40
20
0
12/12/1996
12/12/1998
12/12/2000
12/12/2002
12/12/2004
12/12/2006
12/12/2008
12/12/2010

1/17/2003

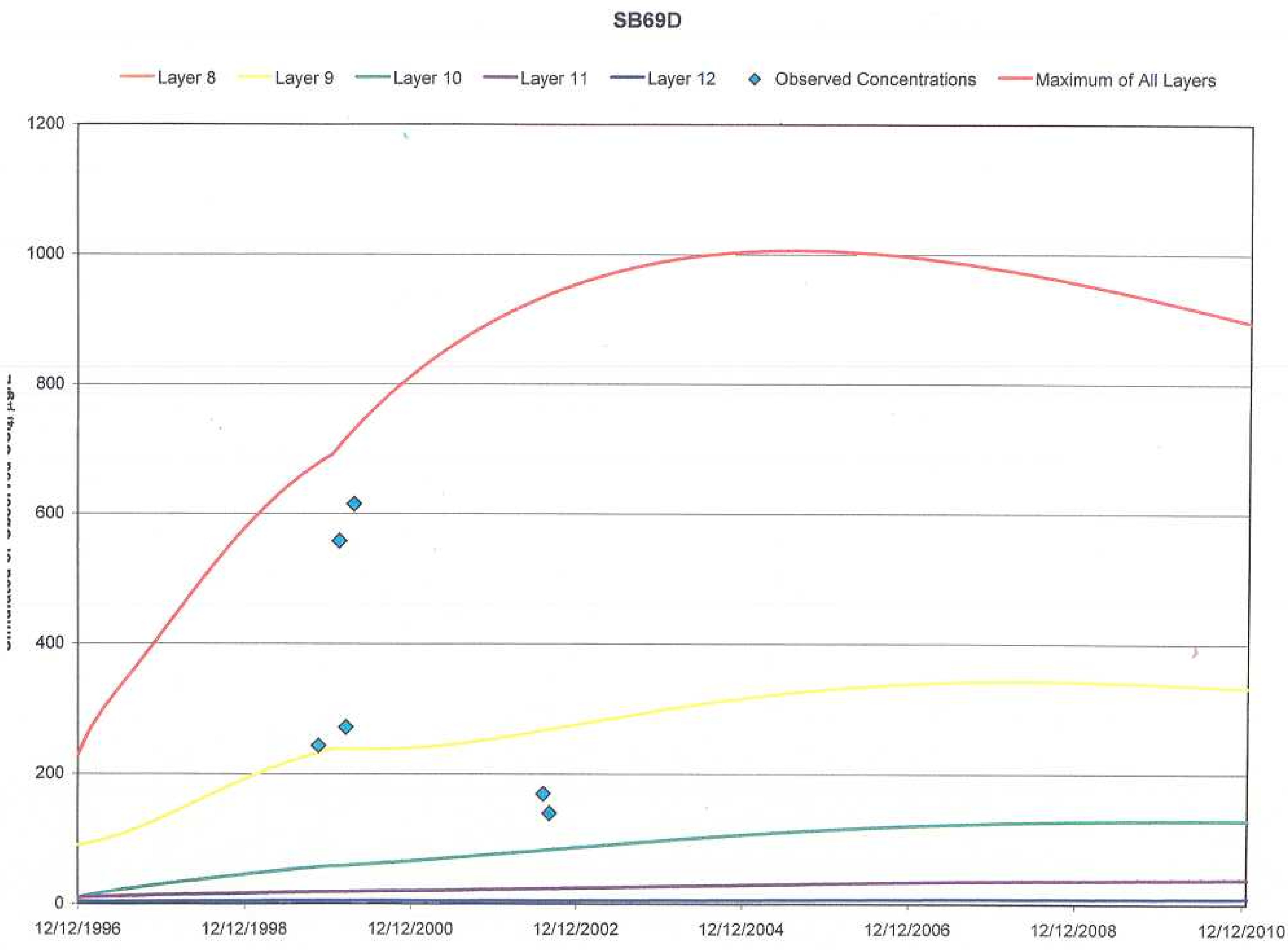
D2


Layer 11
Layer 12
Observed Concentrations
Maximum of All Layers
10
9
8
7
6
5
4
3
2
1
0
12/12/1996
12/12/1998
12/12/2000
12/12/2002
12/12/2004
12/12/2006
12/12/2008
12/12/2010

1/17/2003

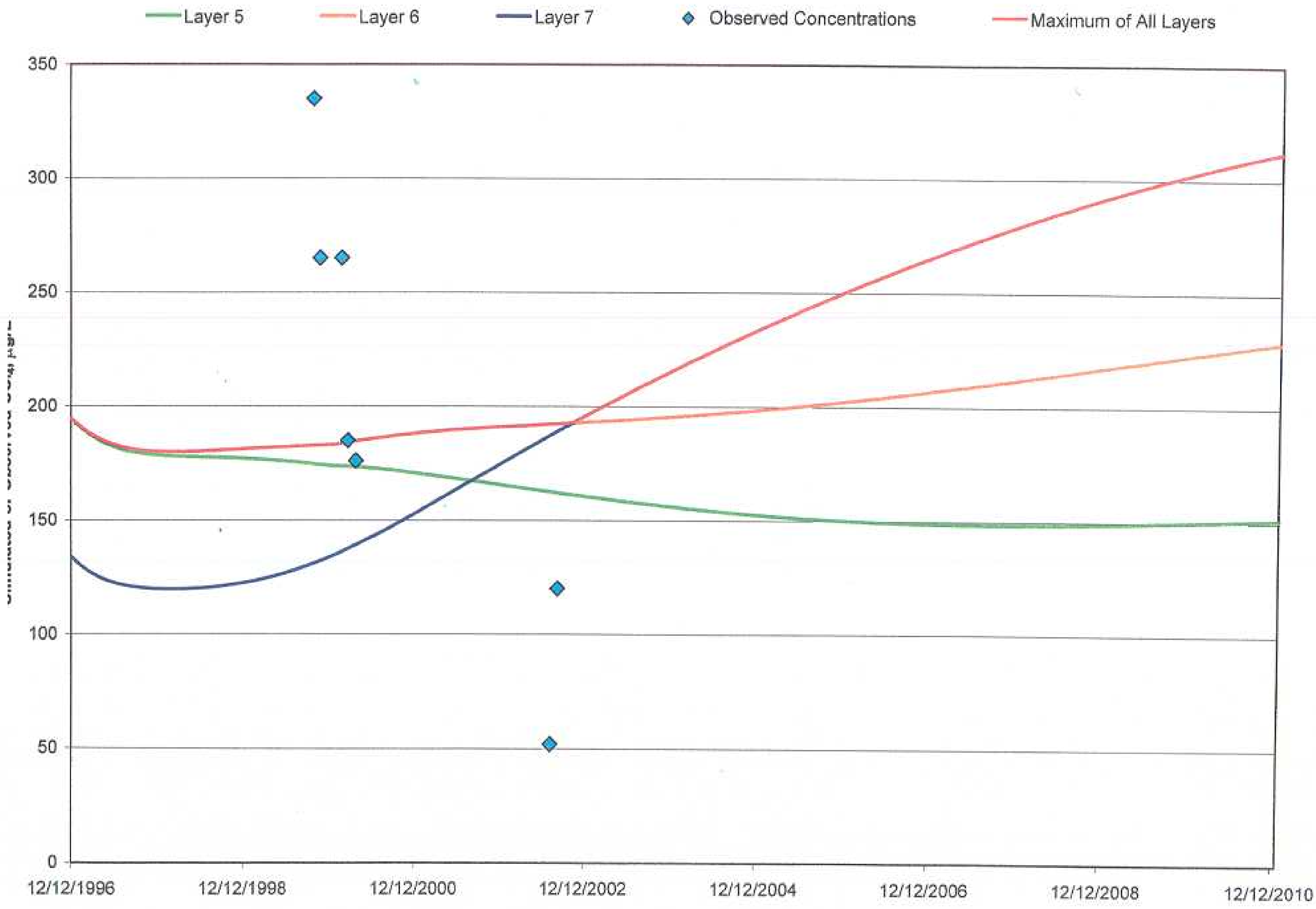

SB69M
Layer 5
Layer 6
Layer 7
Observed Concentrations
Maximum of All Layers
1200
1000
800
600
400
200
0
12/12/1996
12/12/1998
12/12/2000
12/12/2002
12/12/2004
12/12/2006
12/12/2008
12/12/2010

1/17/2003


SB69D
Layer 8
Layer 9
Layer 10
Layer 11
Layer 12
Observed Concentrations
Maximum of All Layers
1200
1000
800
600
400
200
0
12/12/1996
12/12/1998
12/12/2000
12/12/2002
12/12/2004
12/12/2006
12/12/2008
12/12/2010

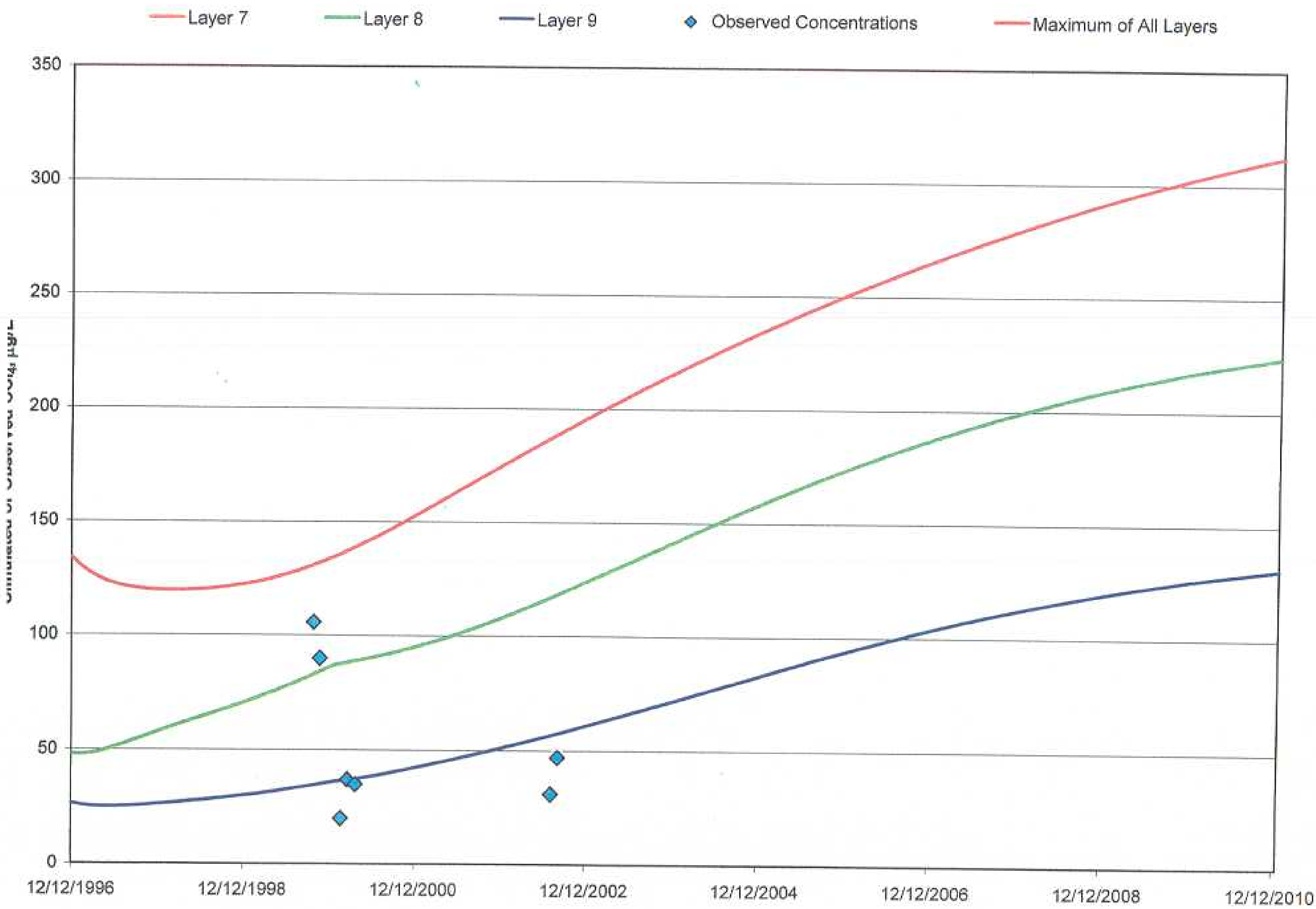
1/17/2003

SB70S



Layer 5
Layer 6
Layer 7
Observed Concentrations
Maximum of All Layers
350
300
250
200
150
100
50
0
12/12/1996
12/12/1998
12/12/2000
12/12/2002
12/12/2004
12/12/2006
12/12/2008
12/12/2010

SB70M



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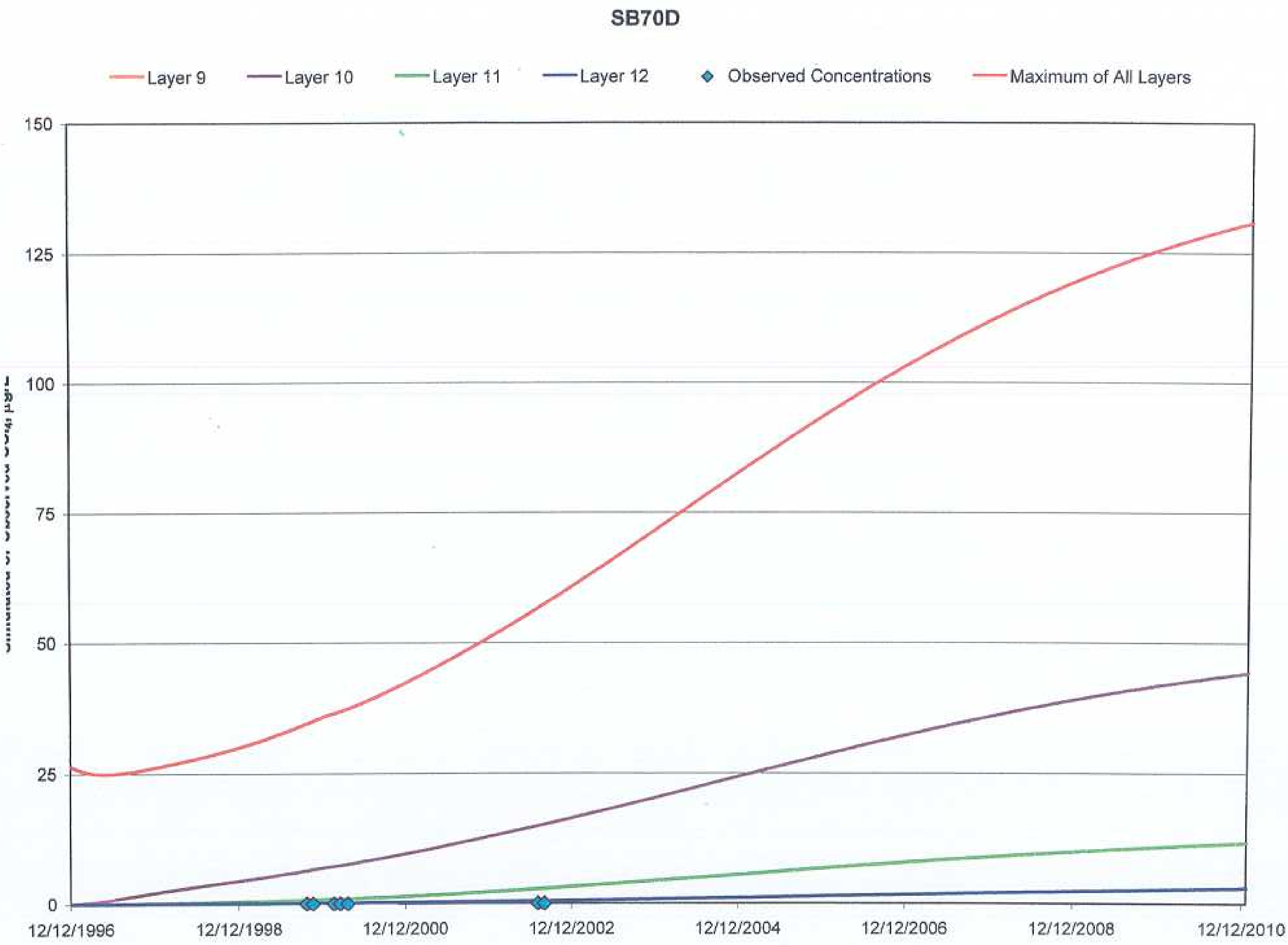
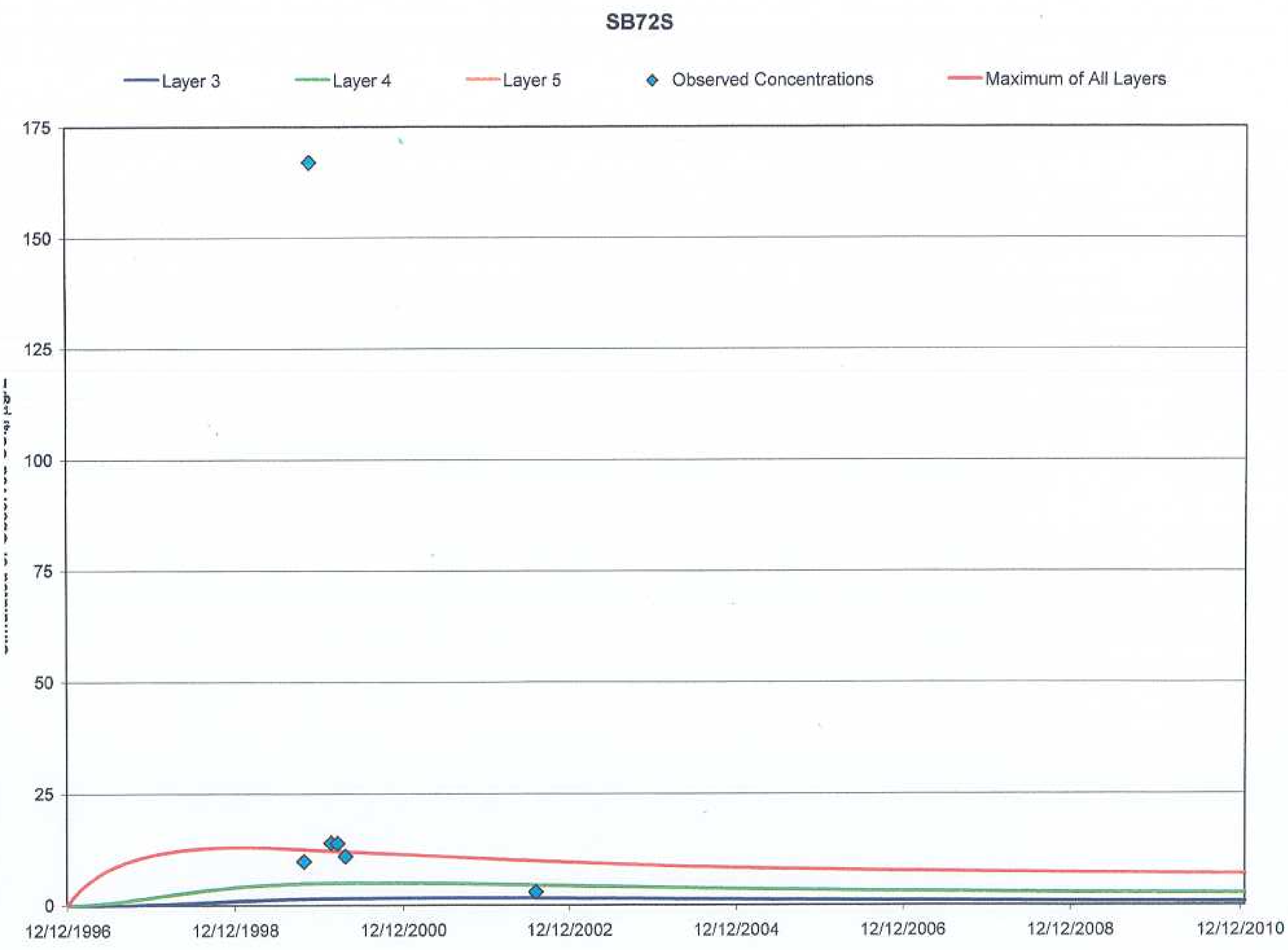
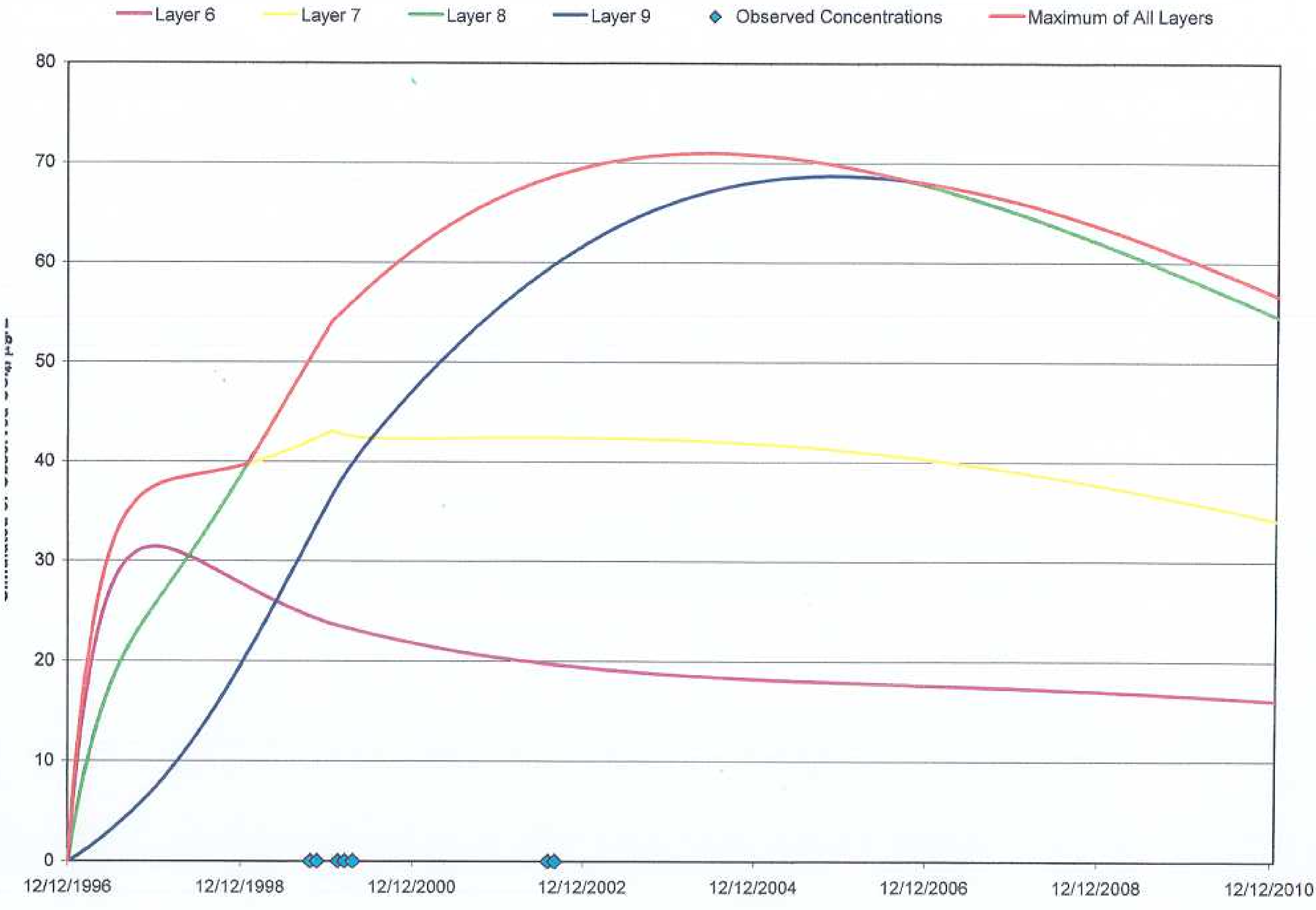

SB70D
Layer 9
Layer 10
Layer 11
Layer 12
Observed Concentrations
Maximum of All Layers
150
125
100
75
50
25
0
12/12/1996
12/12/1998
12/12/2000
12/12/2002
12/12/2004
12/12/2006
12/12/2008
12/12/2010

1/17/2003


SB72S
Layer 3
Layer 4
Layer 5
Observed Concentrations
Maximum of All Layers
175
150
125
100
75
50
25
0
12/12/1996
12/12/1998
12/12/2000
12/12/2002
12/12/2004
12/12/2006
12/12/2008
12/12/2010

1/17/2003

SB72M



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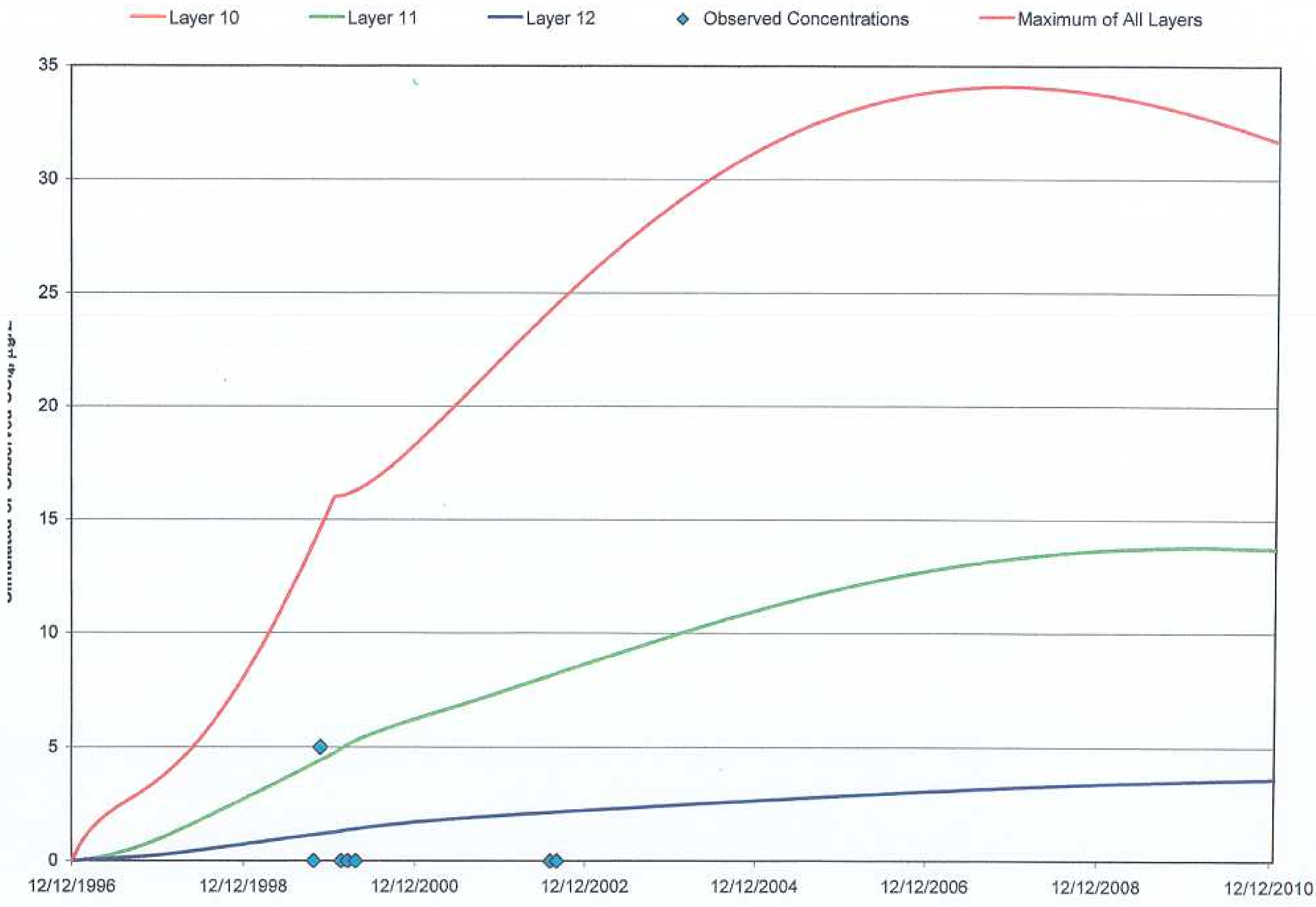
SB72D



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