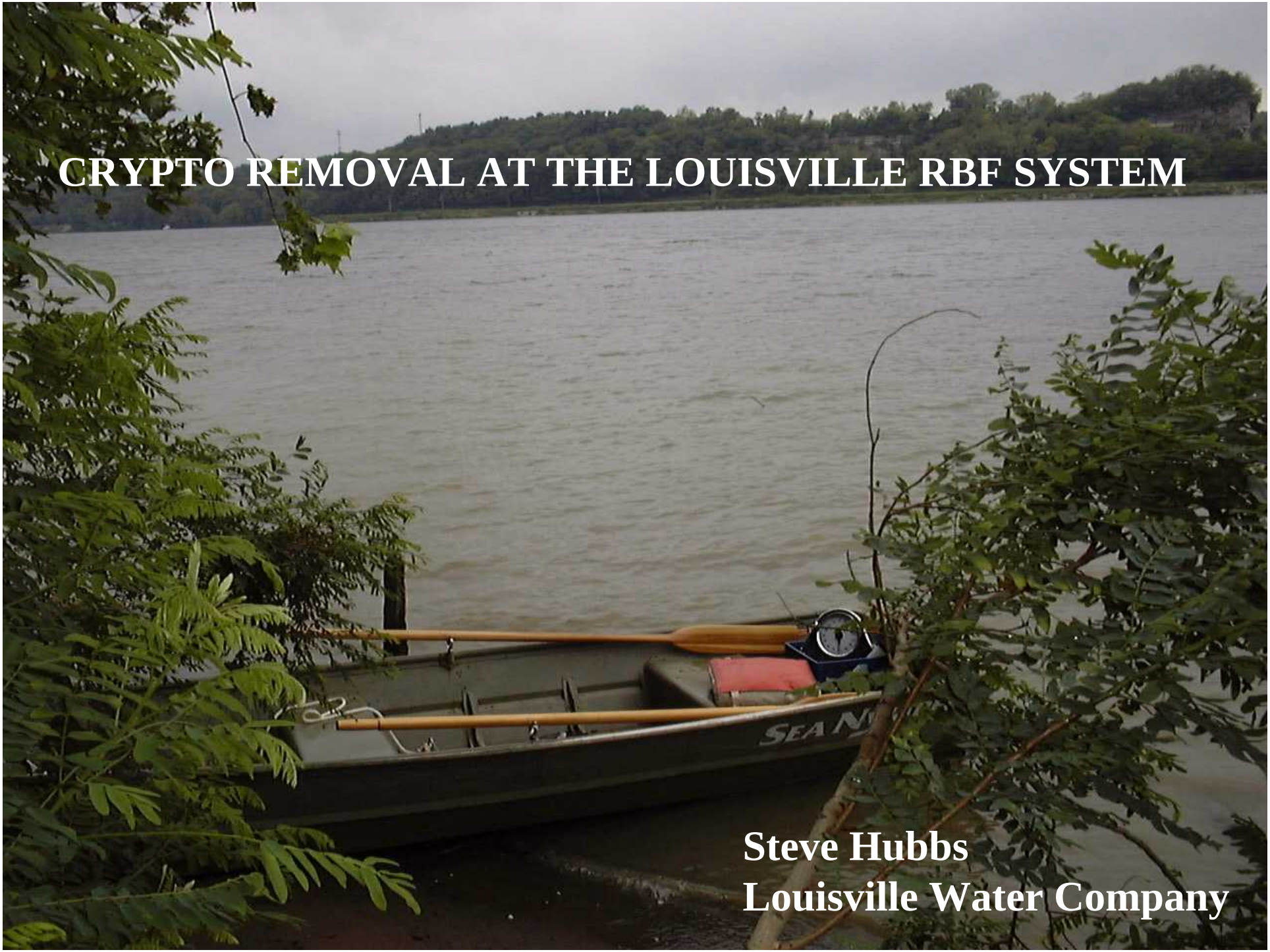
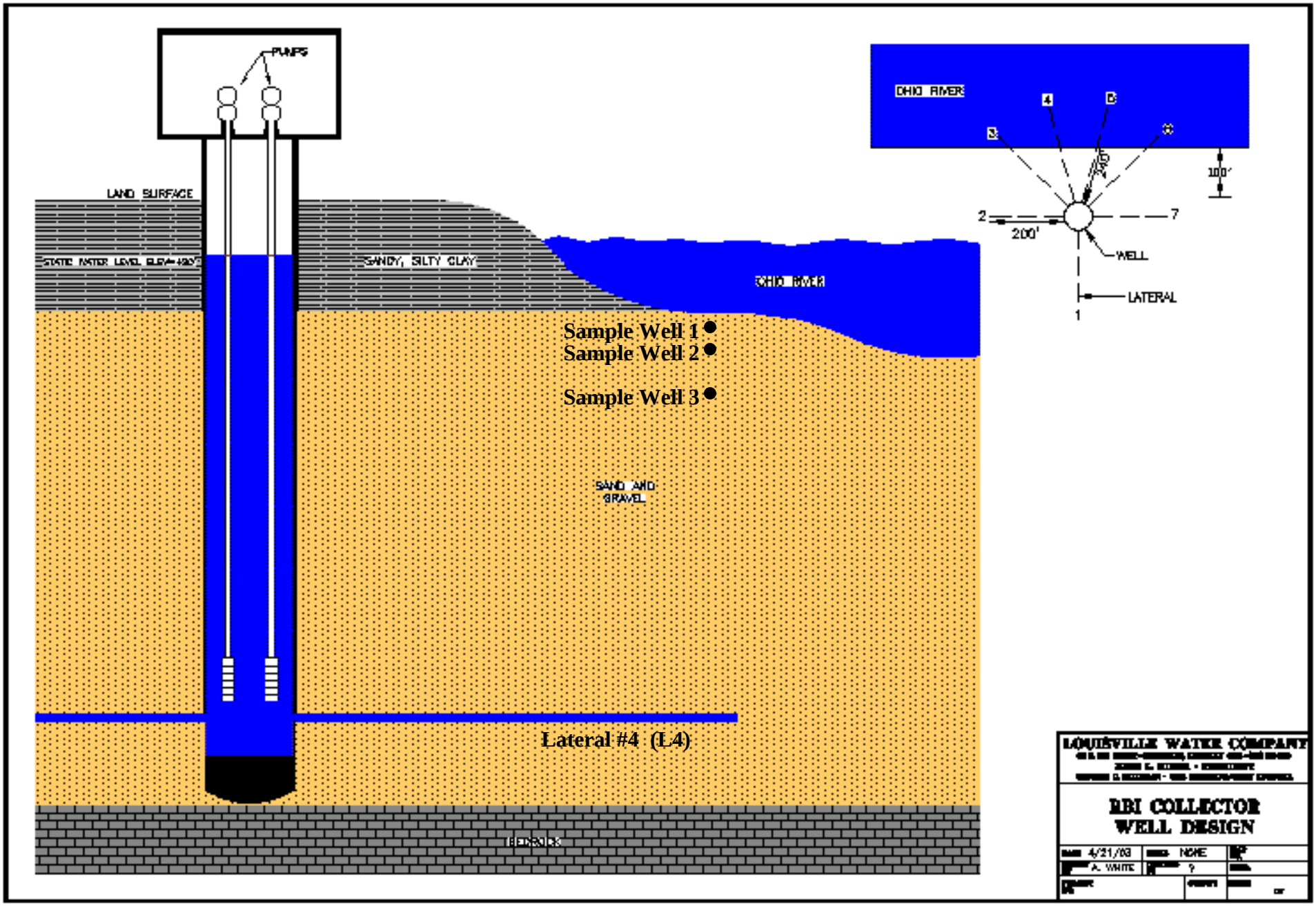


CRYPTO REMOVAL AT THE LOUISVILLE RBF SYSTEM

Steve Hubbs
Louisville Water Company


PUMPS
LAND SURFACE
STATIC WATER LEVEL
SANDY, SILTY CLAY
OHIO RIVER
Sample Well 1
Sample Well 2
Sample Well 3
SAND AND GRAVEL
Lateral #4 (L4)
BEDROCK
OHIO RIVER
4
B
A
C
100'
2
7
200'
WELL
LATERAL
1
LOUISVILLE WATER COMPANY
RBI COLLECTOR WELL DESIGN
4/21/03
NONE
A. WHITE

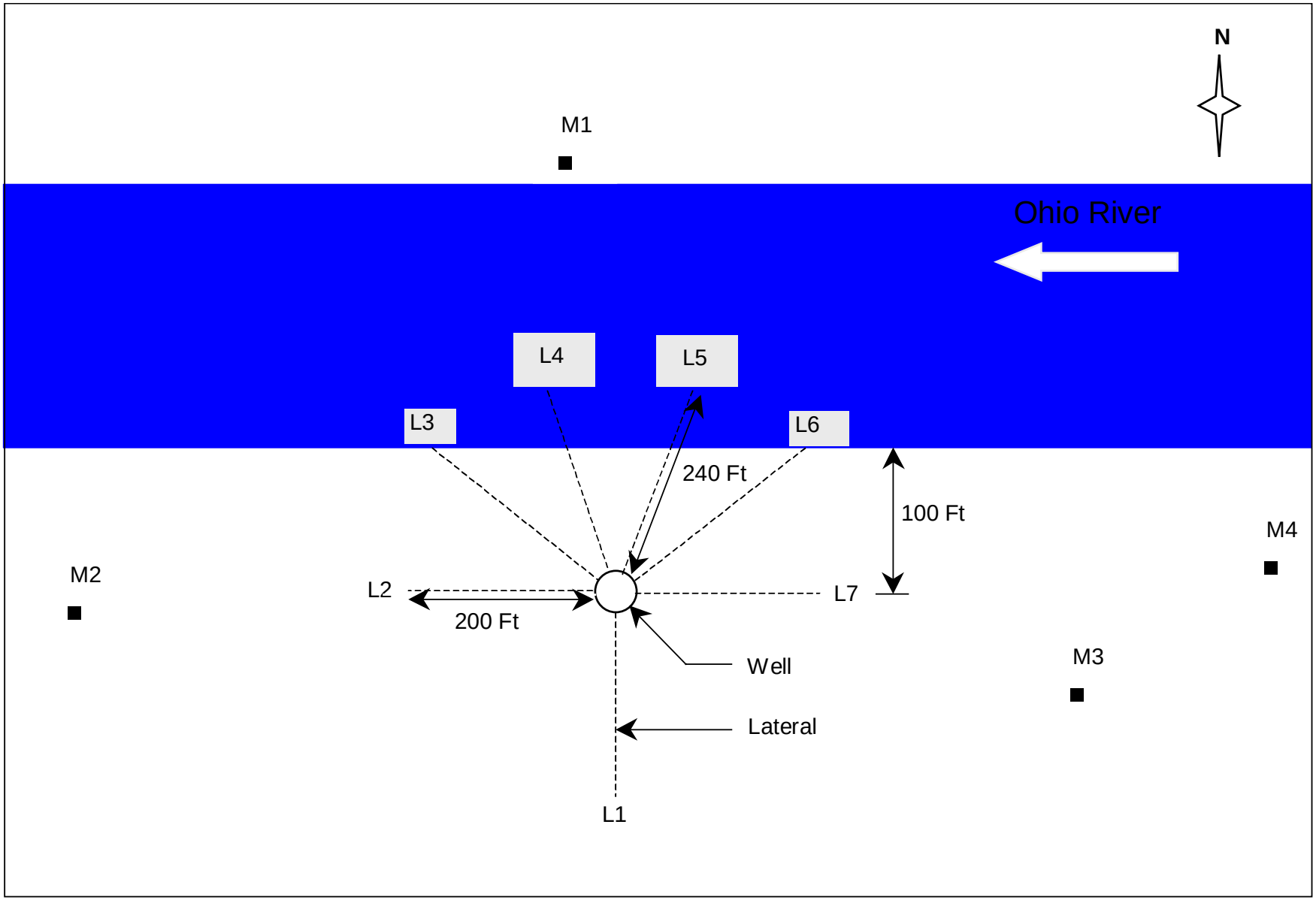


Figure 4.3 Locations of Area-wide Water Quality Sampling Wells

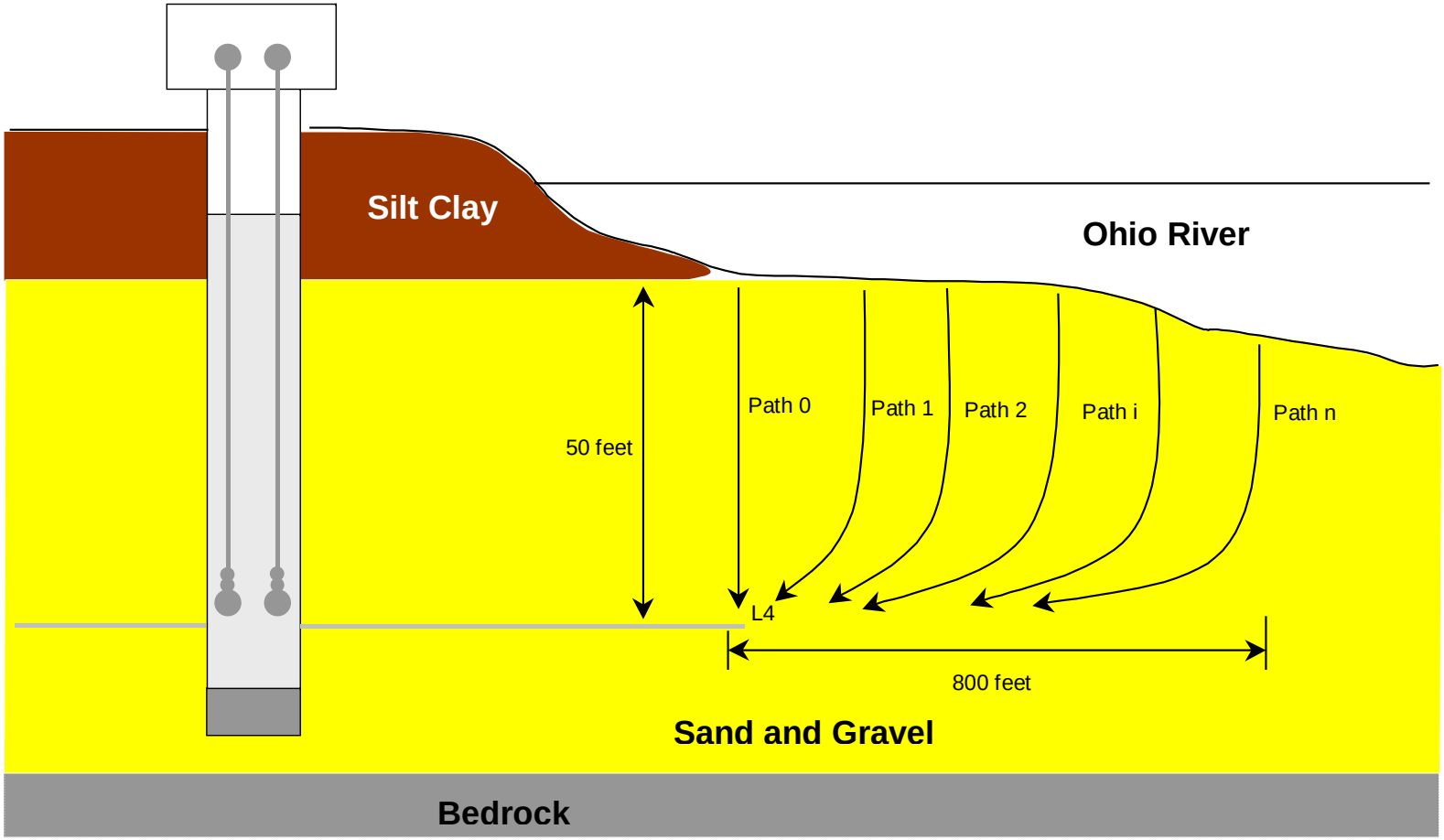
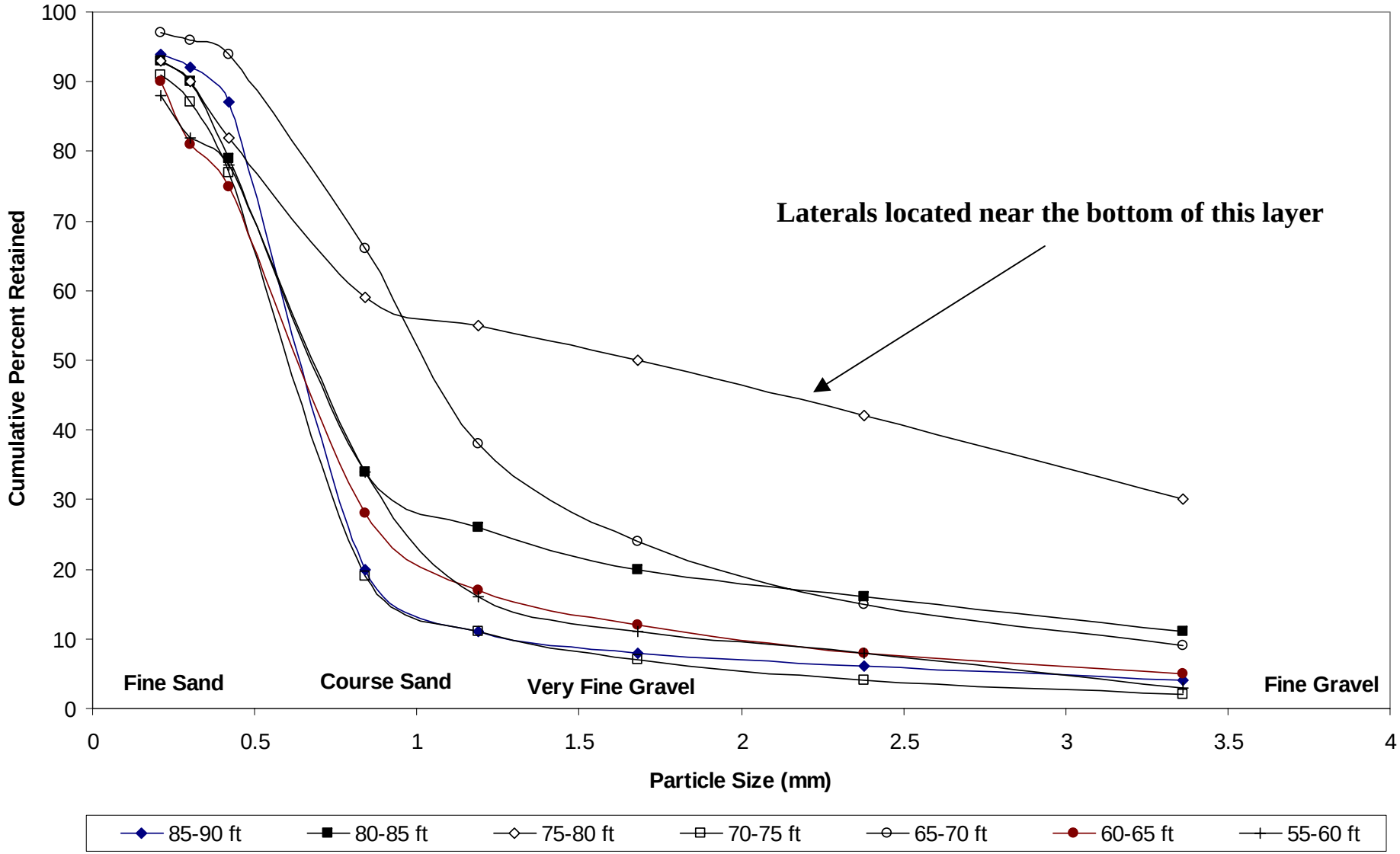


Figure 6.10 2-Dimensional Water Flow Paths from the River to Laterals

Table 1 Effectiveness of RBF for Microbial Removal at Louisville, Kentucky
(n = number of samples)

Parameters	**Sampling Locations or Filtration Depth**				**Typical Log Removal after 50 ft Filtration**
	River	***~5 ft RBF***	***~10 ft RBF***	***>50 ft RBF***	
Turbidity (NTU)	<5 to >900 n>500	0.13 – 1.14 n=21	0.13 – 1.32 n=19	0.05 – 0.69 n=400	Not calculated
Total Coliform (MPN/100 mL)	9 – 165200 n>500	Not measured	Not measured	0 – 165 n=400	3.2 logs
HPC (CFU/mL)	10 – 8820 n>500	Not measured	Not measured	0 – 420 n=400	2.0 logs
Spores (CFU/mL)	30 – 150 n=10	0.53 – 1.1 n=2	0.38 – 1.3 n=2	0 – 0.6 n=34	3.3 logs
MPA - Algae (No./100 L)	0.53 – 65 $x10^6$ n=12	Not measured	Not measured	0 – 66 n=36	>7.1 logs
MPA - Diatoms (No./100 L)	1.3 – 91 $x10^5$ n=12	Not measured	Not measured	0 – 0.26 n=36	>6.7 logs
Crypto (oocyst/L)	**0 – 0.6 n=94 / 15**	**Not measured**	**Not measured**	**0 n=56**	**Not calculated**

Figure 5.1 Particle Size Distribution of Aquifer Materials at Different Depths (at Collector Well)



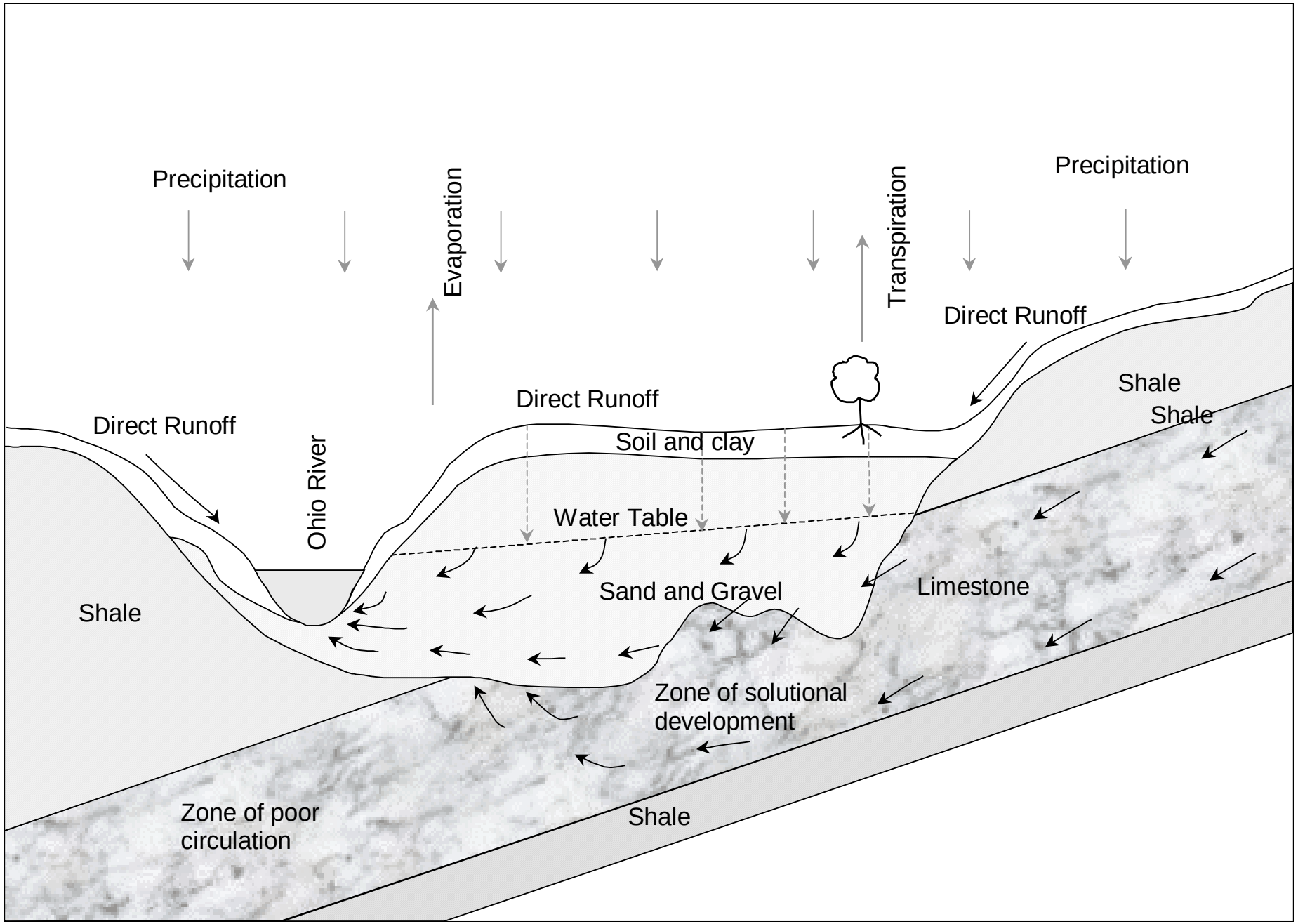

Precipitation
Evaporation
Transpiration
Precipitation
Direct Runoff
Direct Runoff
Direct Runoff
Shale
Shale
Ohio River
Soil and clay
Water Table
Sand and Gravel
Limestone
Shale
Zone of solutional development
Zone of poor circulation
Shale

Figure 6.5 Temperature Profile of Riverbank Filtration during Initial Pumping

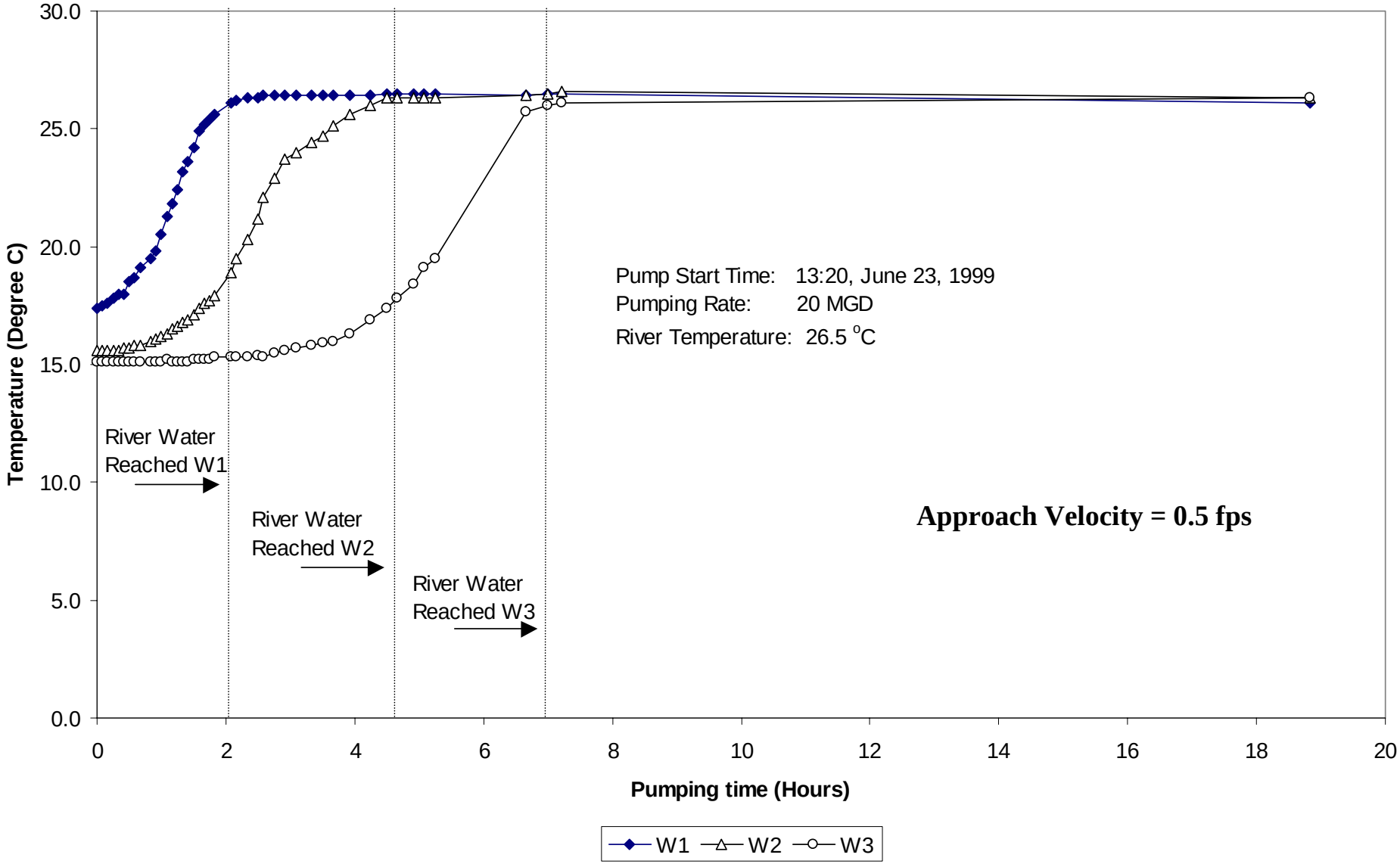


Figure 7.1 Turbidity Results of the Ohio River and the Collector Well

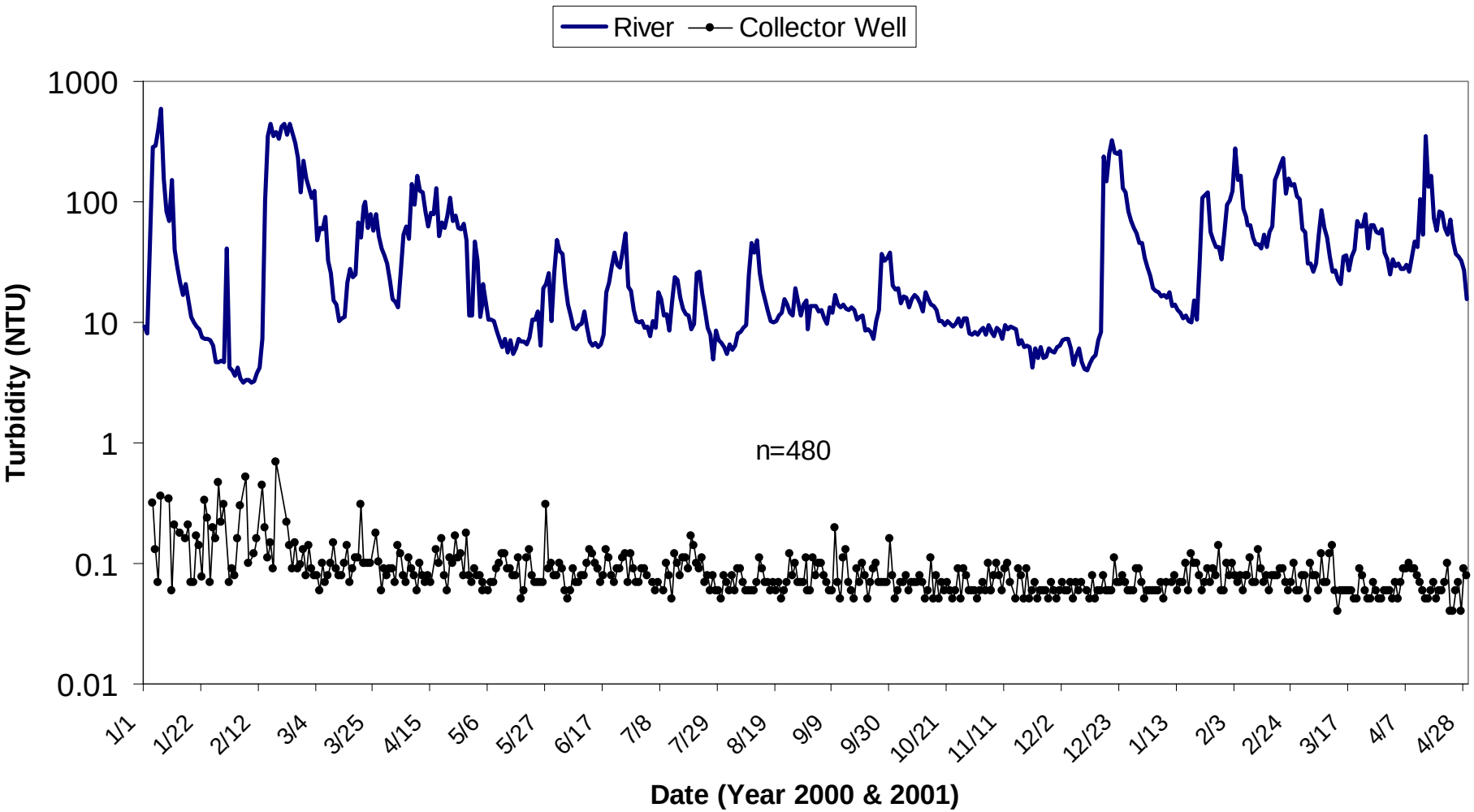


Figure 7.2 Turbidity Removal as a Function of Filtration Distance

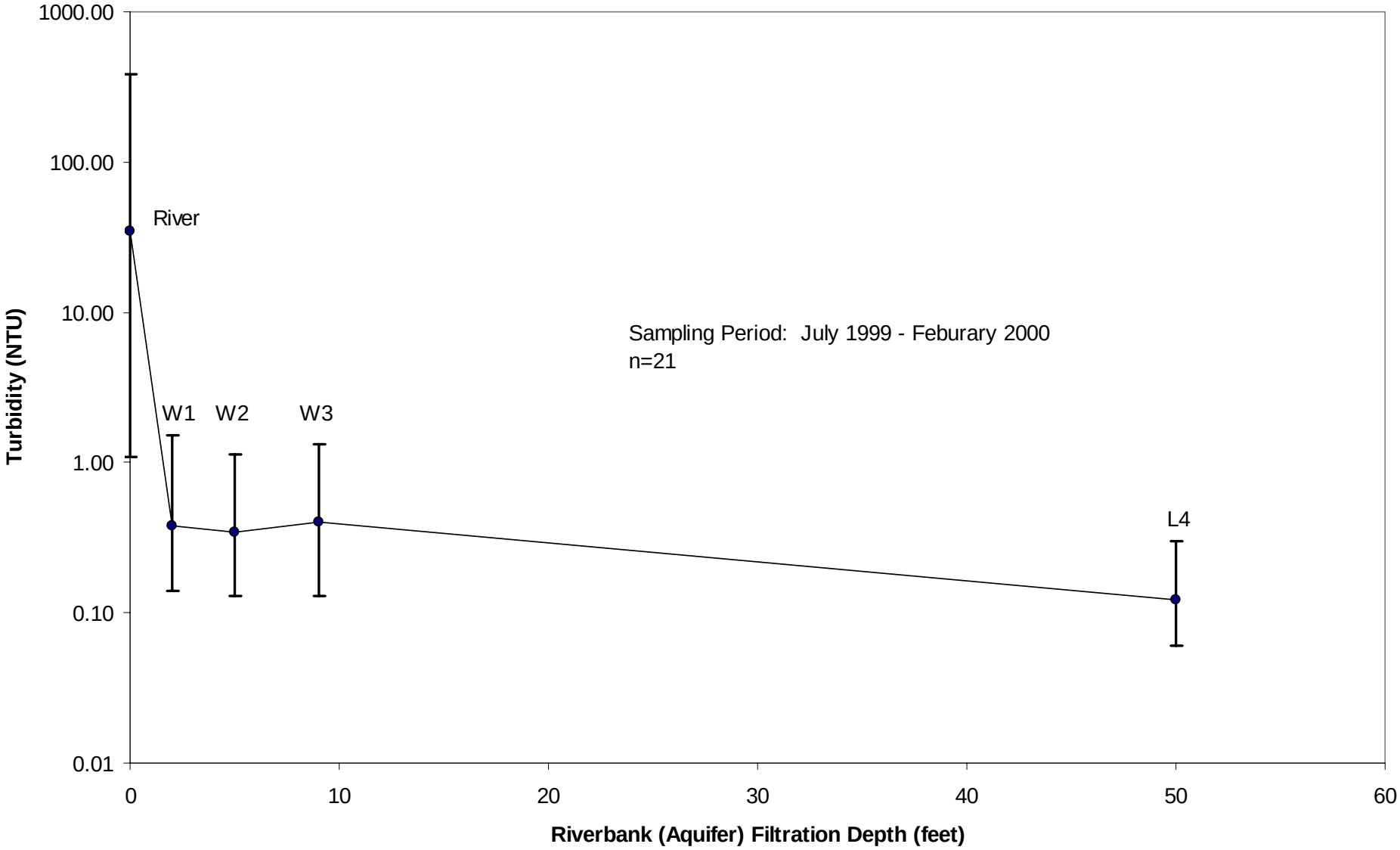


Figure 7.4 Total Coliform Concentration in the River and Collector Well

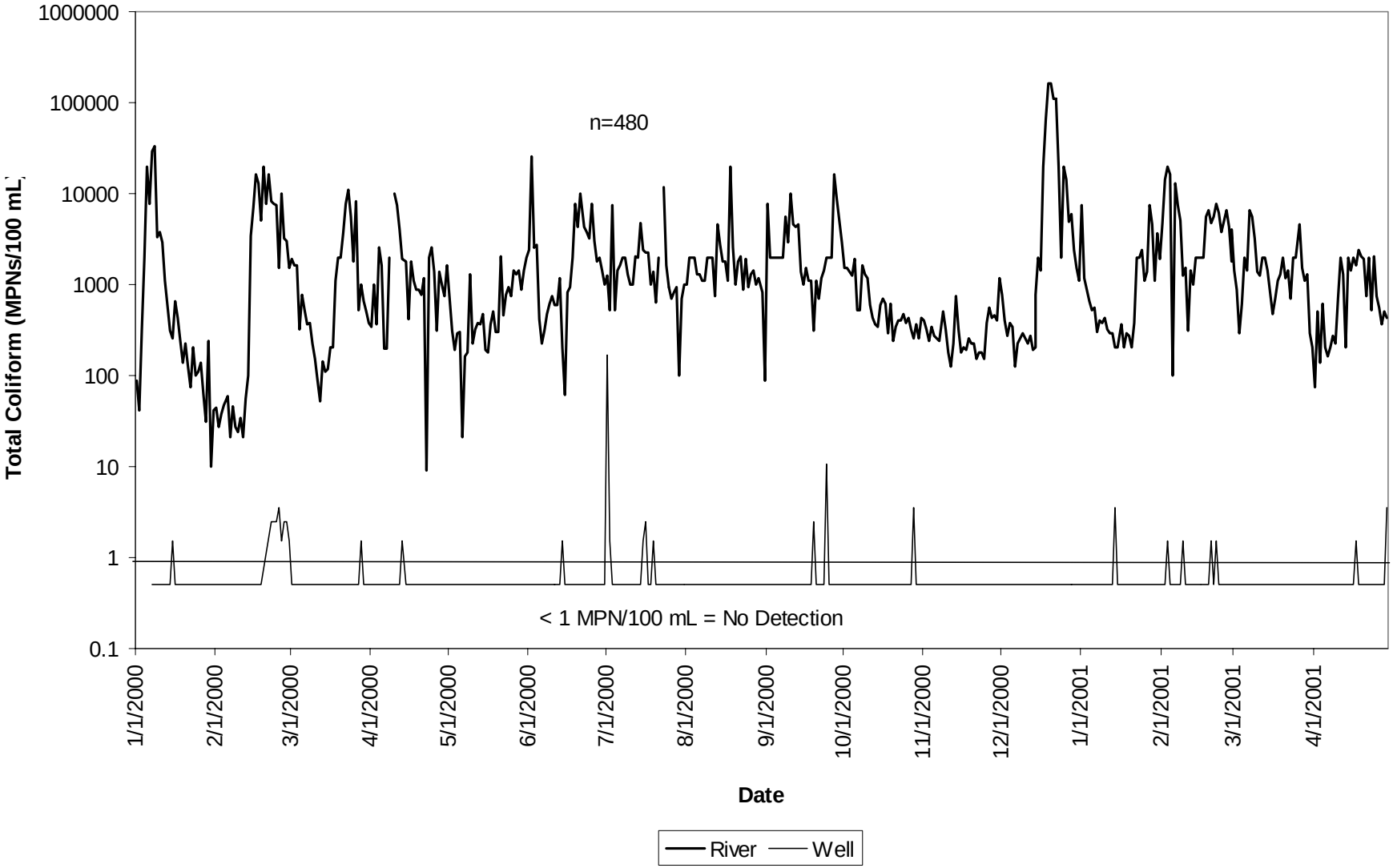


Figure 7.5 HPC Concentration in the River and Collector Well

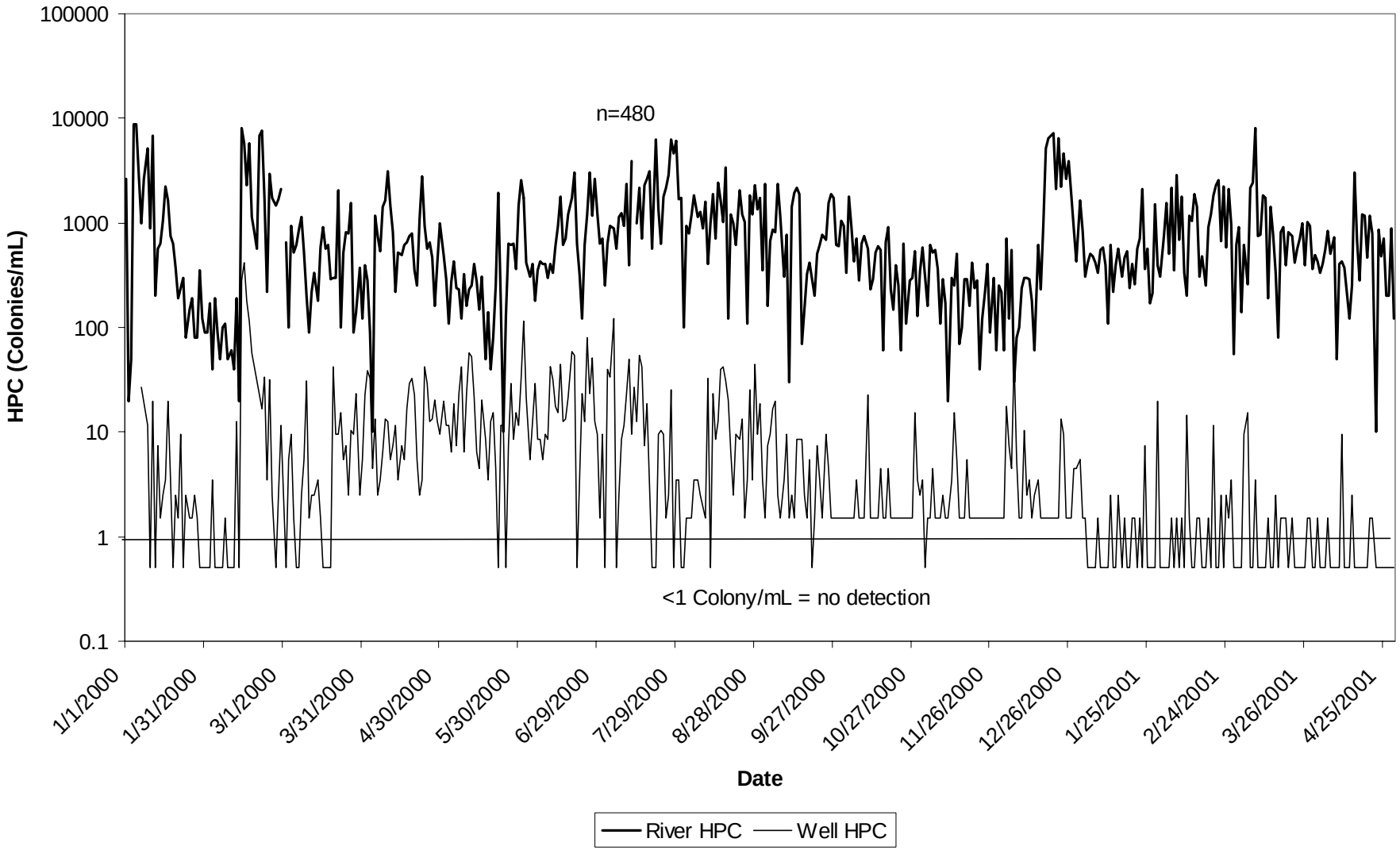


Figure 7.6 Log Removal of Total Coliform through Riverbank Filtration

(from the river to the collector well excluding groundwater dilution)

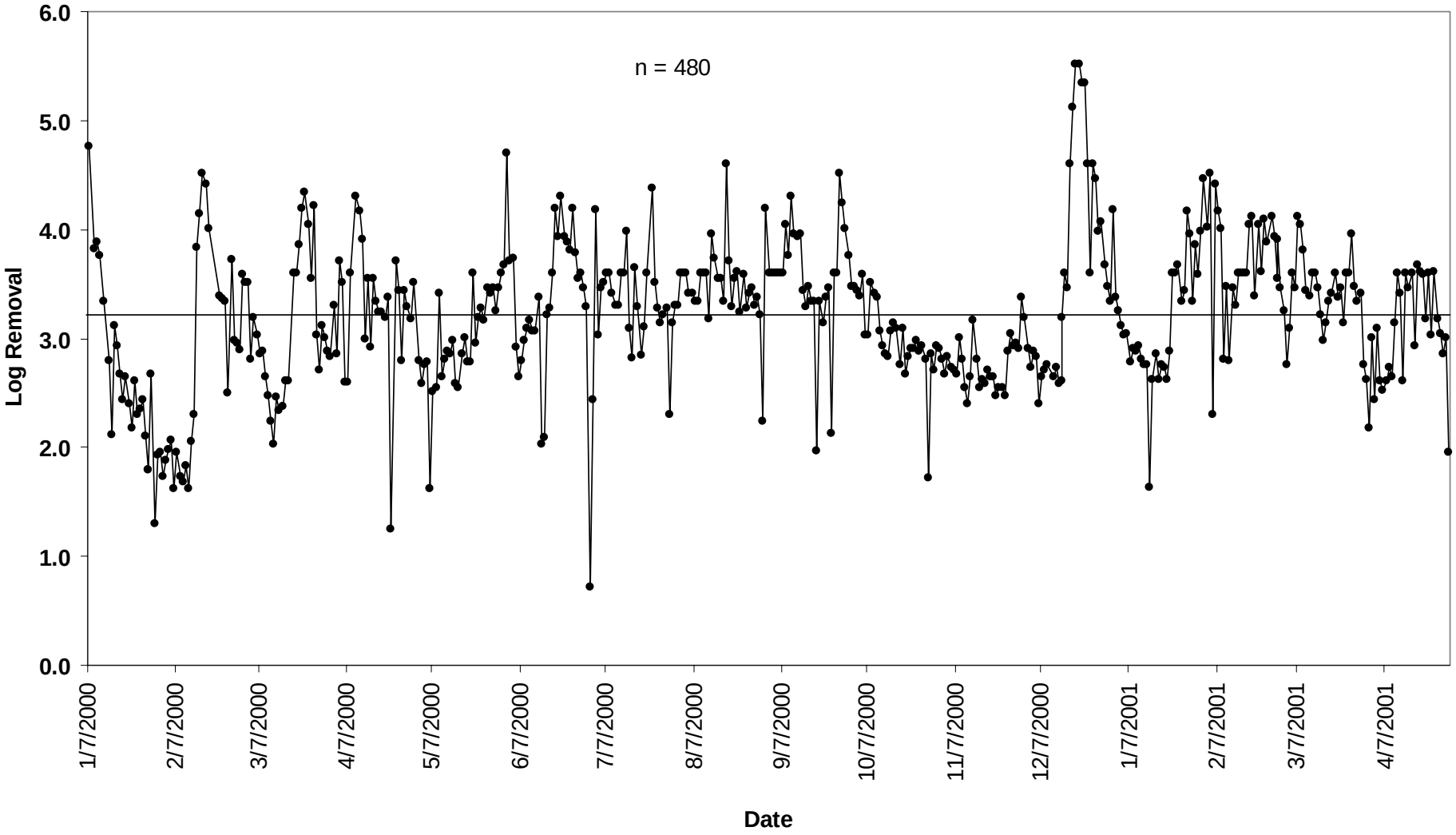


Figure 7.7 Log Removal of HPC through Riverbank Filtration

(from the river to the collector well excluding groundwater dilution)

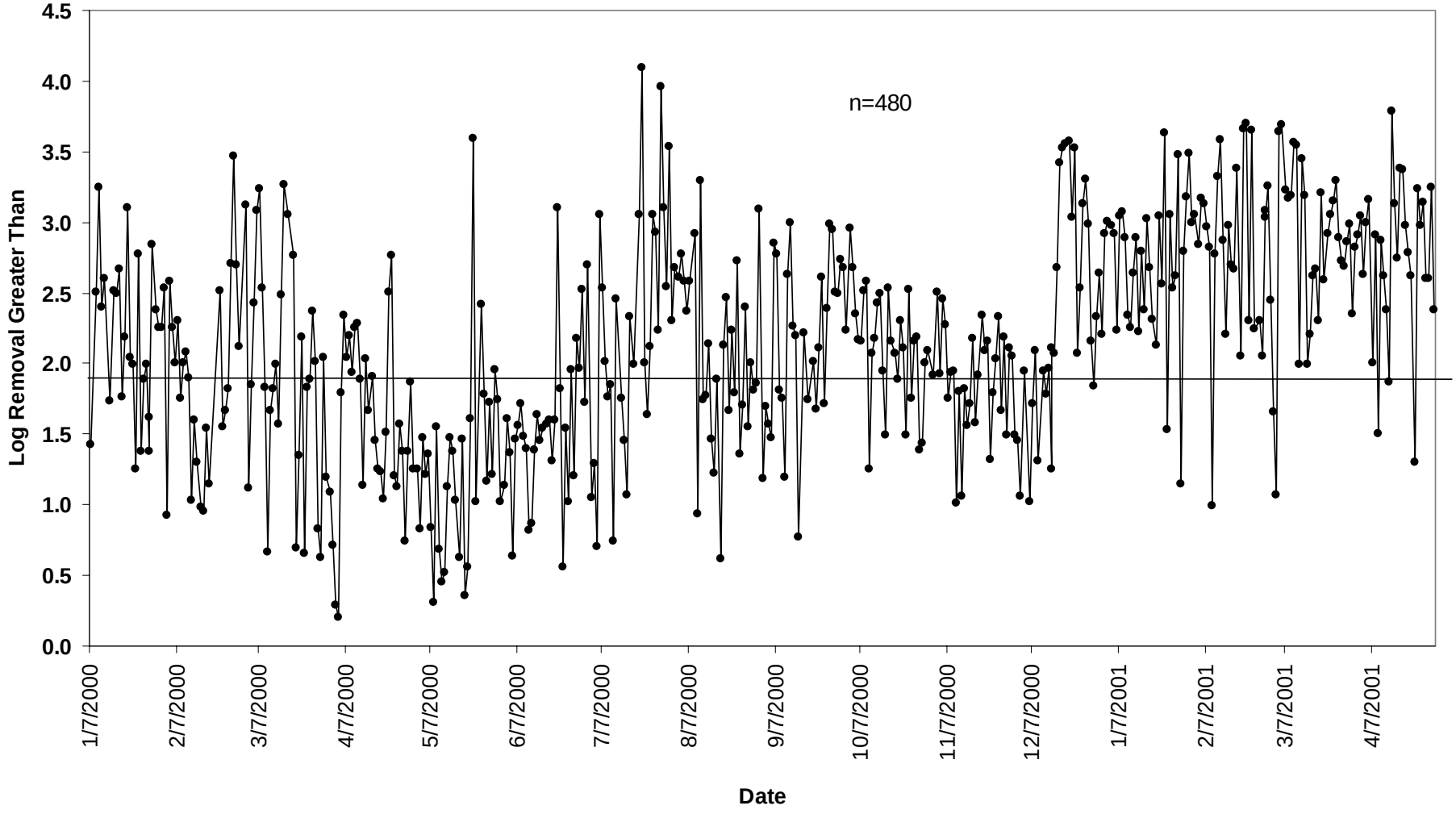


Figure 7.8 Total Aerobic Spore Concentration in the River and Well Water

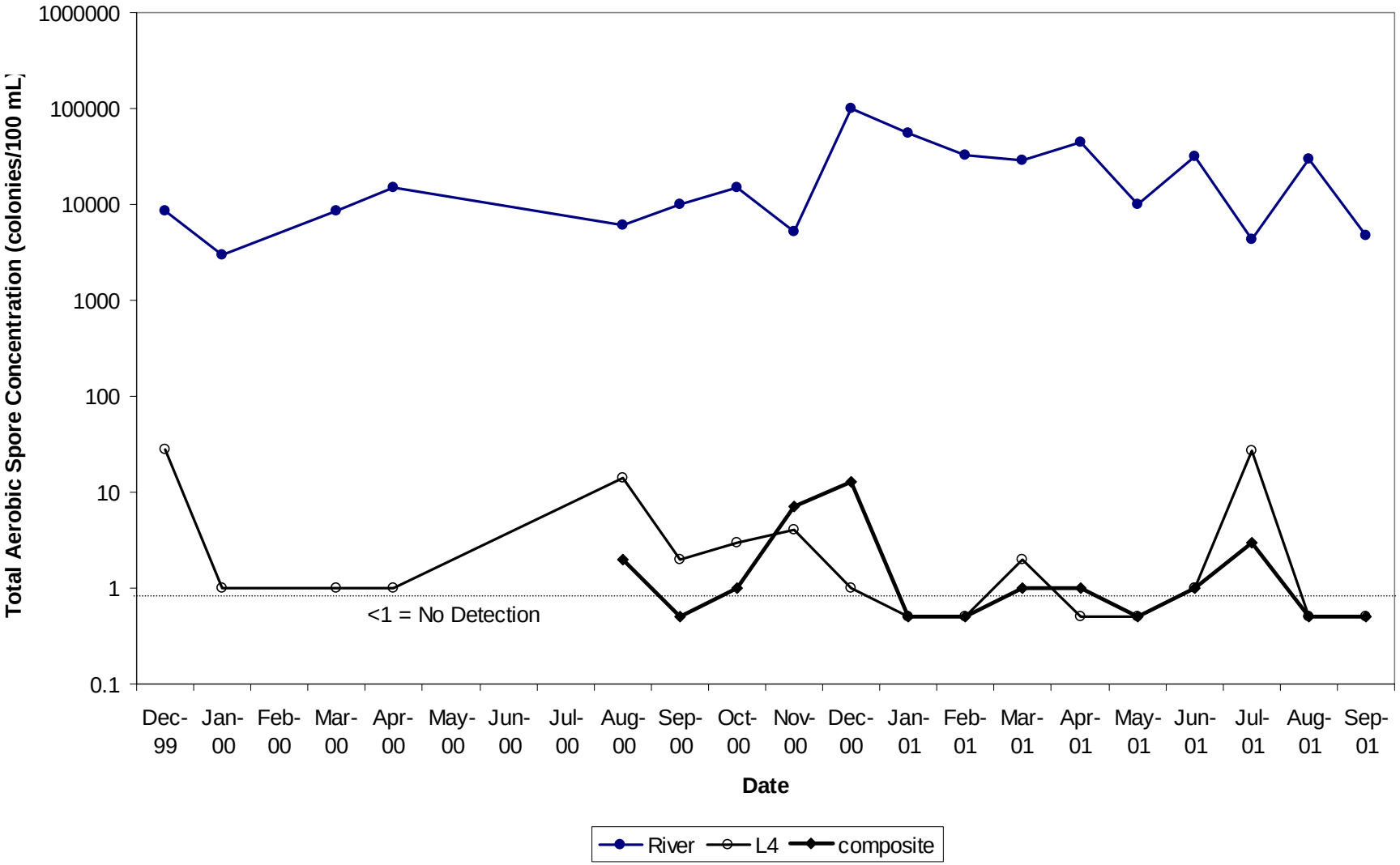


Figure 7.9 Total Aerobic Spore Concentrations in the River and the Riverbank Filtrates

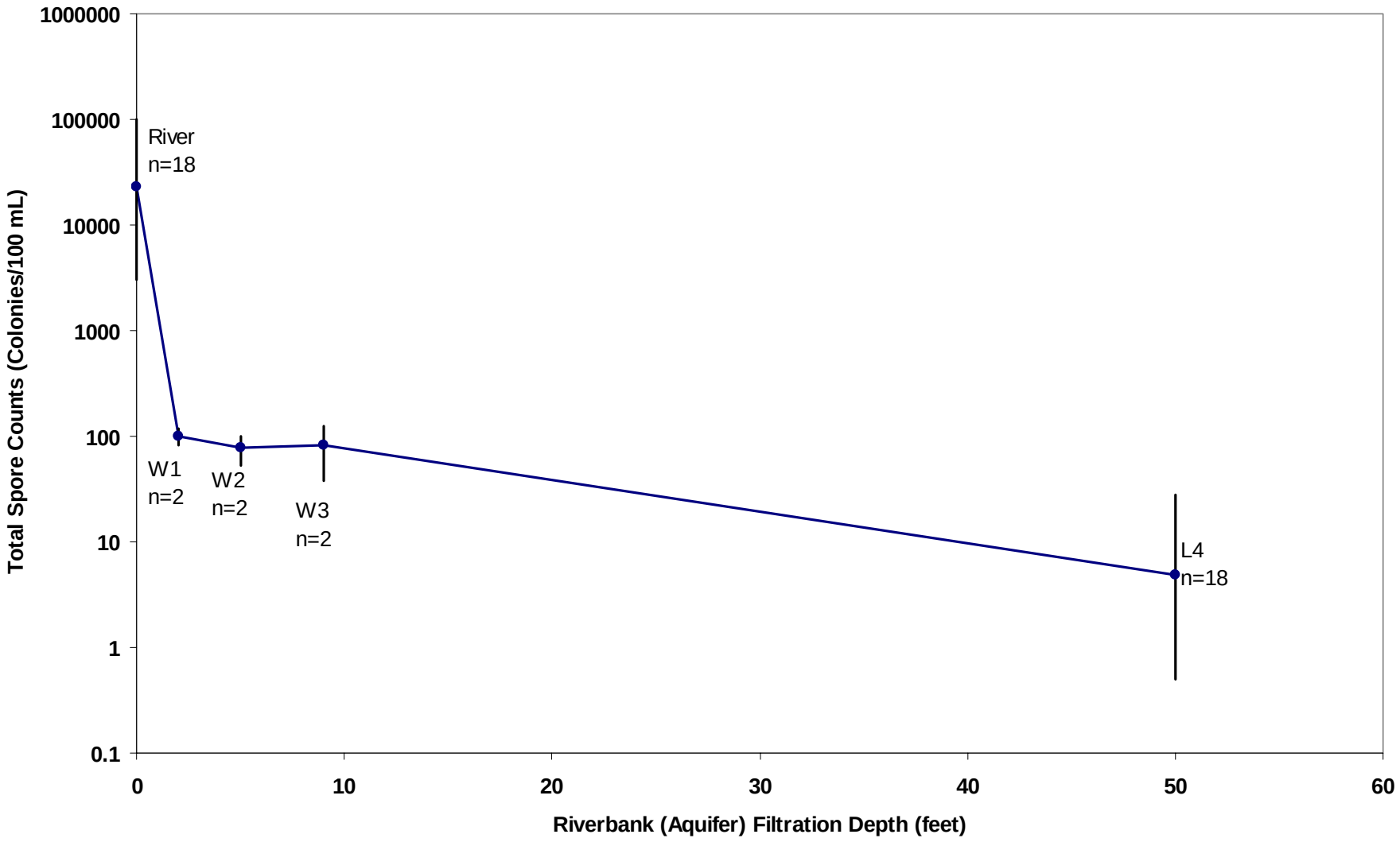


Figure 7.10 Average Log Removal of Total Aerobic Spore Count through Riverbank Filtration (excluding groundwater dilution effect)

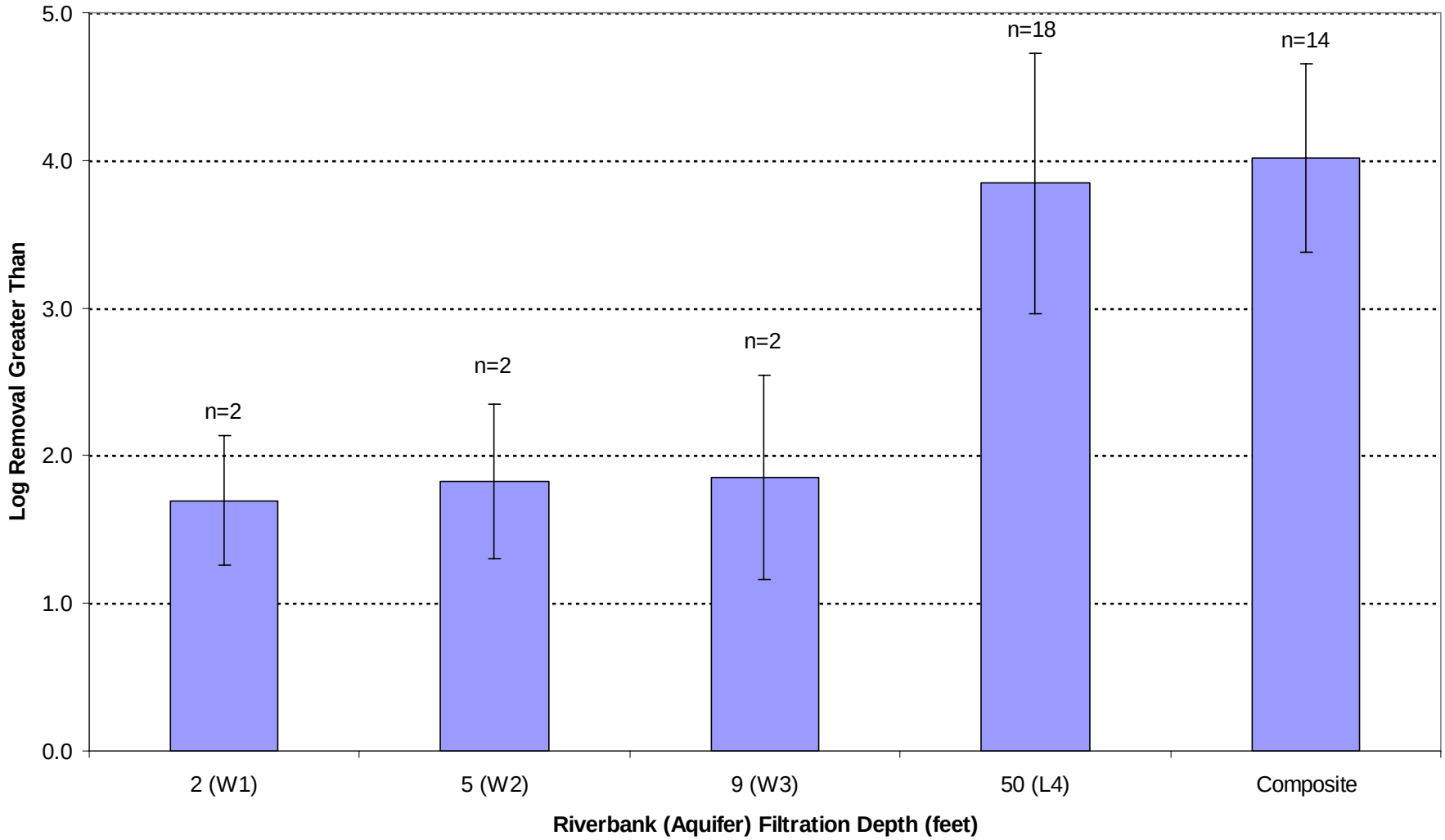


Figure 7.11 Total Aerobic Spore Concentration in the River, Laterals, and Collector Well

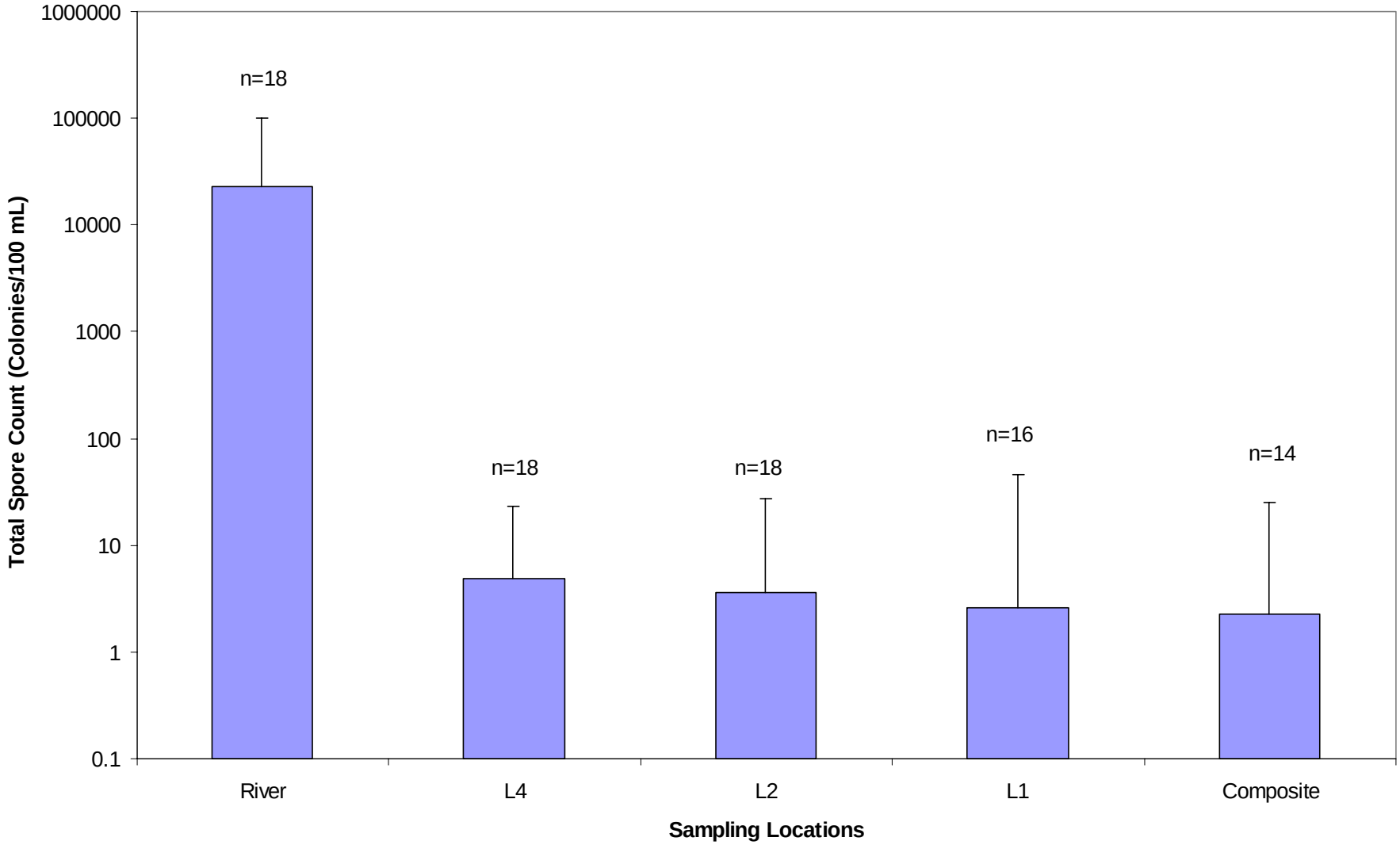


Figure 7.12 Particle Removal in L1

(excluding groundwater dilution Impact)

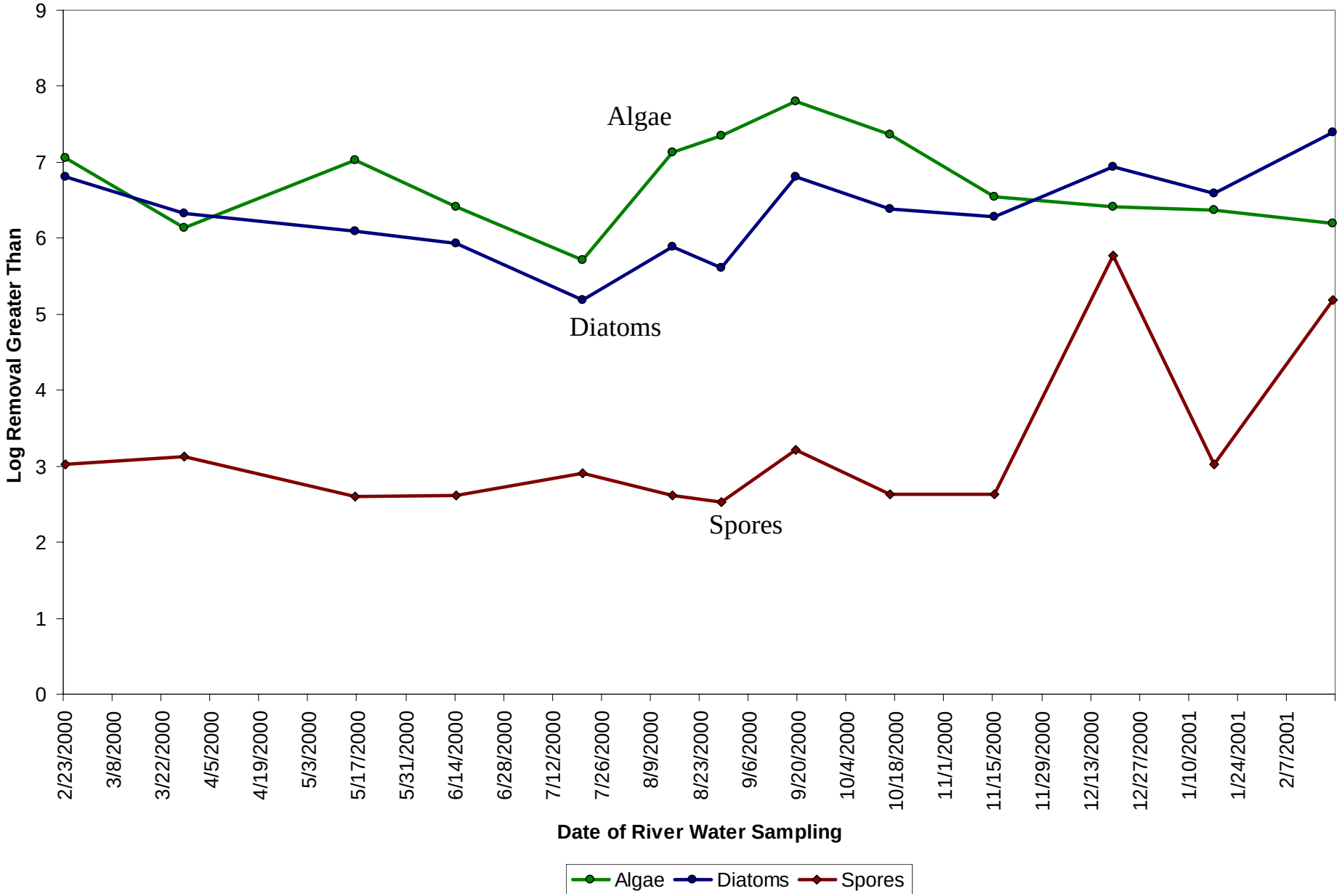


Figure 7.13 Particle Removal in L2

(excluding groundwater dilution impact)

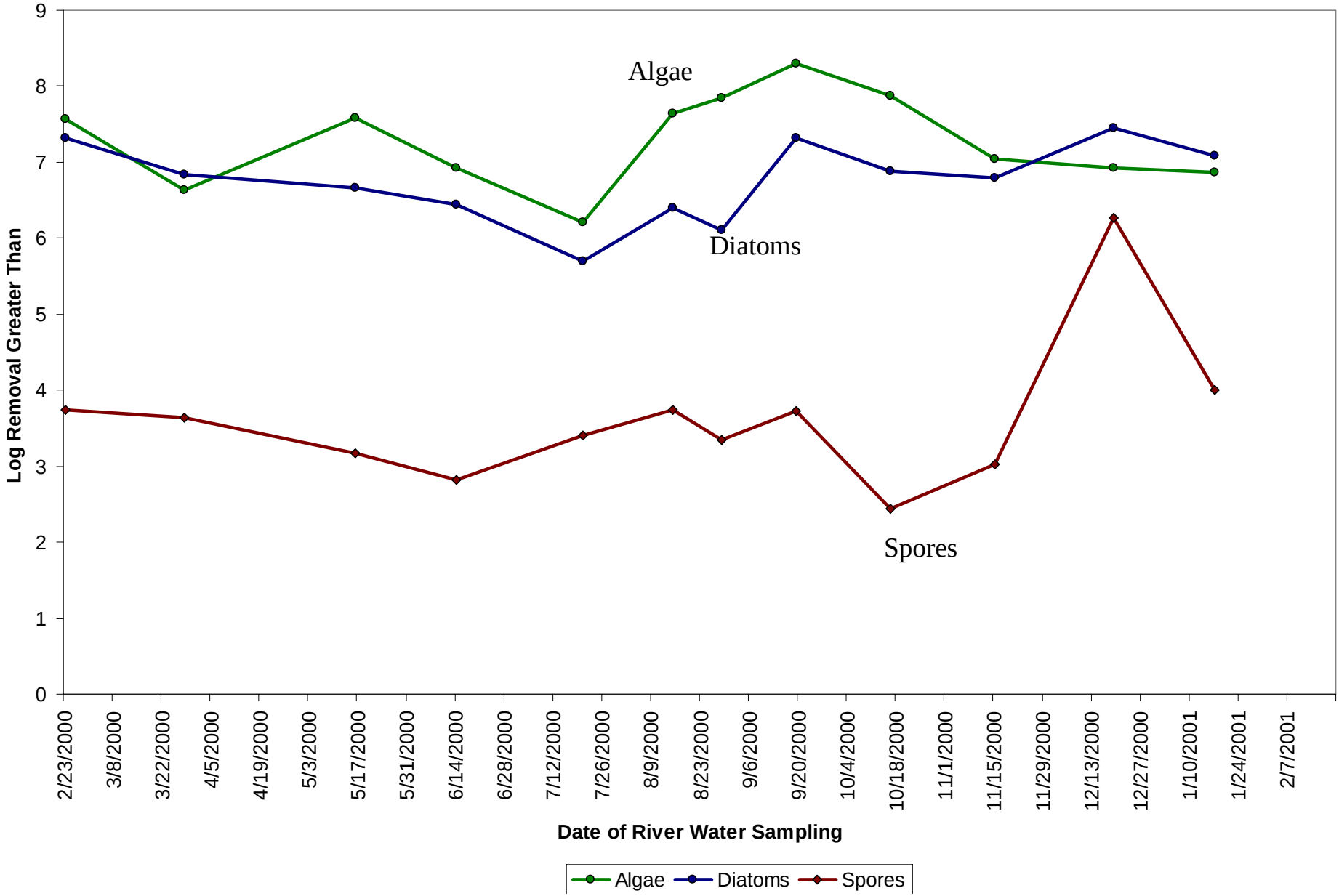


Figure 7.14 Particle Removal in L4

(excluding groundwater dilution impact)

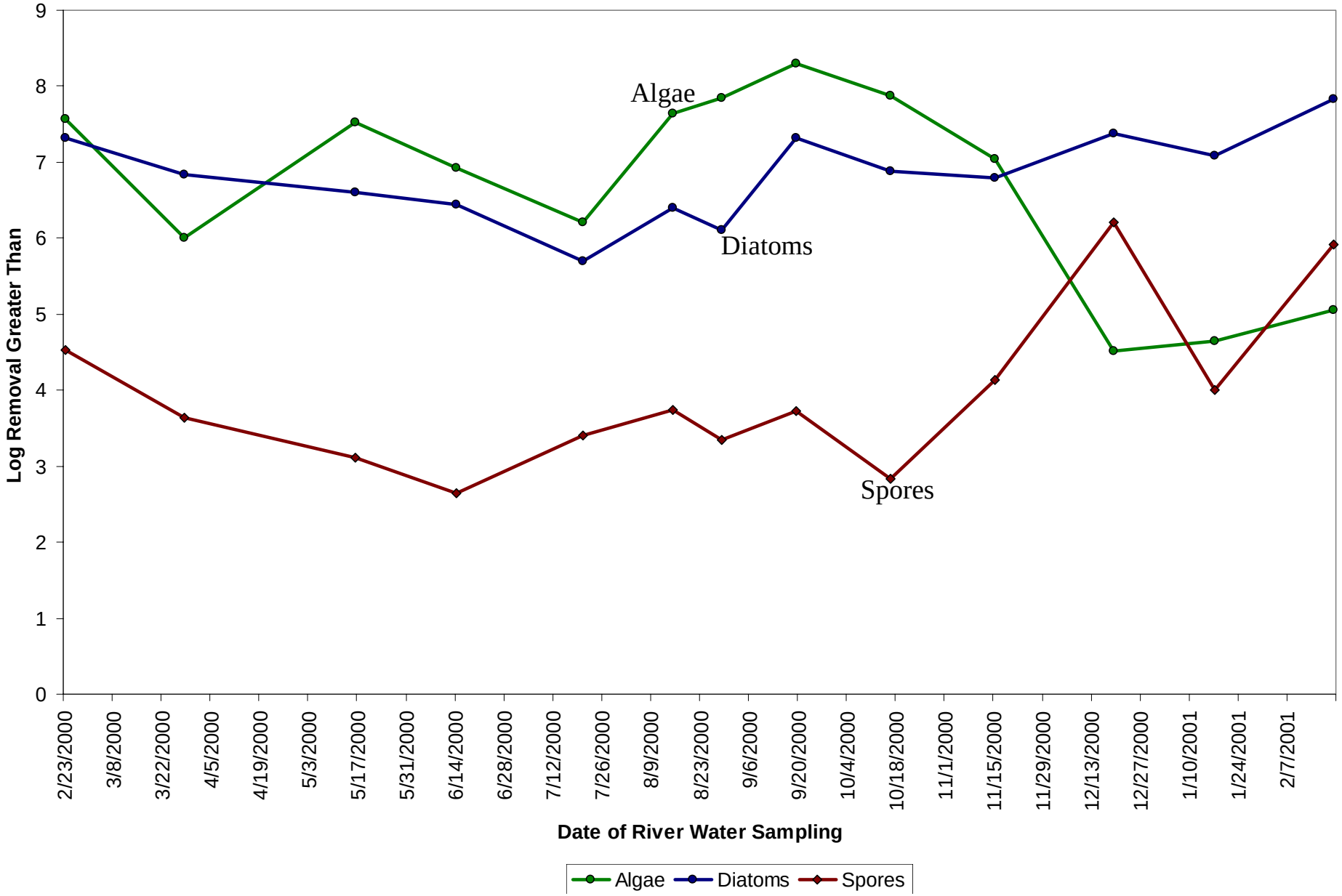


Table 1 Effectiveness of RBF for Microbial Removal at Louisville, Kentucky
(n = number of samples)

Parameters	**Sampling Locations or Filtration Depth**				**Typical Log Removal after 50 ft Filtration**
	River	***~5 ft RBF***	***~10 ft RBF***	***>50 ft RBF***	
Turbidity (NTU)	<5 to >900 n>500	0.13 – 1.14 n=21	0.13 – 1.32 n=19	0.05 – 0.69 n=400	Not calculated
Total Coliform (MPN/100 mL)	9 – 165200 n>500	Not measured	Not measured	0 – 165 n=400	3.2 logs
HPC (CFU/mL)	10 – 8820 n>500	Not measured	Not measured	0 – 420 n=400	2.0 logs
Spores (CFU/mL)	30 – 150 n=10	0.53 – 1.1 n=2	0.38 – 1.3 n=2	0 – 0.6 n=34	3.3 logs
MPA - Algae (No./100 L)	0.53 – 65 $x10^6$ n=12	Not measured	Not measured	0 – 66 n=36	>7.1 logs
MPA - Diatoms (No./100 L)	1.3 – 91 $x10^5$ n=12	Not measured	Not measured	0 – 0.26 n=36	>6.7 logs
Crypto (oocyst/L)	**0 – 0.6 n=94**	**Not measured**	**Not measured**	**0 n=56**	**Not calculated**

CONCLUSIONS

- Approach velocities are similar to Slow Sand Filters.
- Media composition is similar to Slow Sand Filters.
- Similar geologic formations would be expected to yield similar results.
- Turbidity is a pretty good indicator of performance.
- Performance is predictable and easily evaluated.
- It works well with DPB reduction strategies.
- It mediates the impact of spills on rivers.

CONCLUSIONS *continued...*

- **RBF is a technology that should be encouraged by regulations.**
- **Assigning minimal Crypto removal credit does not encourage the use of this technology.**

Table 7.1 MPA, Giardia and Cryptosporidium Results of River Water

Category	**Sampling Date (2000 – 2001)**												
	2/23	3/28	5/16	6/14	7/20	8/15	8/29	9/19	10/16	11/15	12/19	1/17	2/20
pH	7.6	7.6	7.8	7.7	7.6	7.6	7.6	7.9	7.8	7.7	7.9	7.6	7.6
Turbidity (NTU)	180	13	15	7.3	3.0	12	4.0	11	14	8.7	249	10	50
Sample Volume (L)	189	280	235	348	242	208	276	252	223	299	110	307	110
Packed Pellet Volume (mL)	20	2	2	3	0.75	2.0	1.0	10	2.0	2.0	20	2.25	20
Detection Limit (No. /100 L)	2.6E+3	3.6E+2	4.2E+2	4.3E+2	8.3E+2	9.1E+2	7.1E+2	1.7E+3	4.5E+2	1.1E+3	6.1E+4	3.3E+3	9.1E+4
Algae (No. /100 L)	1.2E+7	1.4E+6	1.1E+7	2.7E+6	5.3E+5	1.4E+7	2.3E+7	6.5E+7	2.4E+7	3.6E+6	2.7E+6	2.4E+6	1.4E+6
Amoebae (No. /100 L)	5.3E+3	ND	ND	ND	ND	ND	ND	ND	ND	ND	3.0E+5	ND	2.7E+5
Crustaceans/Parts (No. /100 L)	2.6E+3	ND	ND	4.3E+2	ND	9.1E+2	1.4E+3	ND	ND	ND	6.1E+4	ND	ND
Diatoms (No. /100 L)	6.7E+6	2.2E+6	1.3E+6	9.0E+5	1.6E+5	8.1E+5	4.2E+5	6.8E+6	2.5E+6	2.0E+6	9.1E+6	4.0E+6	2.2E+7
Insects/Parts (No. /100 L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	9.1E+4
Invertebrates/Eggs (No. /100 L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Nematodes/Eggs (No. /100 L)	2.6E+3	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.2E+5	ND	ND
Pollen (No. /100 L)	5.3E+3	1.1E+3	ND	ND	ND	ND	ND	ND	ND	1.1E+3	6.1E+4	ND	3.6E+5
Protozoa (Free-living,No./100L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	3.4E+5	ND	ND	2.7E+5
Rotifers/Eggs (No. /100 L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Spores (No. /100 L)	1.1E+4	1.4E+3	4.2E+2	4.3E+2	ND	1.8E+3	7.1E+2	ND	ND	4.4E+3	6.1E+5	ND	2.7E+5
Vegetative Debris (No. /100 L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.1E+3	1.2E+5	ND	3.6E+5
Giardia Cysts (No./100 L)	**<30**	**10**	**<23.8**	**<27.0**	**<7.2**	**6.1**	**<2.9**	**15.4**	**6.1**	**<9.2**	**125**	NA	250
Cryptosporidium Oocysts (No./100 L)	**<30**	**<1.4**	**<23.8**	**<27.0**	**<7.2**	**<6.1**	**<2.9**	**<15.4**	**<6.1**	**<9.2**	**<125**	NA	333

Table 7.4 MPA, Giardia and Cryptosporidium Results of Water from Lateral 4

Category	**Sampling Date (2000 – 2001)**												
	2/23	3/28	5/16	6/14	7/20	8/15	8/29	9/19	10/16	11/15	12/19	1/17	3/6
pH	7.6	7.7	7.7	7.6	7.8	7.7	7.7	7.6	7.6	7.7	7.7	7.6	7.7
Turbidity (NTU)	0.50	0.10	0.10	0.10	0.50	0.10	0.09	0.10	0.10	0.40	0.50	0.10	0.10
Sample Volume (L)	1896	2937	2543	1381	2055	871	1662	1972	1628	1151	2244	1007	3024
Packed Pellet Volume (mL)	0.10	Trace	0.10	0.04	0.05	0.05	0.05	0.20	0.05	0.20	0.50	0.10	0.2
Detection Limit (No. /100 L)	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.30	0.26	0.26
Algae (No. /100 L)	ND	1.1	ND	ND	ND	ND	ND	ND	ND	ND	66	44	9.8
Amoebae (No. /100 L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Crustaceans/Parts (No. /100 L)	ND	ND	ND	ND	ND	ND	ND	ND	0.26	0.26	ND	ND	ND
Diatoms (No. /100 L)	ND	ND	0.26	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Insects/Parts (No. /100 L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Invertebrates/Eggs (No. /100 L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Nematodes/Eggs (No. /100 L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pollen (No. /100 L)	ND	ND	1.6	1.8	ND	0.26	ND	ND	ND	ND	ND	ND	ND
Protozoa (Free-living,No./100L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	16000	16000	4000	81000
Rotifers/Eggs (No. /100 L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Spores (No. /100 L)	0.26	ND	ND	0.78	ND	ND	ND	ND	0.52	ND	0.30	ND	0.26
Vegetative Debris (No. /100 L)	ND	ND	ND	ND	ND	0.52	ND	0.26	ND	0.26	ND	ND	ND
Giardia Cysts (No./100 L)	**<0.4**	**<0.1**	**<0.9**	**<0.4**	**<0.8**	**<1.3**	**<0.7**	**<1.1**	**<0.9**	**<0.7**	<1.5	<0.9	<0.8
Cryptosporidium Oocysts (No./100 L)	**<0.4**	**<0.1**	**<0.9**	**<0.4**	**<0.8**	**<1.3**	**<0.7**	**<1.1**	**<0.9**	**<0.7**	<1.5	<0.9	<0.8