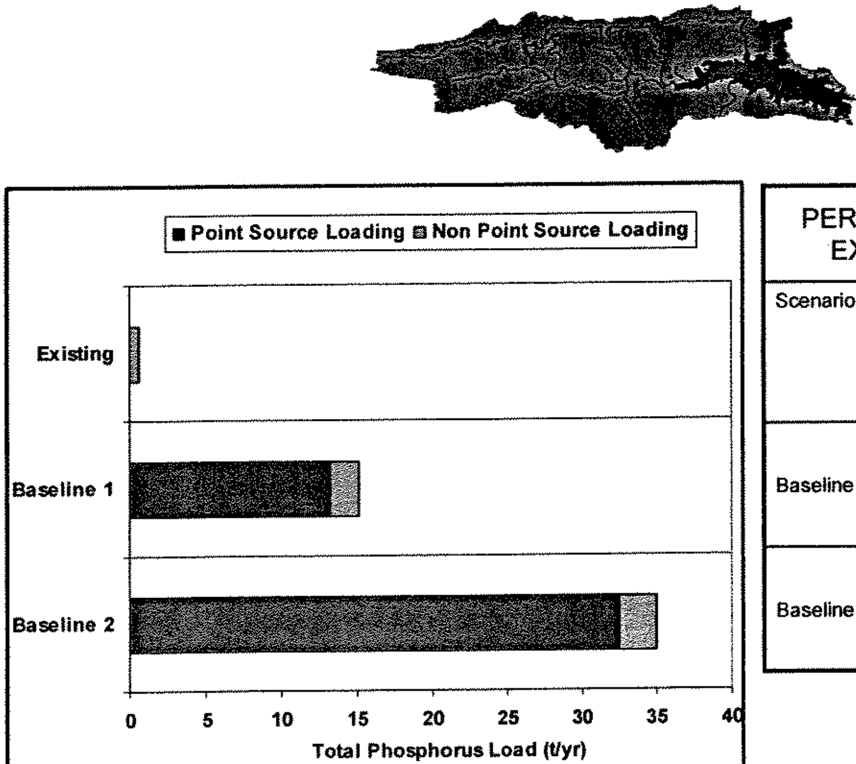
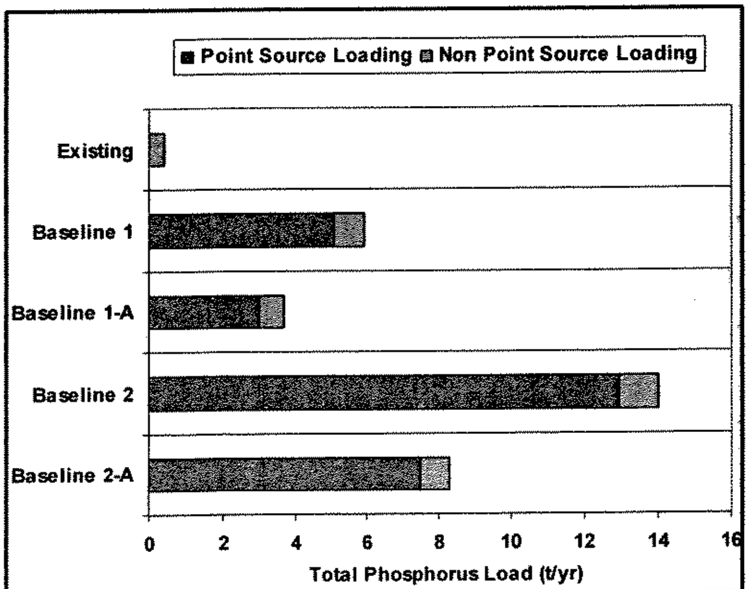


PERCENT INCREASE OVER EXISTING TOTAL LOAD

Scenario	[illegible]	Non Point Source	Total
Baseline 1	[illegible]	220%	2419%
Baseline 2	[illegible]	309%	5721%

Figure 22. Annual Phosphorus Load from the Middle Zone Subwatersheds



PERCENT INCREASE OVER EXISTING TOTAL LOAD			
Scenario	[illegible]	Non Point Source	Total
Baseline 1	[illegible]	109%	1345%
Baseline 1-A	[illegible]	66%	796%
Baseline 2	[illegible]	153%	3311%
Baseline 2-A	[illegible]	91%	1918%

Figure 23. Annual Phosphorus Load from the Lower Zone Subwatersheds

5.1.3 Total Nitrogen Loads to Lake Maumelle

The percentage increase in total nitrogen loading is approximately one-half the percentage increase in total phosphorus loading for the two baseline scenarios. Table 19 summarizes the nitrogen loads from nonpoint and point sources in the Lake Maumelle Watershed from each loading zone. The majority of the increase under the baseline scenarios is from point source loading.

Table 19. Nitrogen Loads (t/yr) from Nonpoint and Point Sources in the Lake Maumelle Watershed by Zone (areal loading in lb/ac/yr in parentheses)

Scenario	Upstream	Middle	Lower	Total
Loads From Nonpoint Sources				
Existing	49 (1.7)	9 (1.3)	6 (1.6)	64 (1.6)
Baseline 1	64 (2.2)	19 (2.7)	9 (2.5)	92 (2.3)
Baseline 1A	64 (2.2)	19 (2.7)	8 (2.1)	91 (2.3)
Baseline 2	64 (2.2)	23 (3.3)	11 (2.9)	98 (2.5)
Baseline 2A	64 (2.2)	23 (3.3)	9 (2.3)	96 (2.4)
Loads From Point Sources				
Existing	0 (0)	0 (0)	0 (0)	0 (0)
Baseline 1	85 (3)	84 (12)	30 (8.1)	199 (5.1)
Baseline 1A	85 (3)	84 (12)	18 (4.8)	187 (4.7)
Baseline 2	89 (3.1)	212 (30.1)	77 (20.8)	378 (9.6)
Baseline 2A	89 (3.1)	212 (30.1)	45 (12)	346 (8.8)
Total Load				
Existing	49 (2)	9 (1)	6 (2)	64 (2)
Baseline 1	149 (5)	103 (15)	39 (11)	291 (7)
Baseline 1A	149 (5)	103 (15)	26 (7)	278 (7)
Baseline 2	154 (5)	235 (33)	88 (24)	476 (12)
Baseline 2A	154 (5)	235 (33)	54 (14)	442 (11)

Figure 24 shows the nitrogen load to Lake Maumelle for each baseline modeling scenario as well as the percent increase over existing conditions. Figure 25 shows the percent contributions of point and nonpoint sources to the overall increase.

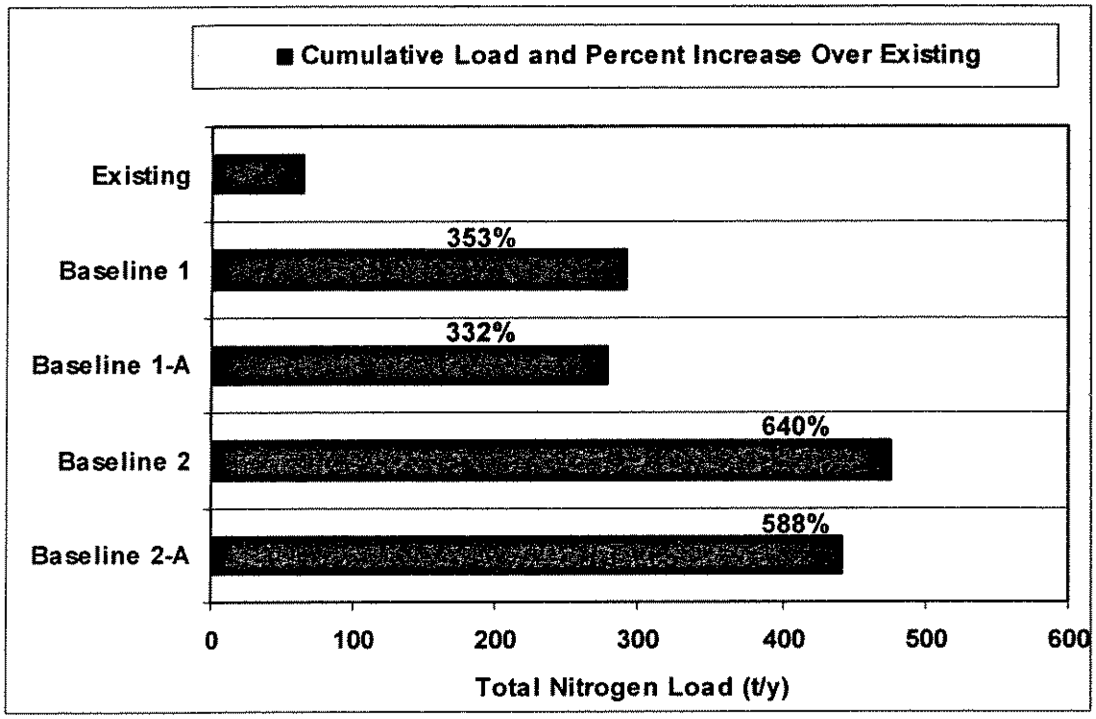


Figure 24. Total Annual Nitrogen Load to Lake Maumelle

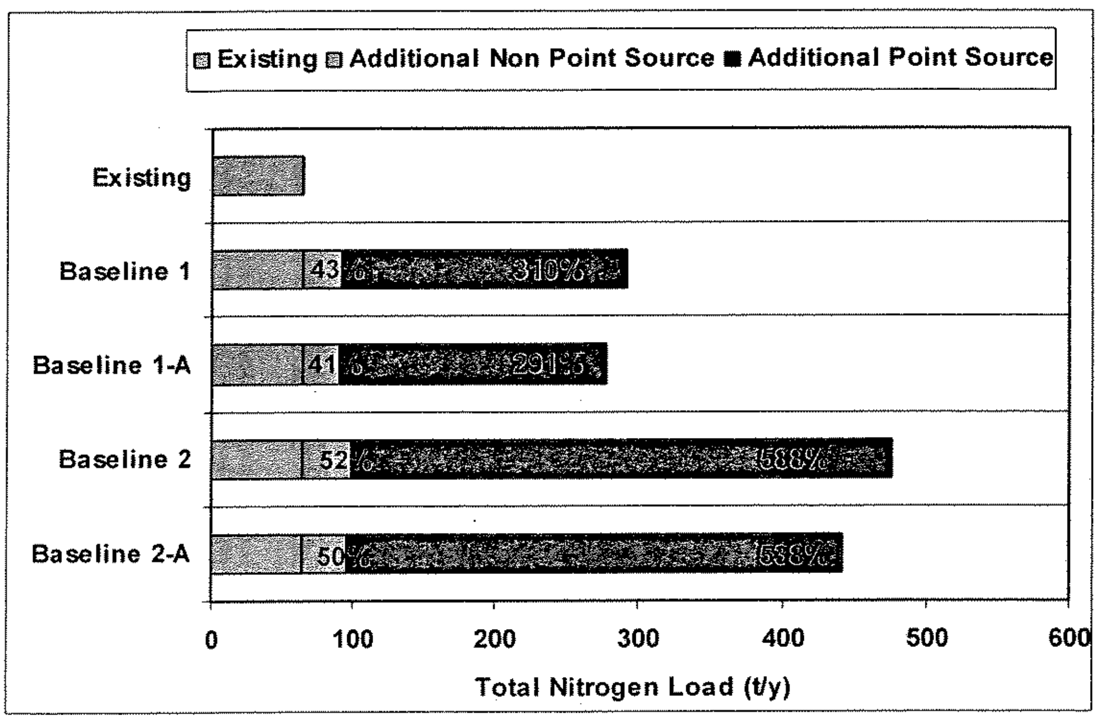
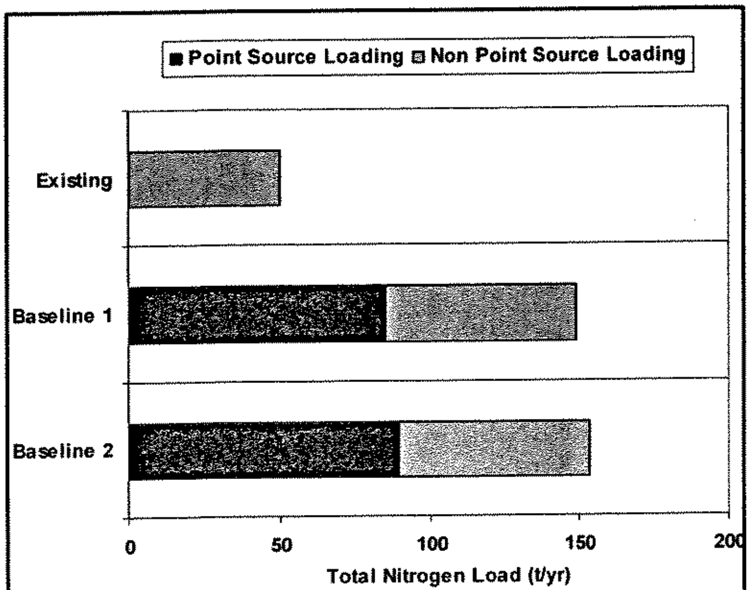


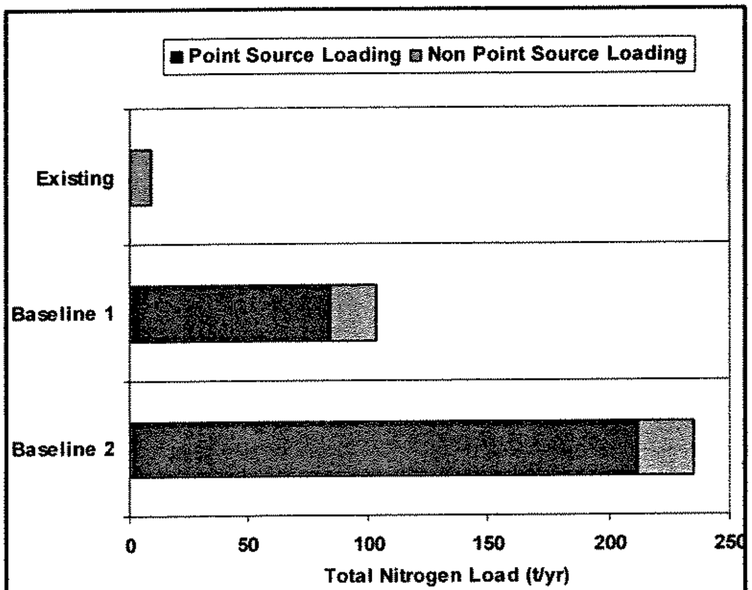
Figure 25. Point and Nonpoint Source Annual Nitrogen Loads to Lake Maumelle

Figure 26 through Figure 28 show the nitrogen load from each loading zone.



PERCENT INCREASE OVER EXISTING TOTAL LOAD			
Scenario	Point Source	Non Point Source	Total
Baseline 1	171%	29%	200%
Baseline 2	180%	30%	210%

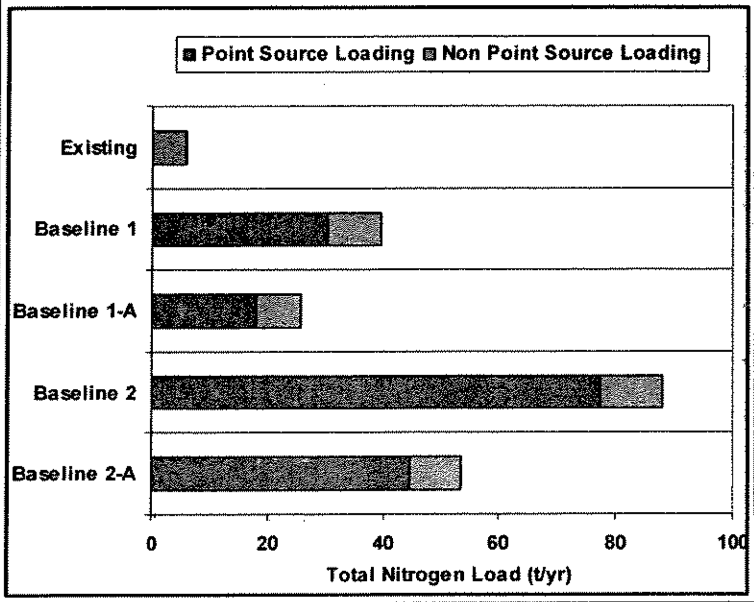
Figure 26. Annual Nitrogen Load from the Upstream Zone Subwatersheds



PERCENT INCREASE OVER EXISTING TOTAL LOAD

Scenario	Point Source	Non Point Source	Total
Baseline 1	[illegible]	113%	1059%
Baseline 2	[illegible]	160%	2537%

Figure 27. Annual Nitrogen Load from the Middle Zone Subwatersheds



PERCENT INCREASE OVER EXISTING TOTAL LOAD

Scenario	[illegible]	Non Point Source	Total
Baseline 1	[illegible]	50%	567%
Baseline 1-A	[illegible]	34%	336%
Baseline 2	[illegible]	79%	1386%
Baseline 2-A	[illegible]	47%	803%

Figure 28. Annual Nitrogen Load from the Lower Zone Subwatersheds

5.1.4 Total Organic Carbon Loads to Lake Maumelle

Total organic carbon (TOC) loads are not predicted to increase as much as the other parameters because native forest cover produces significant loads of naturally occurring organic compounds such as humic acids. For the watershed as a whole, TOC loading is predicted to increase by about 26 percent under Baseline Scenario 1 and 39 percent under Baseline Scenario 2. The percent increases in the middle and lower lake zones are higher on average, ranging up to 140 percent in the middle lake zone under Baseline Scenario 2. Nonpoint source increases slightly outweigh predicted contributions from point sources. Table 20 summarizes the organic carbon loads from nonpoint and point sources in the Lake Maumelle Watershed from each loading zone.

Table 20. Total Organic Carbon Loads (t/yr) from Nonpoint and Point Sources in the Lake Maumelle Watershed by Zone (areal loading in lb/ac/yr in parentheses)

Scenario	Upstream	Middle	Lower	Total
Loads From Nonpoint Sources				
Existing	682 (24)	116 (16)	82 (22)	880 (22)
Baseline 1	758 (26)	174 (25)	101 (27)	1,033 (26)
Baseline 1A	758 (26)	174 (25)	94 (25)	1,026 (26)
Baseline 2	763 (27)	209 (30)	112 (30)	1,084 (28)
Baseline 2A	763 (27)	209 (30)	100 (27)	1,072 (27)
Loads From Point Sources				
Existing	0 (0)	0 (0)	0 (0)	0 (0)
Baseline 1	32 (1.1)	32 (4.5)	16 (4.4)	80 (2)
Baseline 1A	32 (1.1)	32 (4.5)	10 (2.6)	73 (1.9)
Baseline 2	33 (1.2)	69 (9.7)	42 (11.2)	144 (3.6)
Baseline 2A	33 (1.2)	69 (9.7)	24 (6.4)	126 (3.2)
Total Load				
Existing	682 (24)	116 (16)	82 (22)	880 (22)
Baseline 1	790 (28)	206 (29)	117 (31)	1,113 (28)
Baseline 1A	790 (28)	206 (29)	104 (28)	1,099 (28)
Baseline 2	796 (28)	278 (39)	154 (41)	1,228 (31)
Baseline 2A	796 (28)	278 (39)	124 (33)	1,198 (30)

Figure 29 shows the organic carbon load to Lake Maumelle for each baseline modeling scenario as well as the percent increase over existing conditions. Figure 30 shows the percent contributions of point and nonpoint sources to the overall increase.

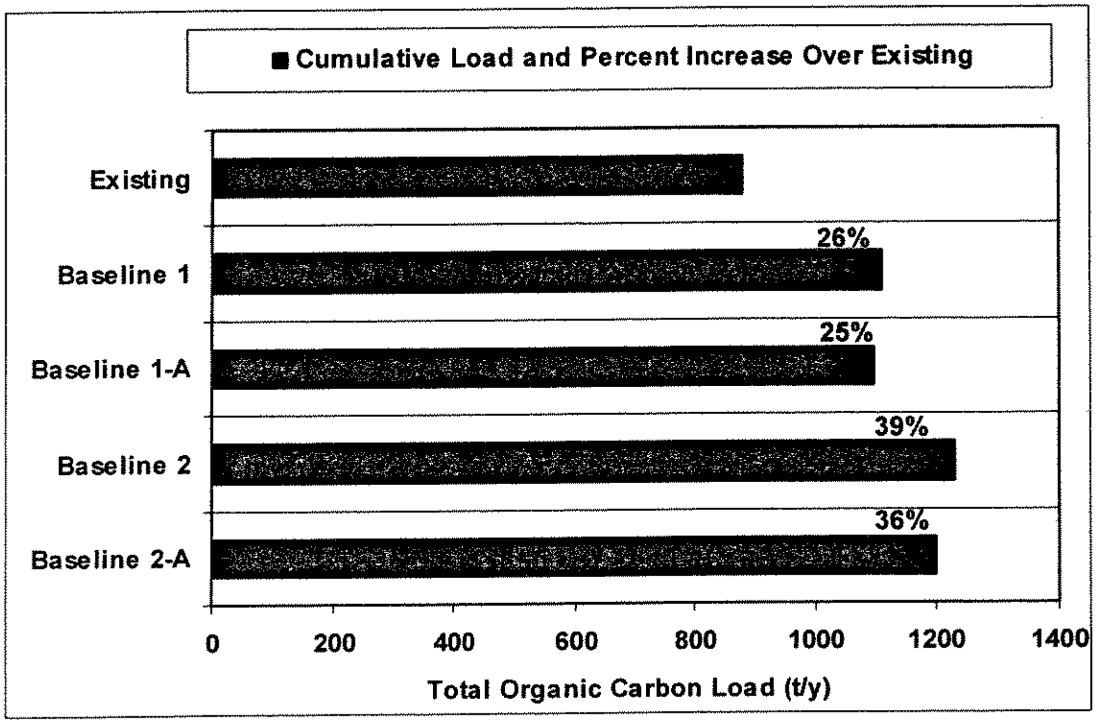


Figure 29. Annual Total Organic Carbon Load to Lake Maumelle

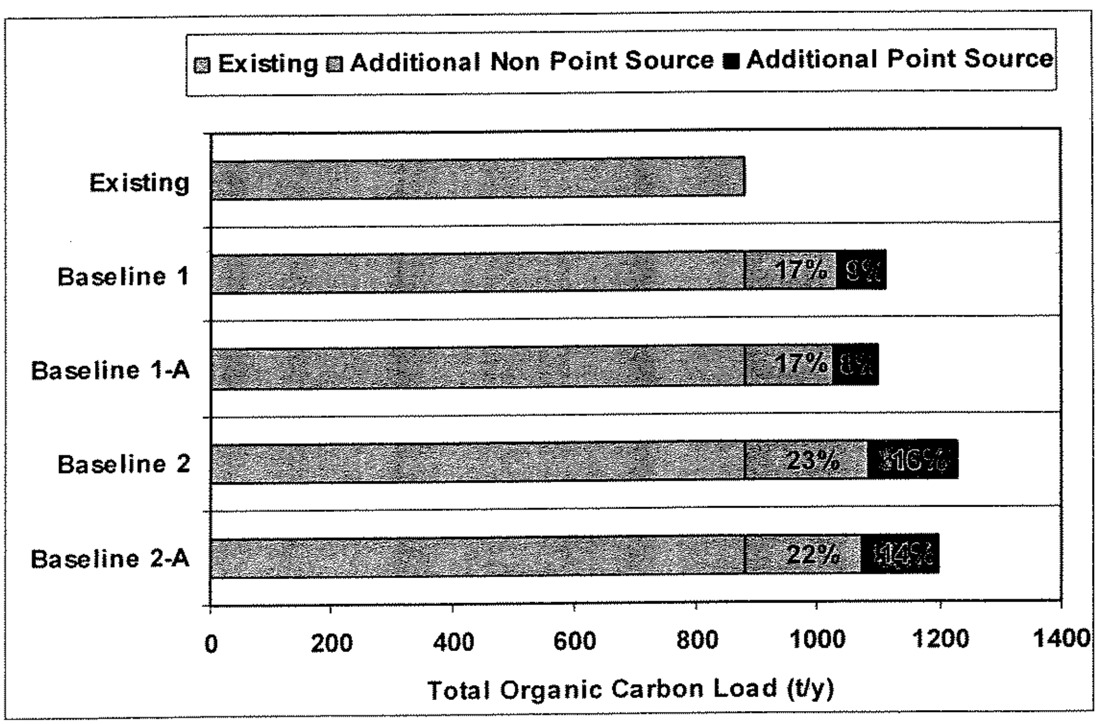
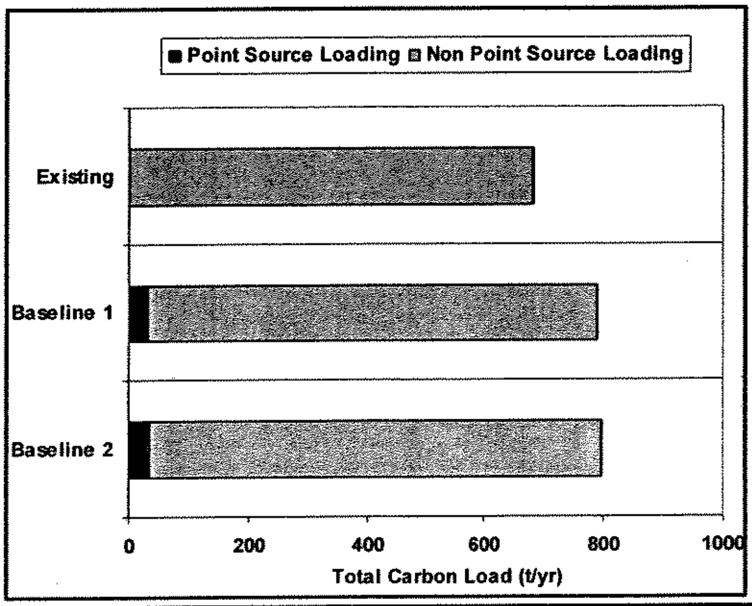


Figure 30. Point and Nonpoint Source Annual Total Organic Carbon Loads to Lake Maumelle

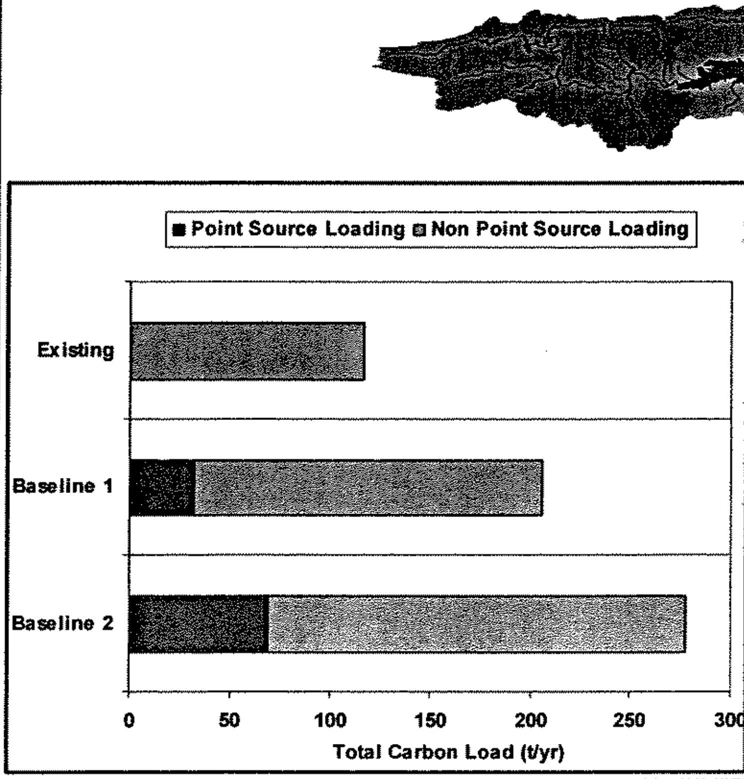
Figure 31 through Figure 33 show the organic carbon load from each loading zone.



PERCENT INCREASE OVER EXISTING TOTAL LOAD

Scenario	Point Source	Non Point Source	Total
Baseline 1	5%	11%	16%
Baseline 2	5%	12%	17%

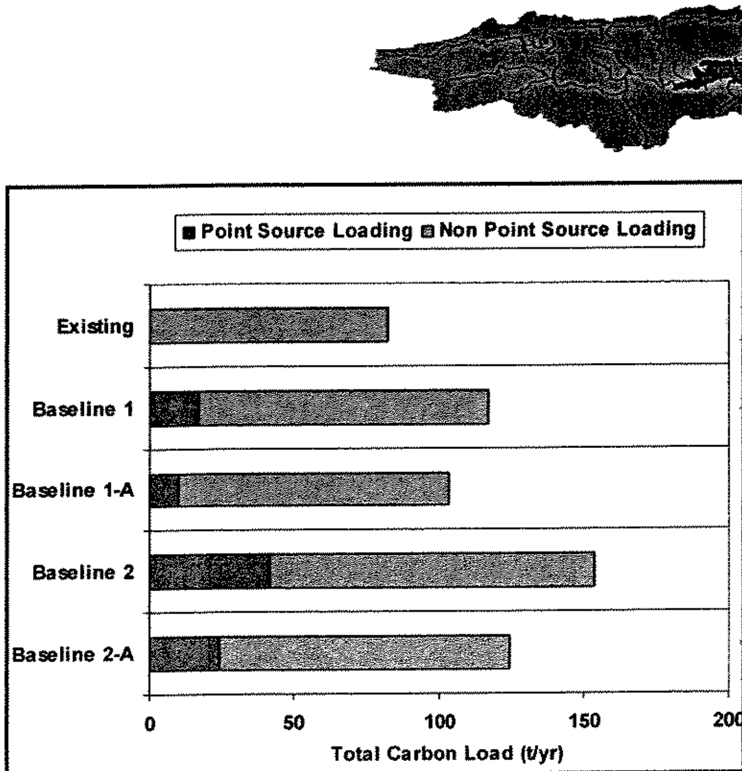
Figure 31. Annual Total Organic Carbon Load from the Upstream Zone Subwatersheds



PERCENT INCREASE OVER EXISTING TOTAL LOAD

Scenario	[illegible]	Non Point Source	Total
Baseline 1	[illegible]	50%	77%
Baseline 2	[illegible]	81%	140%

Figure 32. Annual Total Organic Carbon Load from the Middle Zone Subwatersheds



PERCENT INCREASE OVER EXISTING TOTAL LOAD

Scenario	[illegible]	Non Point Source	Total
Baseline 1	[illegible]	22%	42%
Baseline 1-A	[illegible]	14%	26%
Baseline 2	[illegible]	36%	86%
Baseline 2-A	[illegible]	22%	51%

Figure 33. Annual Total Organic Carbon Load from the Lower Zone Subwatersheds

5.1.5 Fecal Coliform Loads to Lake Maumelle

Fecal coliform loading rates are predicted to increase significantly above existing levels under the Baseline Scenario 1 and 2 assumptions, averaging about 250 and 290 percent, respectively, for the entire watershed.

Table 21 summarizes the fecal coliform loads from nonpoint and point sources in the Lake Maumelle Watershed from each loading zone.

Table 21. Fecal Coliform Load (#/yr) from Nonpoint and Point Sources in the Lake Maumelle Watershed by Zone (areal loading in #/ac/yr in parentheses)

Scenario	Upstream	Middle	Lower	Total
Loads From Nonpoint Sources				
Existing	4.15E+14 (1.45E+13)	1.55E+14 (2.20E+13)	8.10E+13 (2.18E+13)	6.51E+14 (1.65E+13)
Baseline 1	1.00E+15 (3.51E+13)	6.61E+14 (9.39E+13)	2.73E+14 (7.34E+13)	1.94E+15 (4.92E+13)
Baseline 1A	1.00E+15 (3.51E+13)	6.61E+14 (9.39E+13)	1.91E+14 (5.13E+13)	1.85E+15 (4.71E+13)
Baseline 2	1.02E+15 (3.57E+13)	8.95E+14 (1.27E+14)	3.58E+14 (9.64E+13)	2.28E+15 (5.78E+13)
Baseline 2A	1.02E+15 (3.57E+13)	8.95E+14 (1.27E+14)	2.40E+14 (6.44E+13)	2.16E+15 (5.48E+13)
Loads From Point Sources				
Existing	0 (0)	0 (0)	0 (0)	0 (0)
Baseline 1	2.55E+14 (8.93E+12)	6.05E+13 (8.59E+12)	7.88E+12 (2.12E+12)	3.24E+14 (8.22E+12)
Baseline 1A	2.55E+14 (8.93E+12)	6.05E+13 (8.59E+12)	3.04E+12 (8.18E+11)	3.19E+14 (8.10E+12)
Baseline 2	2.52E+14 (8.80E+12)	2.55E+13 (3.63E+12)	3.23E+12 (8.70E+11)	2.81E+14 (7.13E+12)
Baseline 2A	2.52E+14 (8.80E+12)	2.55E+13 (3.63E+12)	1.10E+12 (2.95E+11)	2.79E+14 (7.07E+12)
Total Load				
Existing	4.15E+14 (1.45E+13)	1.55E+14 (2.20E+13)	8.10E+13 (2.18E+13)	6.51E+14 (1.65E+13)
Baseline 1	1.26E+15 (4.40E+13)	7.22E+14 (1.02E+14)	2.81E+14 (7.55E+13)	2.26E+15 (5.74E+13)
Baseline 1A	1.26E+15 (4.40E+13)	7.22E+14 (1.02E+14)	1.94E+14 (5.21E+13)	2.17E+15 (5.52E+13)
Baseline 2	1.27E+15 (4.46E+13)	9.21E+14 (1.31E+14)	3.61E+14 (9.73E+13)	2.56E+15 (6.49E+13)
Baseline 2A	1.27E+15 (4.46E+13)	9.21E+14 (1.31E+14)	2.41E+14 (6.47E+13)	2.44E+15 (6.19E+13)

Figure 34 shows the fecal coliform count to Lake Maumelle for each baseline modeling scenario as well as the percent increase over existing conditions. Figure 35 shows the percent contributions of point and nonpoint sources to the overall increase.

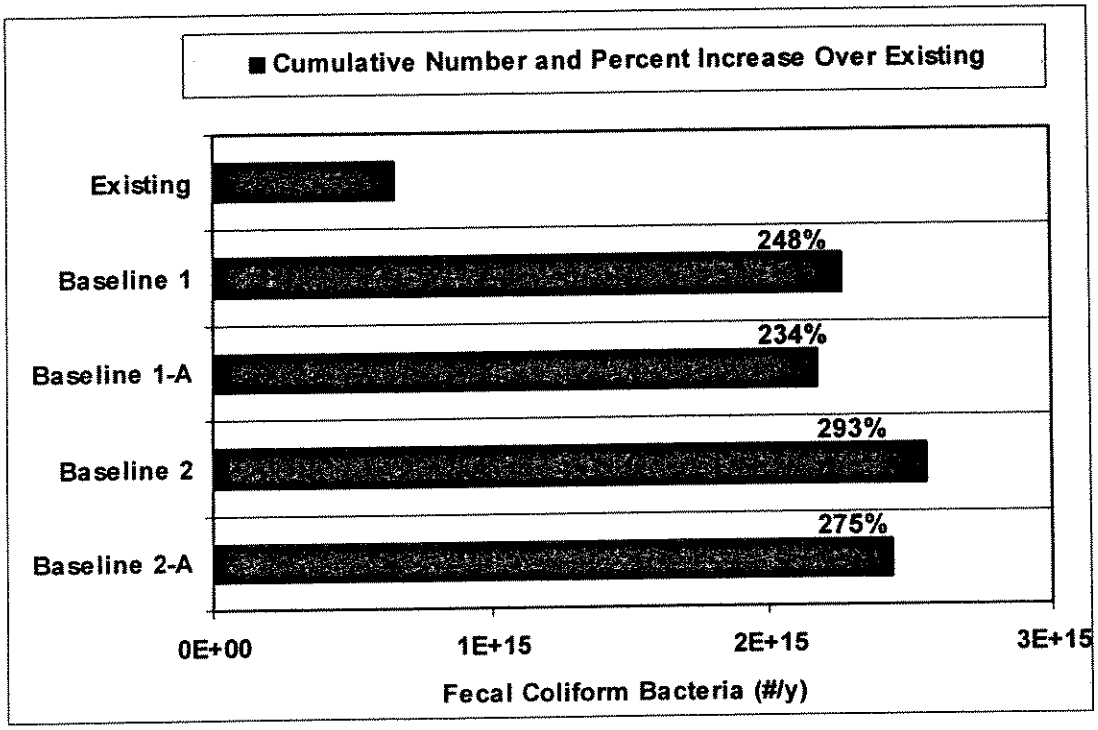


Figure 34. Total Annual Fecal Coliform Load to Lake Maumelle

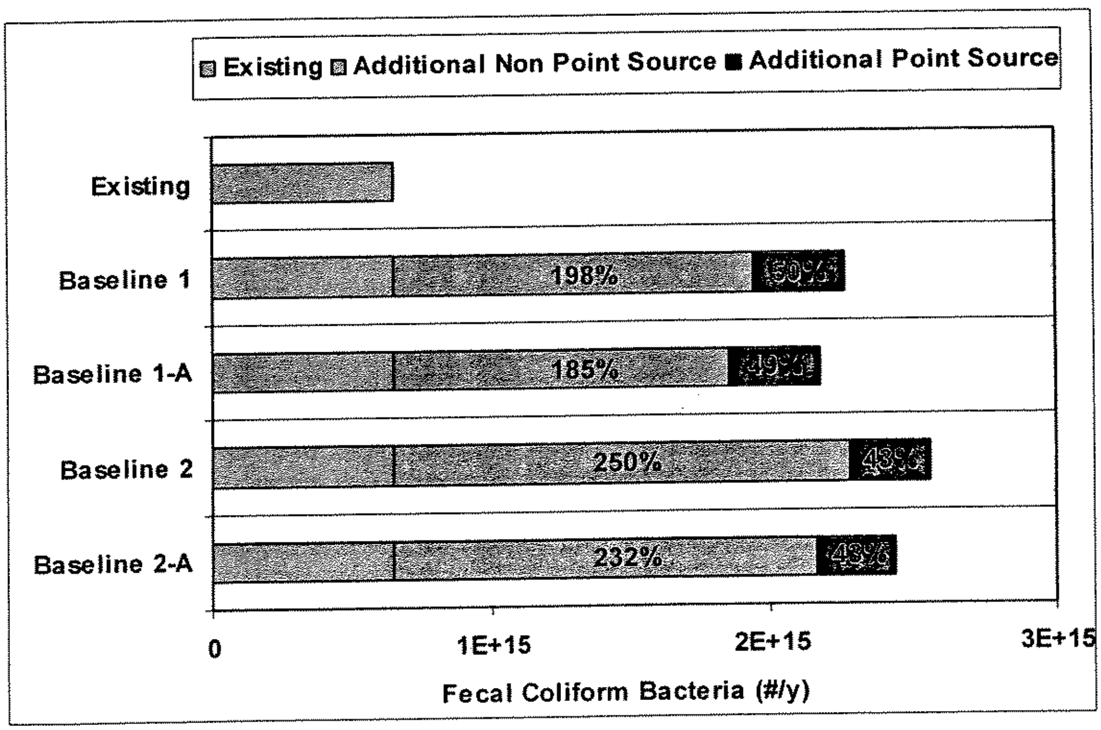
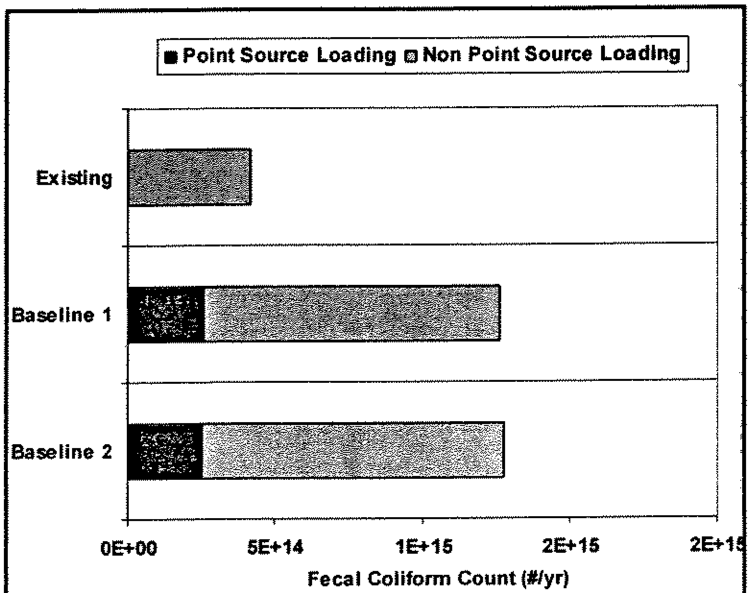


Figure 35. Point and Nonpoint Source Annual Fecal Coliform Load to Lake Maumelle

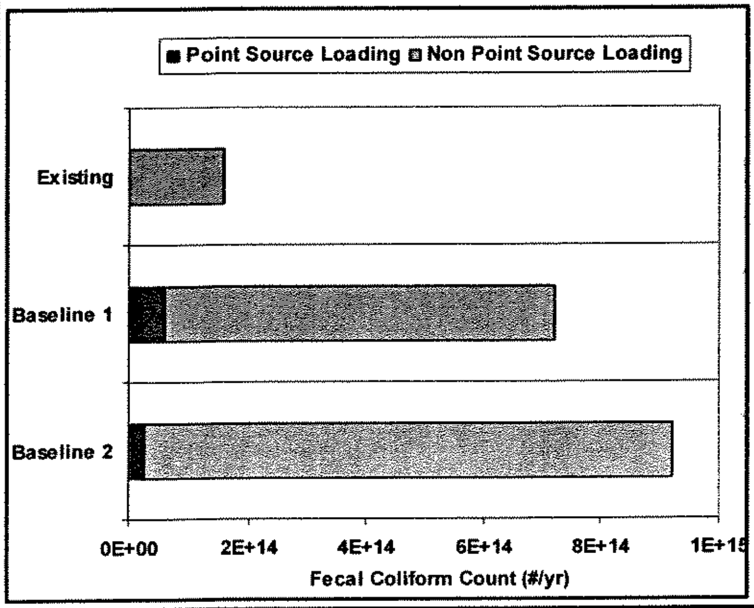
Figure 36 through Figure 38 show the fecal coliform count from each loading zone.



PERCENT INCREASE OVER EXISTING TOTAL LOAD

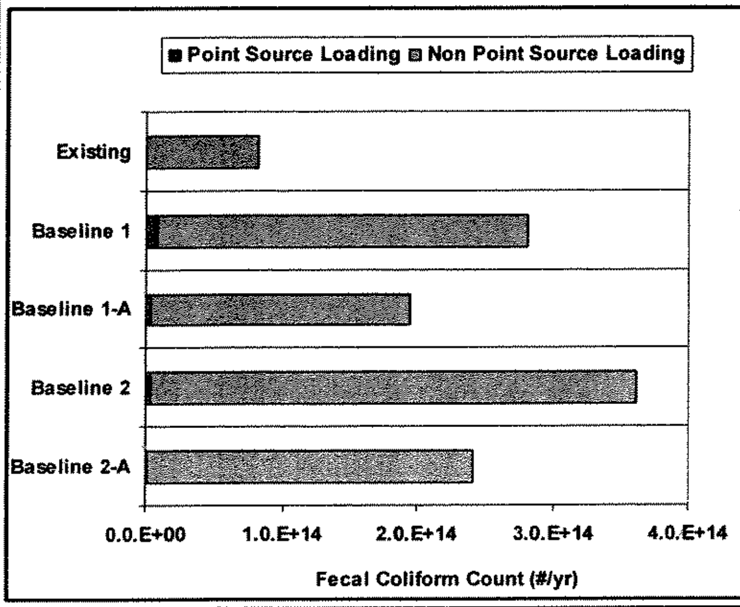
Scenario	Point Source	Non Point Source	Total
Baseline 1	62%	142%	204%
Baseline 2	61%	147%	208%

Figure 36. Annual Fecal Coliform Load from the Upstream Zone Subwatersheds



PERCENT INCREASE OVER EXISTING TOTAL LOAD			
Scenario	Point Source	Non Point Source	Total
Baseline 1	[illegible]	327%	366%
Baseline 2	[illegible]	478%	494%

Figure 37. Annual Fecal Coliform Load from the Middle Zone Subwatersheds



PERCENT INCREASE OVER EXISTING TOTAL LOAD

Scenario	[illegible]	Non Point Source	Total
Baseline 1	[illegible]	237%	247%
Baseline 1-A	[illegible]	136%	140%
Baseline 2	[illegible]	343%	347%
Baseline 2-A	[illegible]	196%	197%

Figure 38. Annual Fecal Coliform Load from the Lower Zone Subwatersheds

5.2 LAKE WATER QUALITY MODEL RESULTS

The period from January 2002 to September 2004 was used for baseline analysis of lake response. This corresponds to the validation period of the model for which model performance is known to accurately reflect existing conditions. To conduct the lake response analysis, the model configurations were updated to reflect the changes in watershed loading, withdrawal rates at the intake, and sediment-water interactions, while all the other external and internal forces and rates were kept identical to the calibrated/validated model.

The baseline simulations used predicted watershed inflows and 2035 monthly withdrawal rates proposed by Central Arkansas Water (average 65 MGD). The modeled water surface elevations of the four scenarios are very close to each other and they all follow a trend similar to the water surface elevations in the existing condition. In general, the modeled elevations are lower than those in the existing condition between June and December. The lowest elevation is around 86.8 m, while the lowest elevation predicted for future scenarios in the existing condition is 87.26 m. The lower elevations in the baseline scenarios are expected because the withdrawal rates in the baseline runs were higher than in the existing condition run.

Under the baseline conditions, the residence times of waters in the lake are slightly reduced in comparison to the existing condition. This is due to the increased withdrawal rates.

No significant differences in the simulated thermal stratification were observed between the baseline scenario and the existing condition. The temperature profiles for the four baseline scenarios are almost identical.

DO in the baseline scenarios follows a trend similar to the existing condition with well-mixed cold weather and strong stratification in warm weather. DO concentrations during stratification in the baseline scenarios are lower than those in the existing condition due to the higher SOD rates caused by higher deposition of organic matter.

5.2.1 Chlorophyll *a* Results

Full year results for chlorophyll *a* are compared to existing conditions in Figure 39 through Figure 41 and Table 22. Figure 42 through Figure 44 and Table 23 provide chlorophyll *a* results for the growing season (May – September) only. Note that in-lake chlorophyll *a* targets (see Table 15) are defined for growing season medians in the mid-lake and lower lake (water intake) zones. All baseline scenario results exceed these targets by substantial amounts. Summer medians in the lower lake zone range from 6.1 μg/L (Scenario 1A) to 10 μg/L (Scenario 2). The predicted maxima under Scenarios 2 and 2A are 25 and 22 μg/L. Concentrations greater than 20 μg/L are generally agreed to represent nuisance bloom conditions (Welch and Jacoby, 2004).

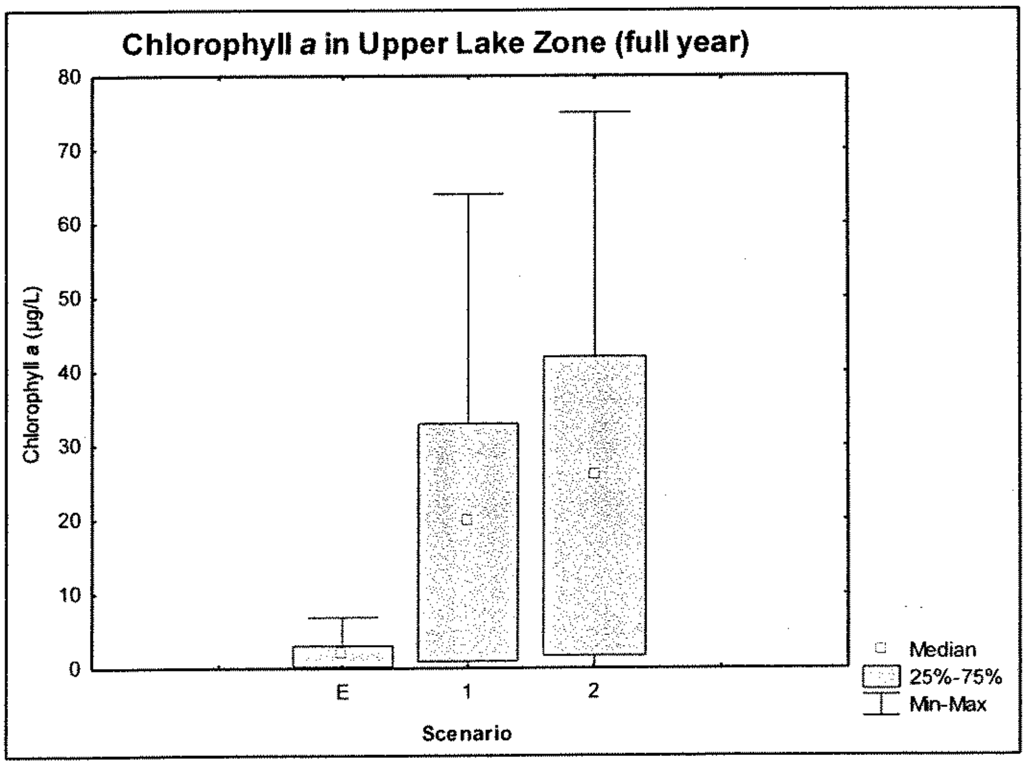


Figure 39. Distribution of Predicted Chlorophyll *a* Concentration for Baseline Scenarios in the Upper Zone of Lake Maumelle

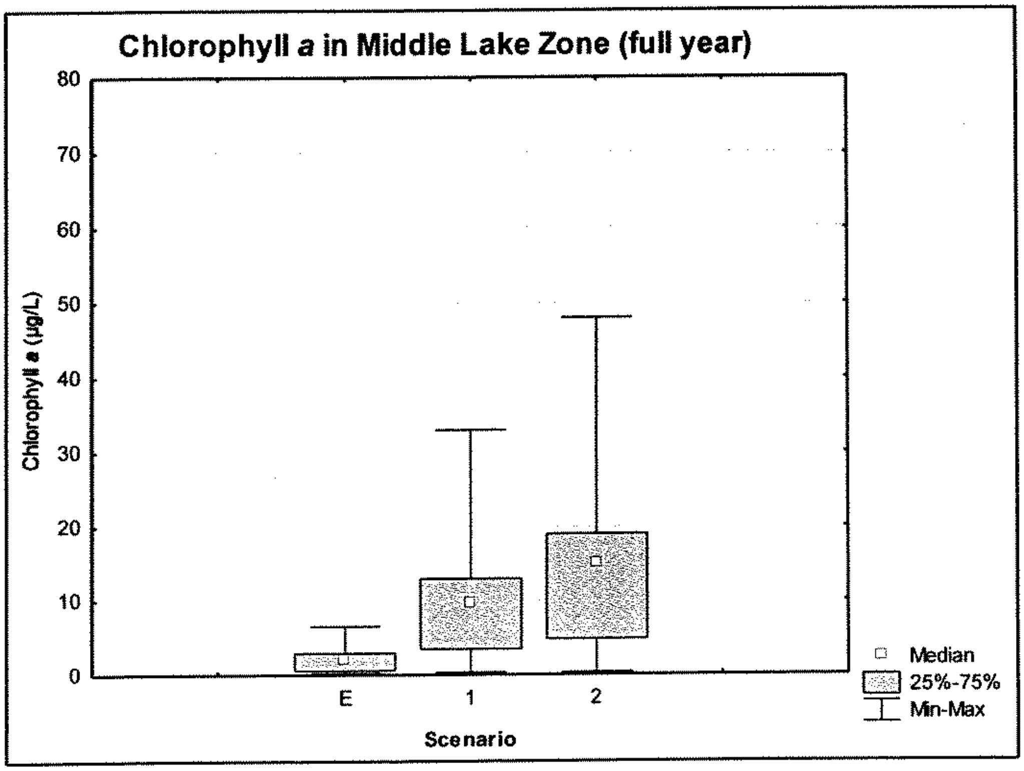


Figure 40. **Distribution of Predicted Chlorophyll *a* Concentration for Baseline Scenarios in the Middle Zone of Lake Maumelle**

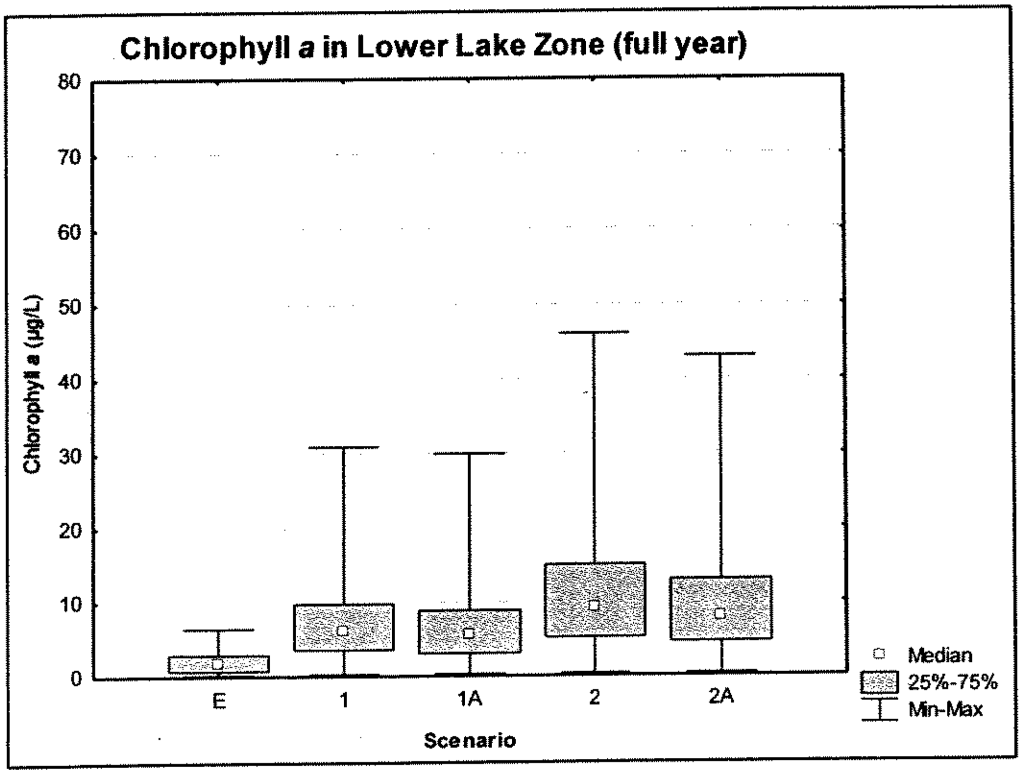


Figure 41. Distribution of Predicted Chlorophyll *a* Concentration for Baseline Scenarios in the Lower Zone of Lake Maumelle

Table 22. Chlorophyll *a* Full-Year Results for Baseline Scenarios

Upper Lake Zone					
Scenario	**Median**	**25 %**	**75 %**	**Minimum**	**Maximum**
E	2	0.25	3.1	0.0013	6.9
1	20	1	33	0	64
2	26	1.7	42	0.000024	75
Middle Lake Zone					
Scenario	**Median**	**25 %**	**75 %**	**Minimum**	**Maximum**
E	2.1	0.63	3	0.24	6.6
1	9.8	3.5	13	0.34	33
2	15	4.8	19	0.35	48
Lower Lake Zone					
Scenario	**Median**	**25 %**	**75 %**	**Minimum**	**Maximum**
E	1.8	0.77	3	0.24	6.5
1	6.2	3.6	9.8	0.33	31
1A	5.6	3.1	8.9	0.33	30
2	9.3	5.2	15	0.34	46
2A	8	4.6	13	0.34	43

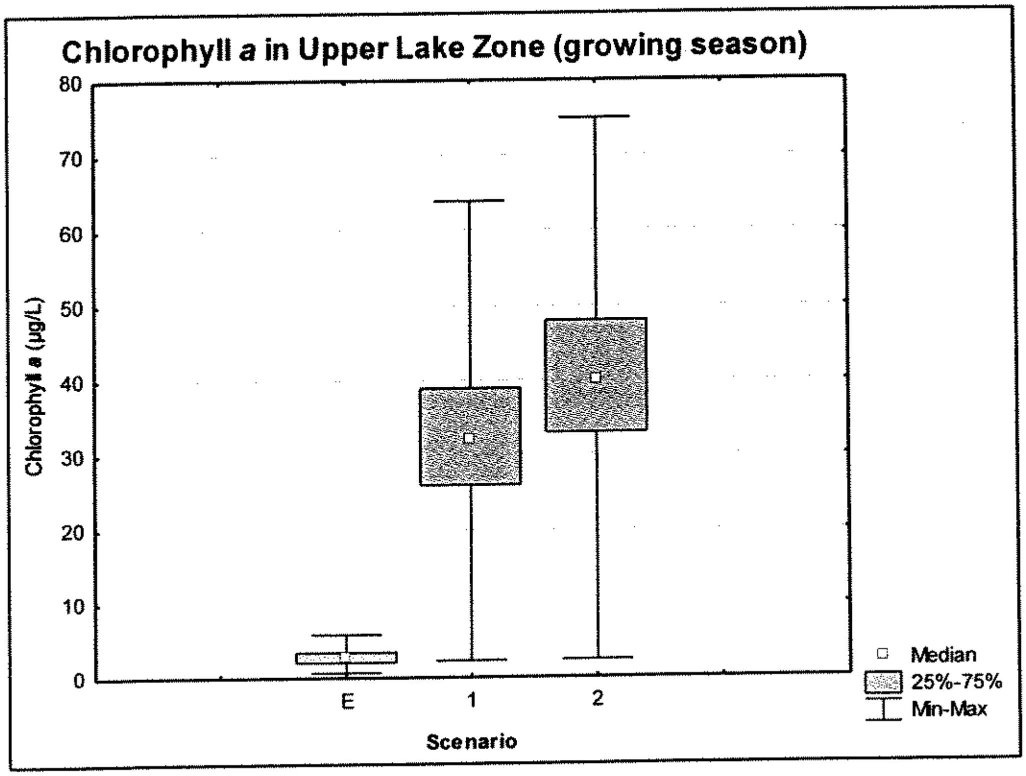


Figure 42. Distribution of Growing-Season Predicted Chlorophyll *a* Concentration for Baseline Scenarios in the Upper Zone of Lake Maumelle

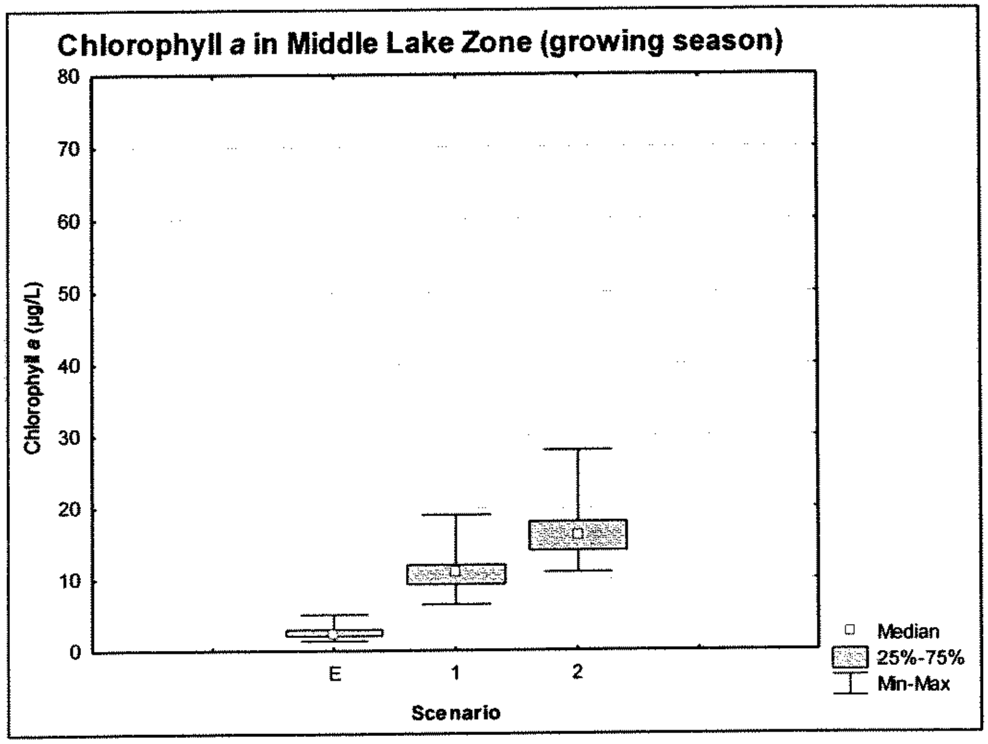


Figure 43. **Distribution of Growing-Season Predicted Chlorophyll *a* Concentration for Baseline Scenarios in the Middle Zone of Lake Maumelle**

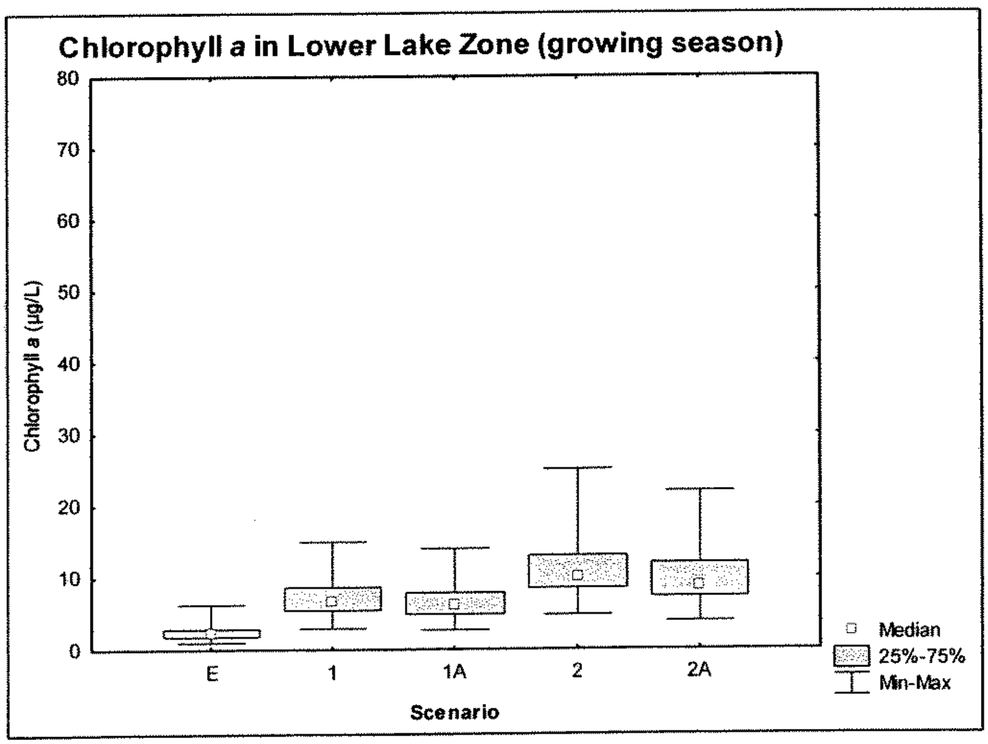


Figure 44. **Distribution of Growing-Season Predicted Chlorophyll *a* Concentration for Baseline Scenarios in the Lower Zone of Lake Maumelle**

Table 23. Chlorophyll a, Summer Growing-Season (May-September) Results for Baseline Scenarios

Chlorophyll *a* (µg/L), Upper Lake Zone					
Scenario	**Median**	**25 %**	**75 %**	**Minimum**	**Maximum**
E	2.7	2.1	3.5	0.72	5.9
1	32	26	39	2.3	64
2	40	33	48	2.4	75
Chlorophyll *a* (µg/L), Middle Lake Zone					
Scenario	**Median**	**25 %**	**75 %**	**Minimum**	**Maximum**
E	2.4	2.1	3	1.4	5.1
1	11	9.3	12	6.5	19
2	16	14	18	11	28
Target	3.5				
Chlorophyll *a* (µg/L), Lower Lake Zone					
Scenario	**Median**	**25 %**	**75 %**	**Minimum**	**Maximum**
E	2.3	1.8	2.9	1	6.3
1	6.7	5.5	8.7	3	15
1A	6.1	4.9	7.9	2.7	14
2	10	8.5	13	4.8	25
2A	8.7	7.3	12	3.9	22
Target	3.0-3.5				

5.2.2 Secchi Depth Results

Secchi depth is used as a surrogate for turbidity and water clarity. The target is less than a 0.2 m decline in annual median Secchi depth in the lower lake zone from existing conditions. For the January 2000 to September 2004 baseline analysis period, the existing median is 2.8, so the target is 2.6 m or greater. Baseline analysis results are shown in Figure 45 through Figure 47 and Table 24. None of the baseline scenarios is predicted to achieve the target.

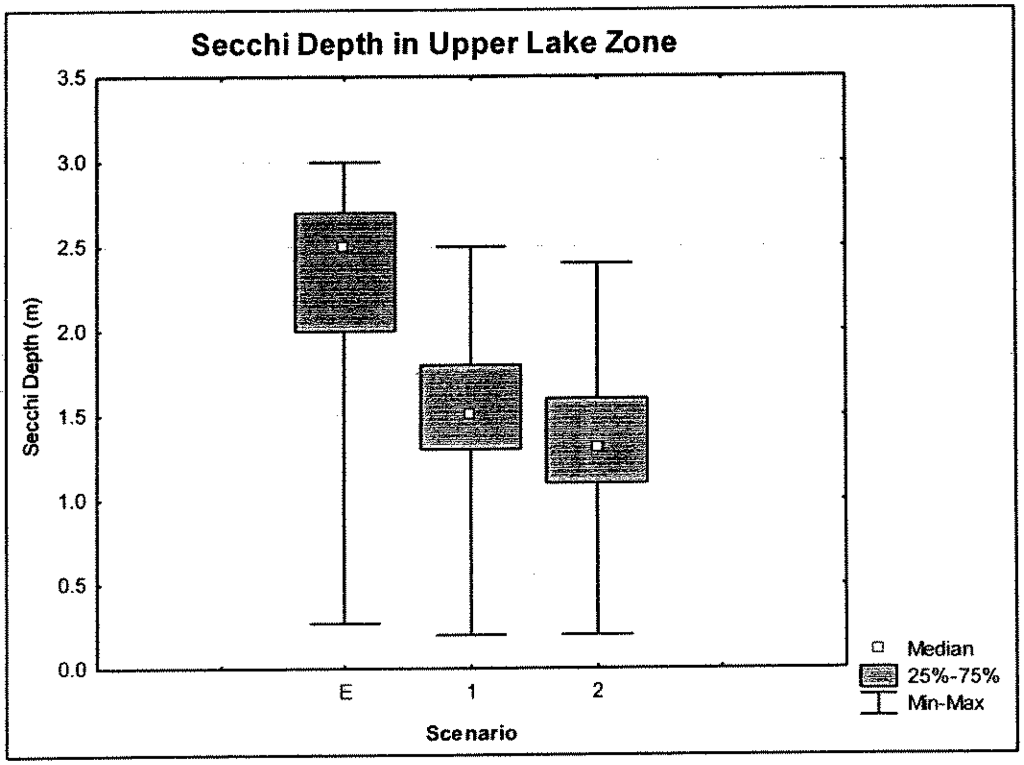


Figure 45. Distribution of Predicted Secchi Depth for Baseline Scenarios in the Upper Zone of Lake Maumelle

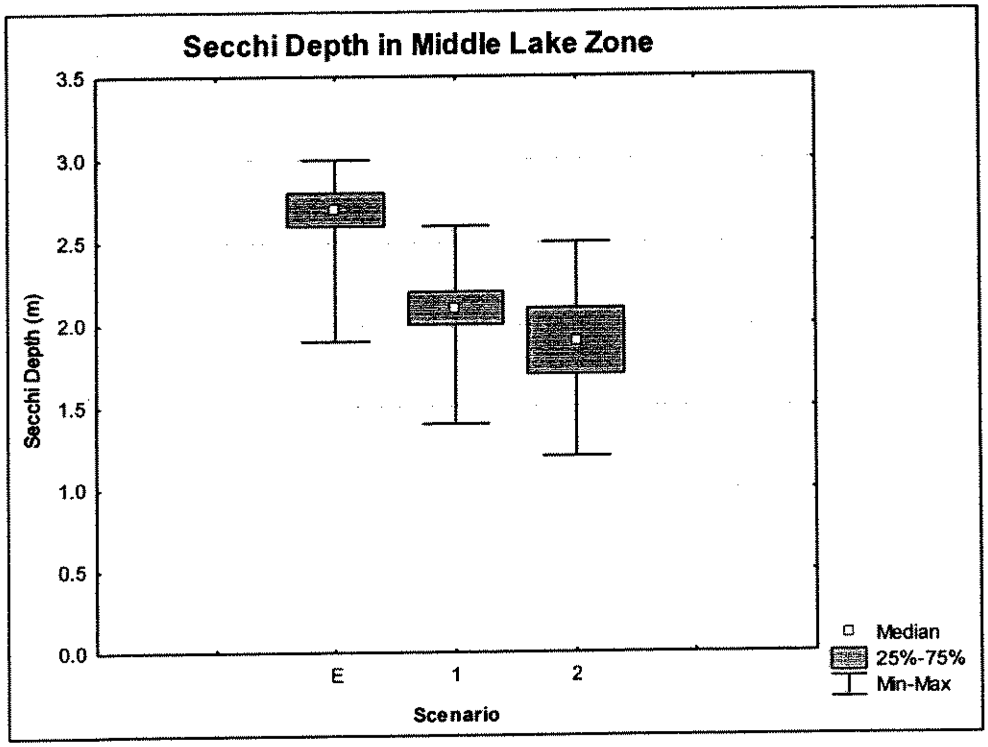


Figure 46. **Distribution of Predicted Secchi Depth for Baseline Scenarios in the Middle Zone of Lake Maumelle**

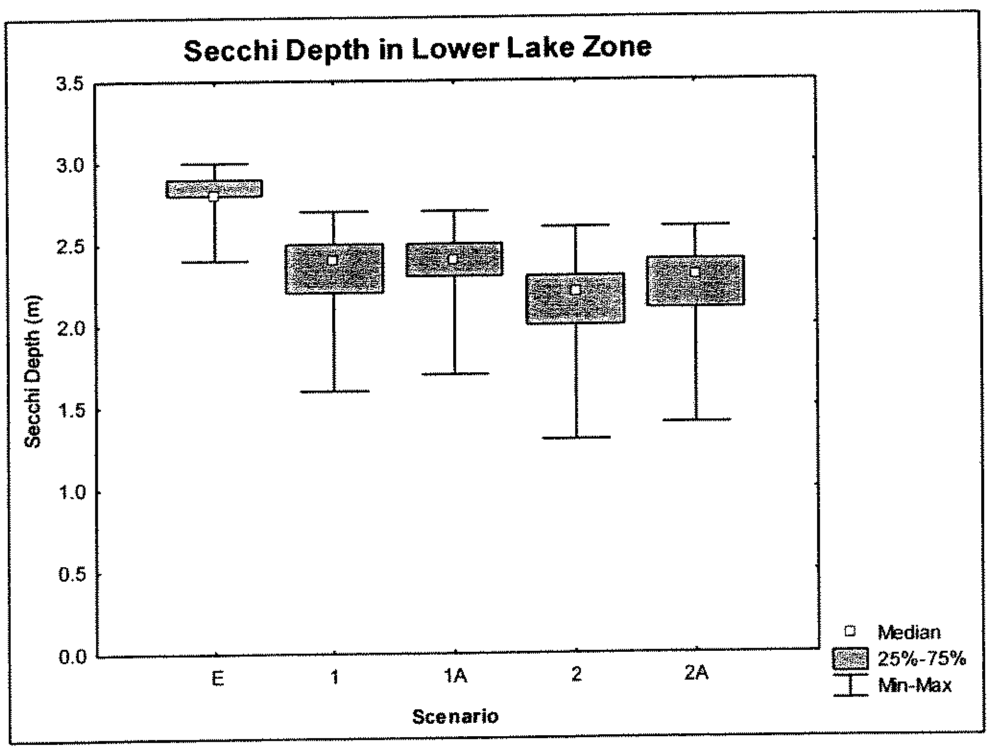


Figure 47. **Distribution of Predicted Secchi Depth for Baseline Scenarios in the Lower Zone of Lake Maumelle**

Table 24. Secchi Depth Results for Baseline Scenarios

Secchi Depth (m), Upper Lake Zone					
Scenario	**Median**	**25 %**	**75 %**	**Minimum**	**Maximum**
E	2.5	2	2.7	0.27	3
1	1.5	1.3	1.8	0.2	2.5
2	1.3	1.1	1.6	0.2	2.4
Secchi Depth (m), Middle Lake Zone					
Scenario	**Median**	**25 %**	**75 %**	**Minimum**	**Maximum**
E	2.7	2.6	2.8	1.9	3
1	2.1	2	2.2	1.4	2.6
2	1.9	1.7	2.1	1.2	2.5
Secchi Depth (m), Lower Lake Zone					
Scenario	**Median**	**25 %**	**75 %**	**Minimum**	**Maximum**
E	2.8	2.8	2.9	2.4	3
1	2.4	2.2	2.5	1.6	2.7
1A	2.4	2.3	2.5	1.7	2.7
2	2.2	2	2.3	1.3	2.6
2A	2.3	2.1	2.4	1.4	2.6
Target	≥ 2.6				

5.2.3 Total Organic Carbon Results

Total organic carbon (TOC) results are summarized in Figure 48 through Figure 50 and Table 25. Changes in TOC are expected to be less dramatic under development than some other parameters because a significant TOC load is generated by native forest cover. The target for TOC is to remain as close as possible to the modeled 1997-2004 median of 2.4 mg/L and keep the median ≤ 3.1 mg/L in the lower lake zone. This is necessary to reduce the risk of formation of harmful disinfection byproducts in the treatment system. All baseline scenarios are predicted to exceed the 3.1 mg/L criterion, being between 0.2 and 0.7 mg/L above the target.

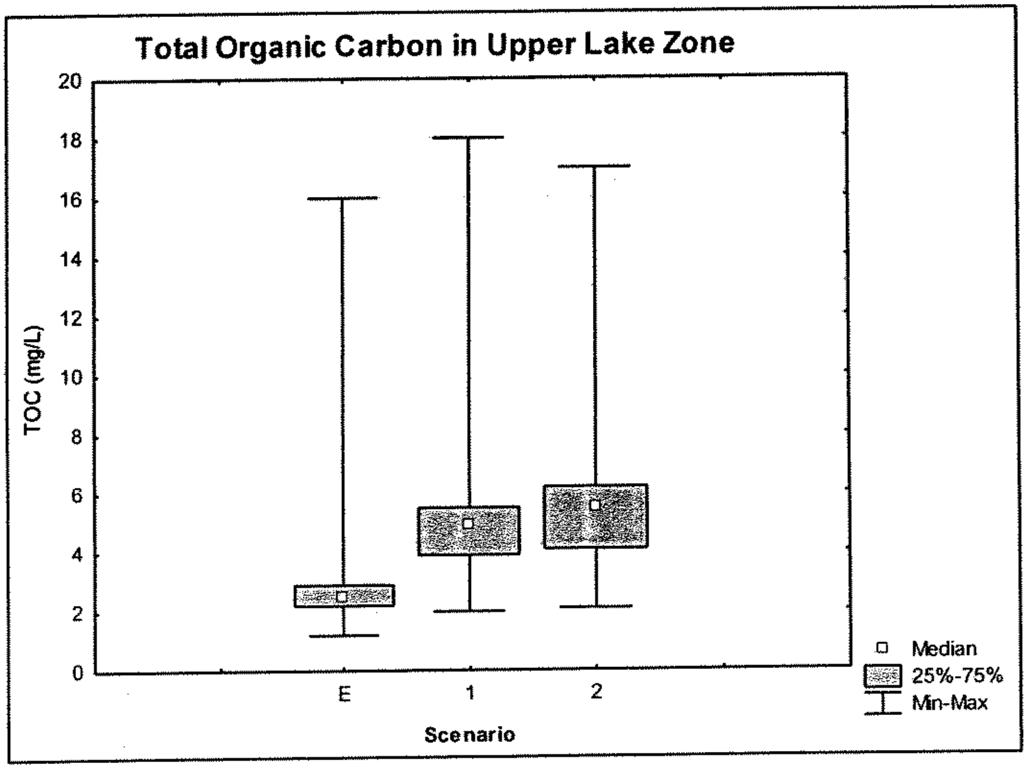


Figure 48. Distribution of Predicted Total Organic Carbon Concentration for Baseline Scenarios in the Upper Zone of Lake Maumelle

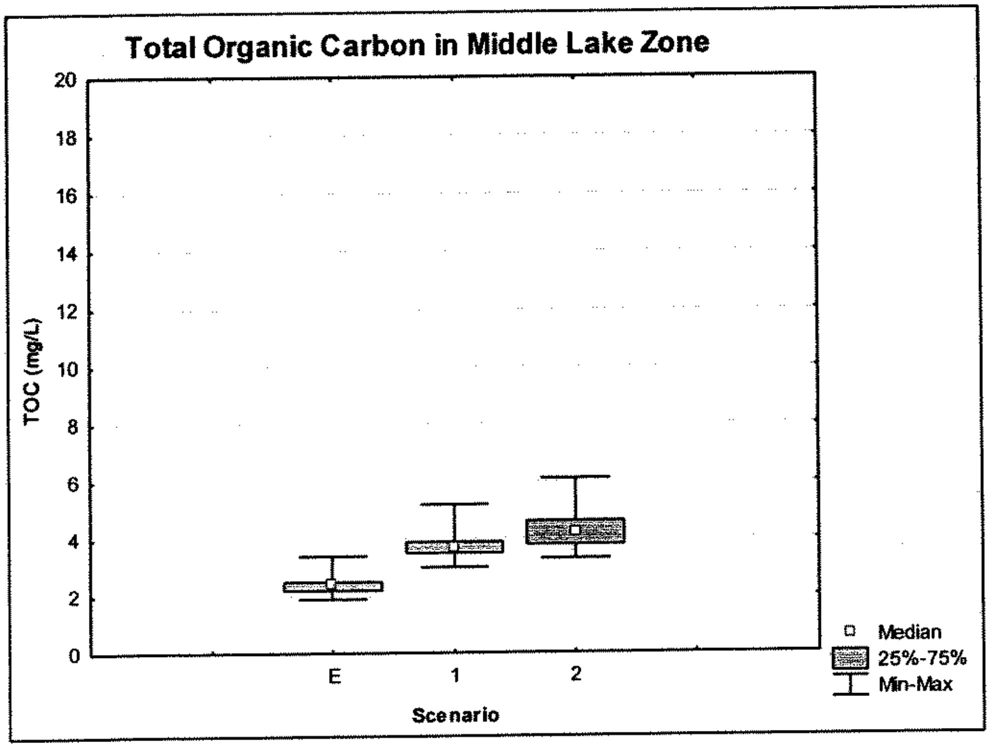


Figure 49. Distribution of Predicted Total Organic Carbon Concentration for Baseline Scenarios in the Middle Zone of Lake Maumelle

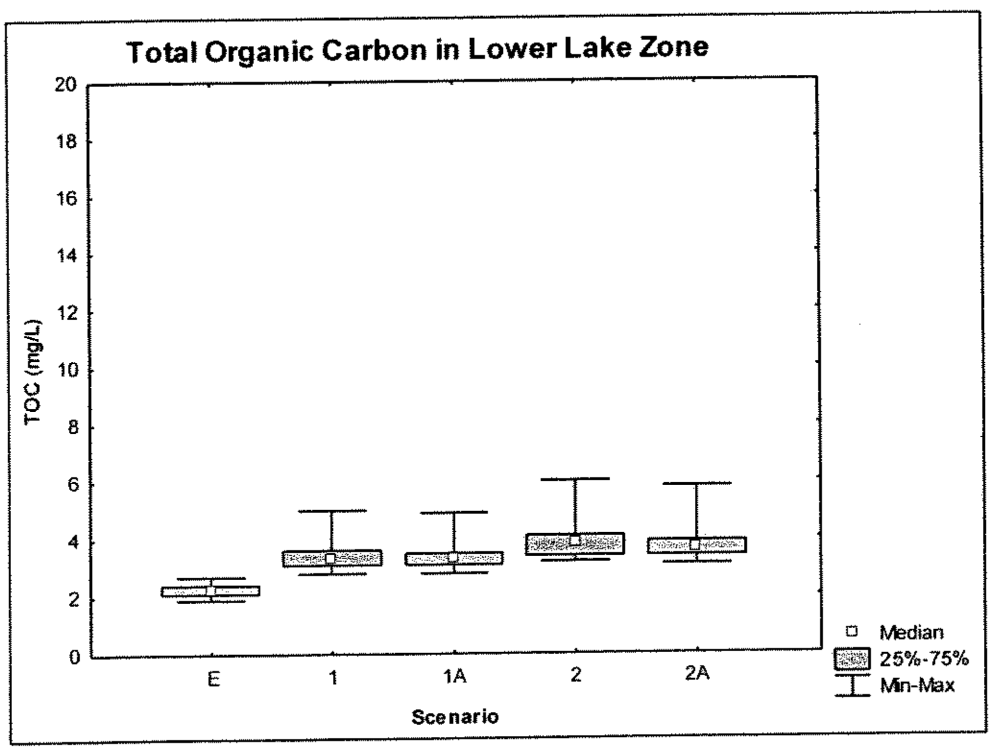


Figure 50. Distribution of Predicted Total Organic Carbon Concentration for Baseline Scenarios in the Lower Zone of Lake Maumelle

Table 25. Total Organic Carbon Results for Baseline Scenarios

Total Organic Carbon (mg/L), Upper Lake Zone					
Scenario	**Median**	**25 %**	**75 %**	**Minimum**	**Maximum**
E	2.5	2.2	2.9	1.2	16
1	4.9	3.9	5.5	2	18
2	5.5	4.1	6.2	2.1	17
Total Organic Carbon (mg/L), Middle Lake Zone					
Scenario	**Median**	**25 %**	**75 %**	**Minimum**	**Maximum**
E	2.4	2.2	2.5	1.9	3.4
1	3.7	3.5	3.9	3	5.2
2	4.2	3.8	4.6	3.3	6.1
Total Organic Carbon (mg/L), Lower Lake Zone					
Scenario	**Median**	**25 %**	**75 %**	**Minimum**	**Maximum**
E	2.2	2.1	2.4	1.9	2.7
1	3.3	3.1	3.6	2.8	5
1A	3.3	3.1	3.5	2.8	4.9
2	3.8	3.4	4.1	3.2	6
2A	3.6	3.4	3.9	3.1	5.8
Target	3.1				

5.2.4 Fecal Coliform Bacteria Results

In the lake, fecal coliform bacteria are used primarily as an indicator of potential risk from more resistant protozoan pathogens. The target is that increases in the annual median should be less than one order of magnitude in the lower lake zone (less than a factor of 10 increase from existing low levels). Results are shown in Figure 51 through Figure 53 and Table 26. All baseline scenarios meet this target, with the best results obtained for the two scenarios (1A and 2A) in which developable land within CAW Zone 1 is purchased by the utility.

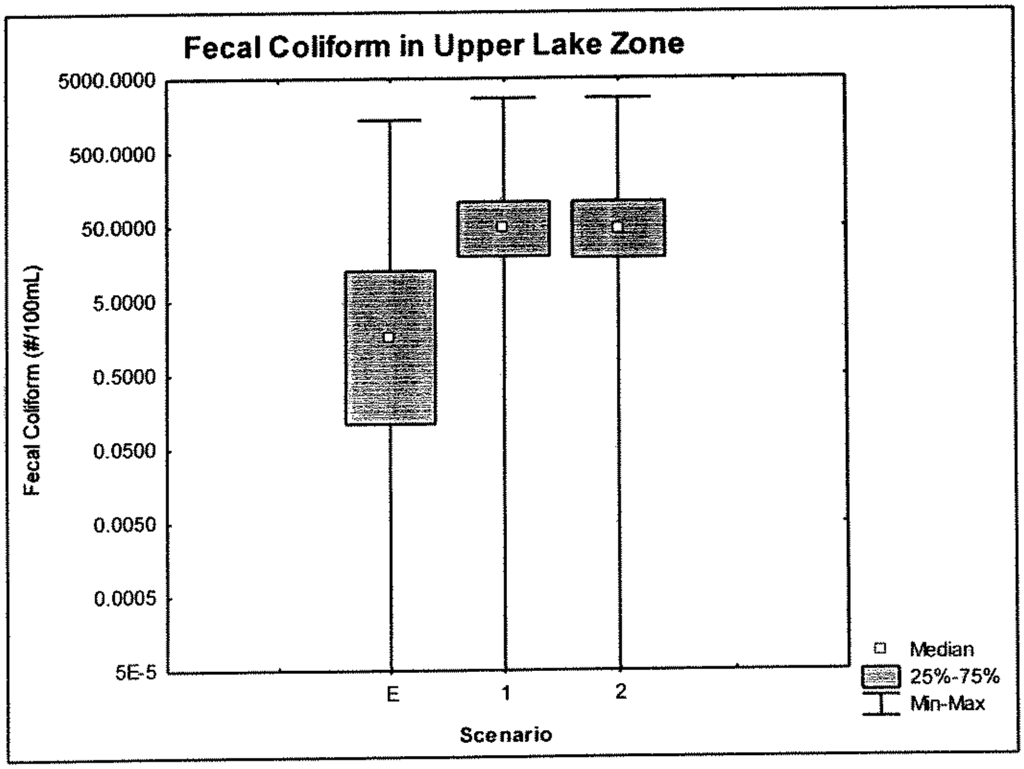


Figure 51. **Distribution of Predicted Fecal Coliform Concentration for Baseline Scenarios in the Upper Zone of Lake Maumelle**

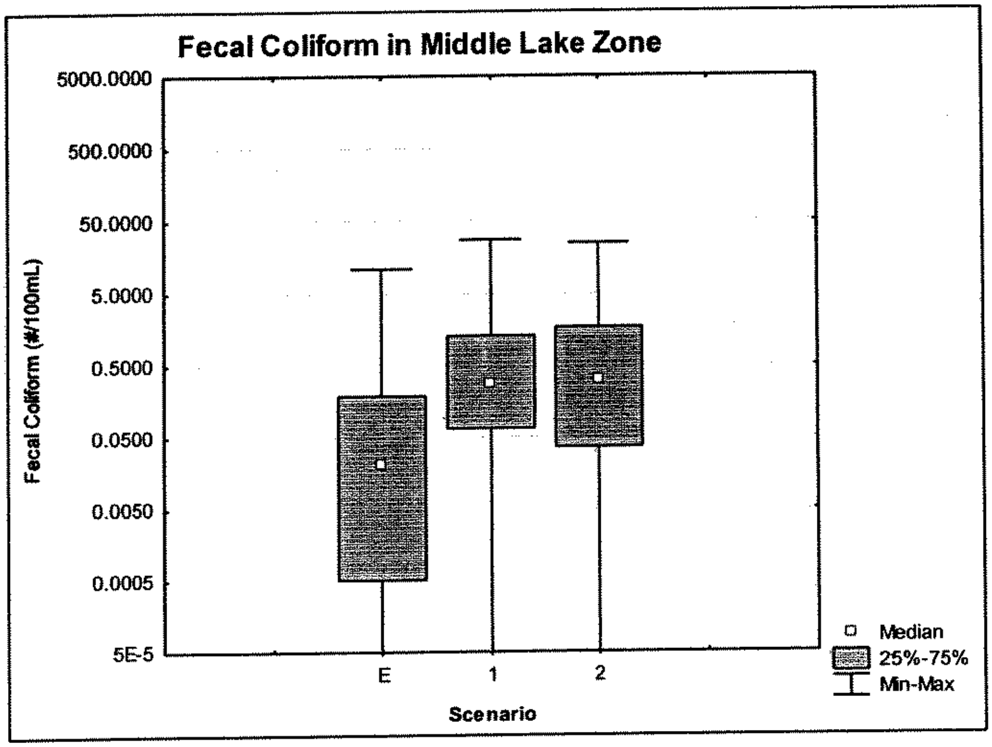


Figure 52. Distribution of Predicted Fecal Coliform Concentration for Baseline Scenarios in the Middle Zone of Lake Maumelle

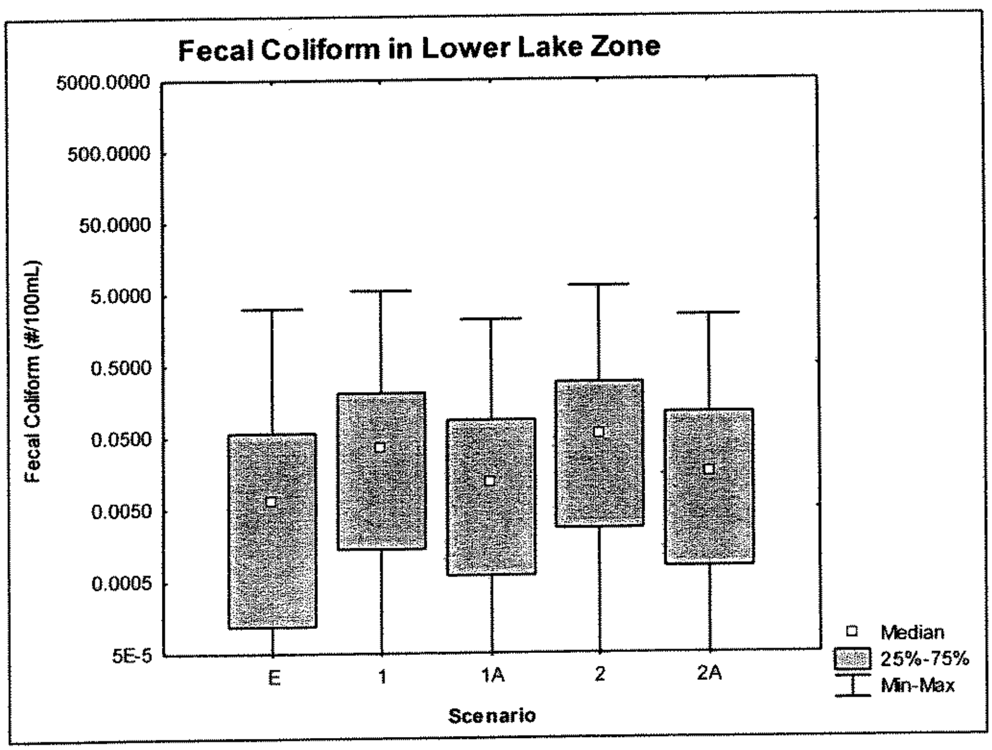


Figure 53. Distribution of Predicted Fecal Coliform Concentration for Baseline Scenarios in the Lower Zone of Lake Maumelle

Table 26. Fecal Coliform Bacteria Results for Baseline Scenarios

Fecal Coliform (#/100mL), Upper Lake Zone					
Scenario	**Median**	**25 %**	**75 %**	**Minimum**	**Maximum**
E	1.6	0.11	13	0	1400
1	48	20	110	0	2700
2	46	19	110	0	2700
Fecal Coliform (#/100mL), Lower Lake Zone					
Scenario	**Median**	**25 %**	**75 %**	**Minimum**	**Maximum**
E	0.021	0.00052	0.19	0	11
1	0.28	0.068	1.3	0	28
2	0.32	0.037	1.7	0	25
Fecal Coliform (#/100mL), Lower Lake Zone					
Scenario	**Median**	**25 %**	**75 %**	**Minimum**	**Maximum**
E	0.0065	0.00012	0.058	0	3.2
1	0.035	0.0014	0.21	0	5.6
1A	0.012	0.0006	0.087	0	2.2
2	0.054	0.0027	0.29	0	6.4
2A	0.016	0.00079	0.11	0	2.5
Target	0.065				

5.3 Time-of-Travel Analysis Results

In addition to understanding the response of the lake to potential unmanaged buildout contaminant loads, it is informative to examine relative travel time of pollutant loads through the watershed. Areas with shorter travel time to the intake present a greater potential risk to the water supply because response time will be short and the opportunity for dilution and decay of a contaminant spill will be reduced. Thus, areas with shorter travel times should be subject to more stringent management to prevent introduction of contaminants into the water supply. To estimate total travel time to the water supply intake, Tetra Tech linked results of models for the three components of travel: overland, instream, and inlake. The approach examines conditions that present a higher level of risk: rapid runoff from the watershed, which decreases loading time, coupled with lake levels a little below full pool, so that the load is not washed over the dam. These are conditions that might arise in response to a summer thunderstorm mobilizing a contaminant spill.

Overland time-of-travel (including small tributary travel time through small and ephemeral channels not explicitly represented in the HSPF model) was estimated using the GBMM model, a grid-based model that uses TR55 and Manning's equation to calculate travel time. The 2-year 24-hour rainstorm was used to drive the overland and small tributary travel time analysis. A stream segment travel time grid was then generated by assigning each subbasin the travel time obtained from the corresponding HSPF reach to the lake boundary using the 95th percentile of average daily velocities simulated in HSPF from 10/1/96 to 9/30/04. Lake travel times were estimated using the EFDC three-dimensional model and a conservative tracer from the inflow point to the lake for each tributary reach. Preliminary results reflect an assumption of a 90 MGD water supply withdrawal. An additional analysis is being conducted at a withdrawal rate of 180 MGD to test the sensitivity of the travel time estimates to the theoretical maximum of planned pump capacity.

Four sets of individual travel time grids were generated: (1) the overland travel time grid, (2) the tributary travel time grid, (3) the mainstem travel time grid, (4) the lake travel time grid, and (5) the total travel time grid. The total travel time grid was generated by combining the first four types of result grids.

5.3.1 Overland Travel Time Grid

The overland flow travel time grid for a 2-year 24-hour rainstorm was generated by calculating sheet flow travel time (Section 2.2.1) from each land cell to the nearest NHD stream cell, HSPF stream segment cell, or the lake boundary cell along the flow path (Figure 54). The travel times for tributary cells, HSPF stream segment cells, and the lake cells are set to zero in this grid.

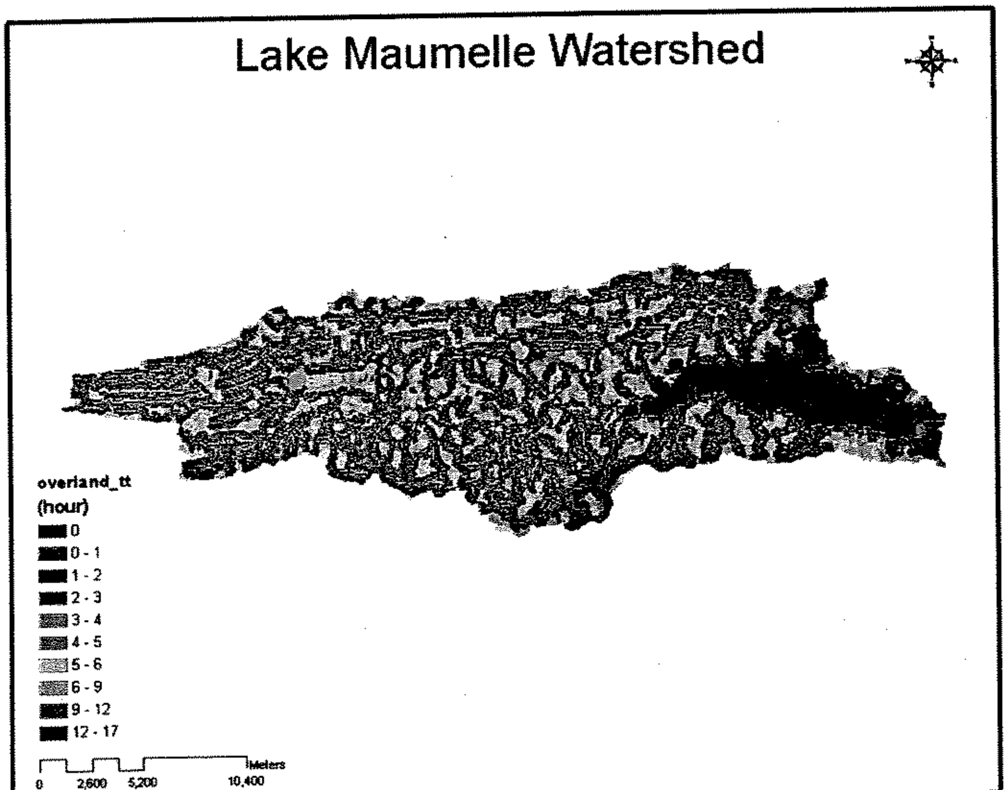


Figure 54. Overland Travel Time Grid for the Lake Maumelle Watershed

The overland flow travel time ranges from 0 to 17 hours depending on the surface roughness, slope, and distance to the nearest waterbody. The flow travel time is longer when the land roughness is higher and slopes are smaller. The average travel time overland is 2.6 hours for the Lake Maumelle watershed. An additional scenario of the overland travel with a 2-year 24-hour rainstorm (4-inches of rain) was also simulated. The overland flow travel time ranges from 0 - 12 hours with an average of 1.4 hours.

5.3.2 Small Tributary Travel Time Grid

The small tributary travel time grid was generated by calculating flow travel time (Section 2.2.2) from each NHD tributary cell to the nearest HSPF stream segment cell or the lake boundary cell along the flow path (Figure 55). The subwatershed of each corresponding tributary is represented with the same travel time as the tributary. The travel times for the land cells, HSPF stream segment cells, and the lake cells are set to zero in this grid.

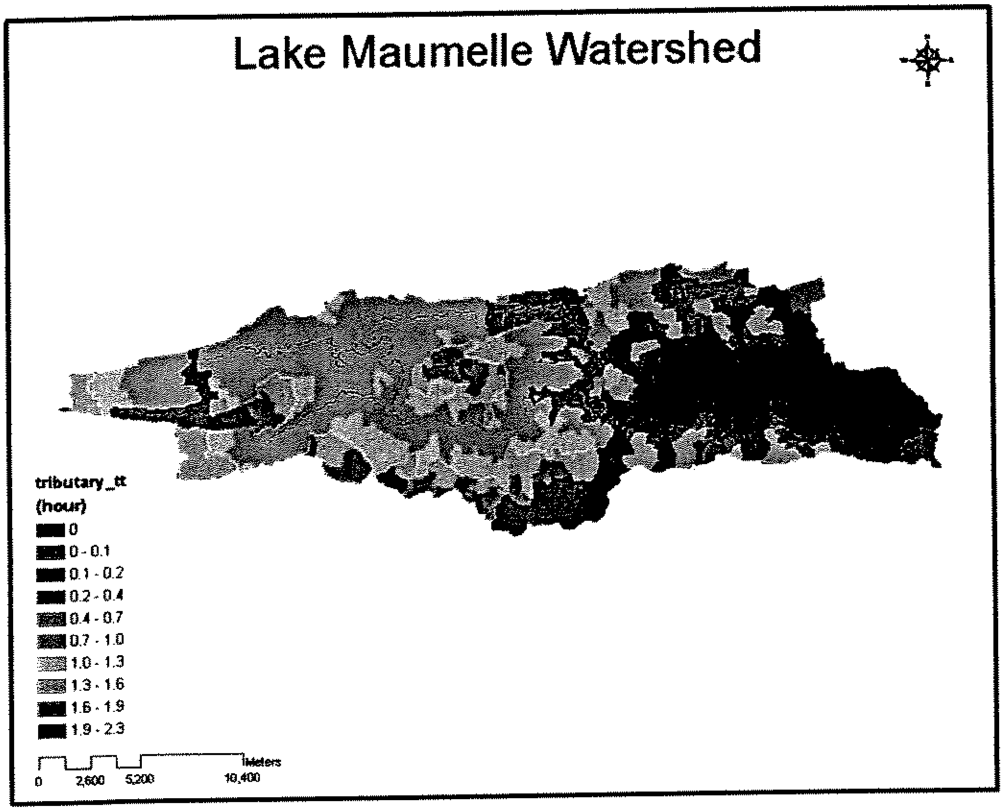


Figure 55. Tributary Travel Time Grid for the Lake Maumelle Watershed

The small tributary travel time ranges from 0-2.3 hours depending on the channel roughness, slope, and distance to the nearest HSPF stream reach. The average travel time in small tributaries is 0.65 hour in the Lake Maumelle watershed.

5.3.3 HSPF Stream Segment Travel Time Grid

Larger streams and the Maumelle River mainstem are explicitly represented in the HSPF model. The HSPF stream segment travel time grid was generated by calculating the 95th percentile of the average flow travel time (Section 2.2.3) from each main stream to the nearest lake boundary along the flow path (Figure 56). The subwatershed of each corresponding HSPF stream segment is represented with the same travel time as the mainstem. The travel times for the land cells, tributary cells, and the lake cells are set to zero in this grid.

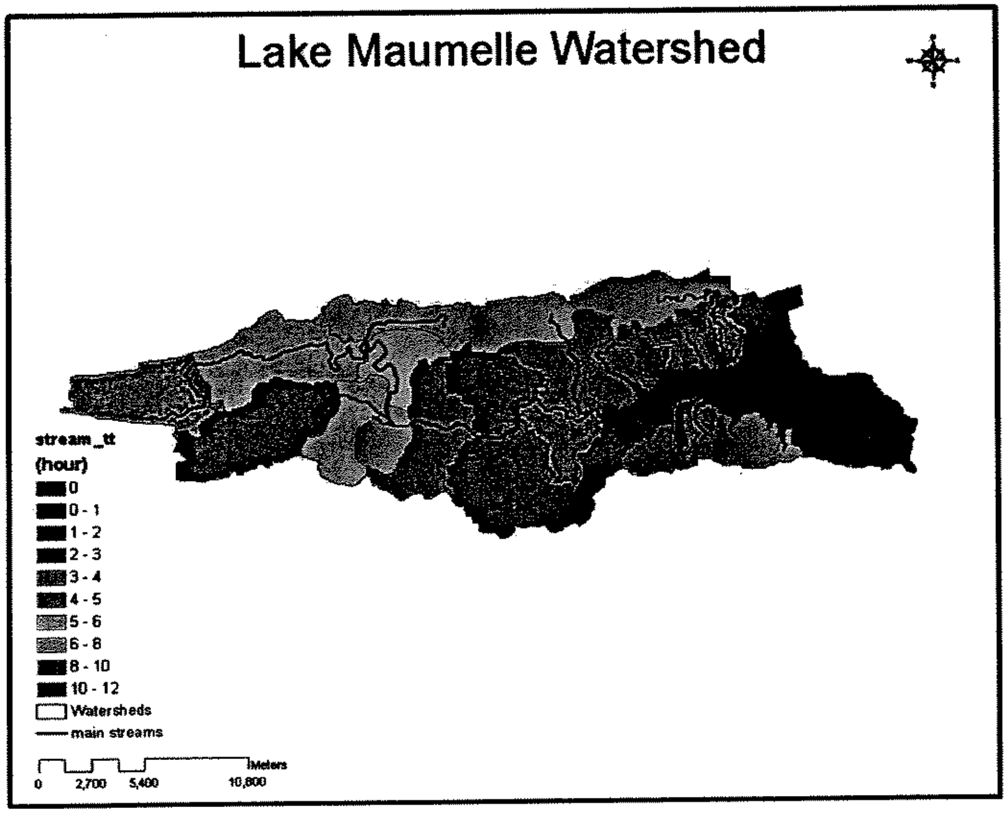


Figure 56. HSPF Stream Segment Travel Time Grid for the Lake Maumelle Watershed

The travel time through the HSPF stream segments ranges from 0 to 12 hours depending on distance to the lake.

5.3.4 Lake Travel Time Grid

The lake travel time grid was generated by calculating flow travel time (Section 2.2.4) from the lake cells with tracers to the intake point in the lake for the 90 MGD withdrawal scenario (Figure 57) and the 180 MGD withdrawal scenario (Figure 58). For each figure, the grid map on the top shows the lake travel time in the context of the entire watershed. The grid map at the bottom shows the flow travel time of the lake. The travel times for the land cells, tributary cells, and the mainstem cells are set to zero for these maps.

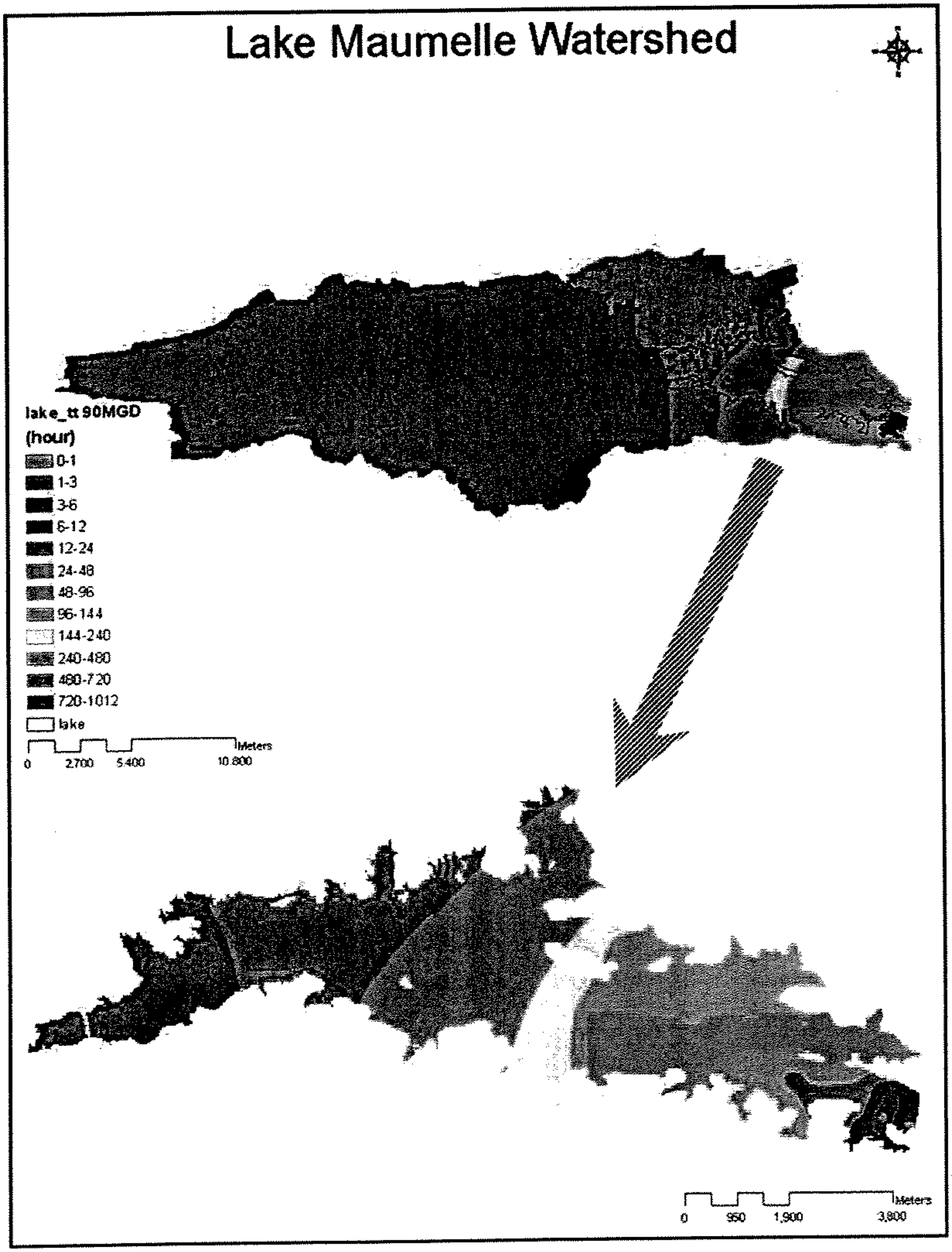


Figure 57. Lake Travel Time Grid for the 90 MGD Withdrawal Scenario

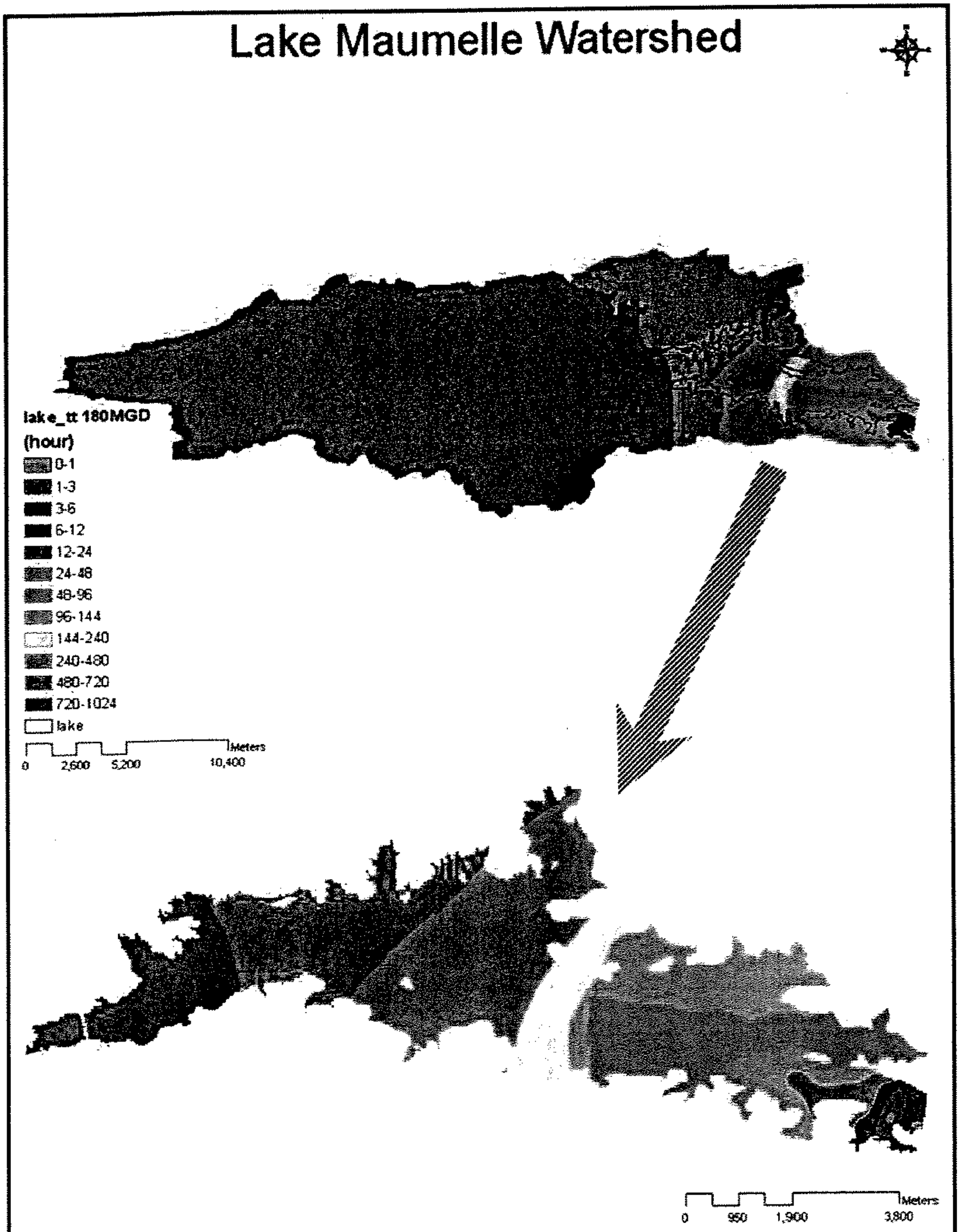


Figure 58. Lake Travel Time Grid for the 180 MGD Withdrawal Scenario

The travel time differences between the 90 MGD and 180 MGD scenarios were determined to evaluate the impact of increasing the withdrawal rate at the intake. In general, the flow travel time differences between the 90 MGD and 180 MGD scenarios were not significant due to the dominant wind impact on lake flow velocity.

For the 90 MGD withdrawal scenario, the shortest tracer travel time to the intake was about 1.3 hours from the cells near the intake. For the 180 MGD withdrawal scenario, the shortest travel time was about 1.0 hour. The longest tracer travel time to the intake was about the same (1012-1024 hours, or about 42 days) from the cells in the upper lake for both the scenarios.

Two major forces drive the movement of water in the lake: wind and water withdrawal. In Lake Maumelle, wind seems to be the dominating force based on a numerical test that compared the flow velocities with and without the wind factor. The water withdrawal causes the water surface elevation to decrease and water to move due to the surface elevation differences. Although the withdrawal might cause a strong current near the intake facility, its impact extent was limited and only affected the flow travel time in few cells near the intake. Overall, the velocity increase caused by the withdrawal was not significant.

The lake travel times in both the 90 MGD and 180 MGD scenarios were significantly longer than those on the land and in the streams in the watershed, largely because the velocities of flow were much lower in the lake (average 3-4 cm/s) than those on the land and in the streams.

5.3.5 Total Travel Time Grid

The total travel time grid was generated by adding together the four separate travel time grids, i.e., overland grid, NHD tributary grid, HSPF stream segment grid, and the lake grid for the 90 MGD scenario (Figure 59) and the 180 MGD scenario (Figure 60), respectively.

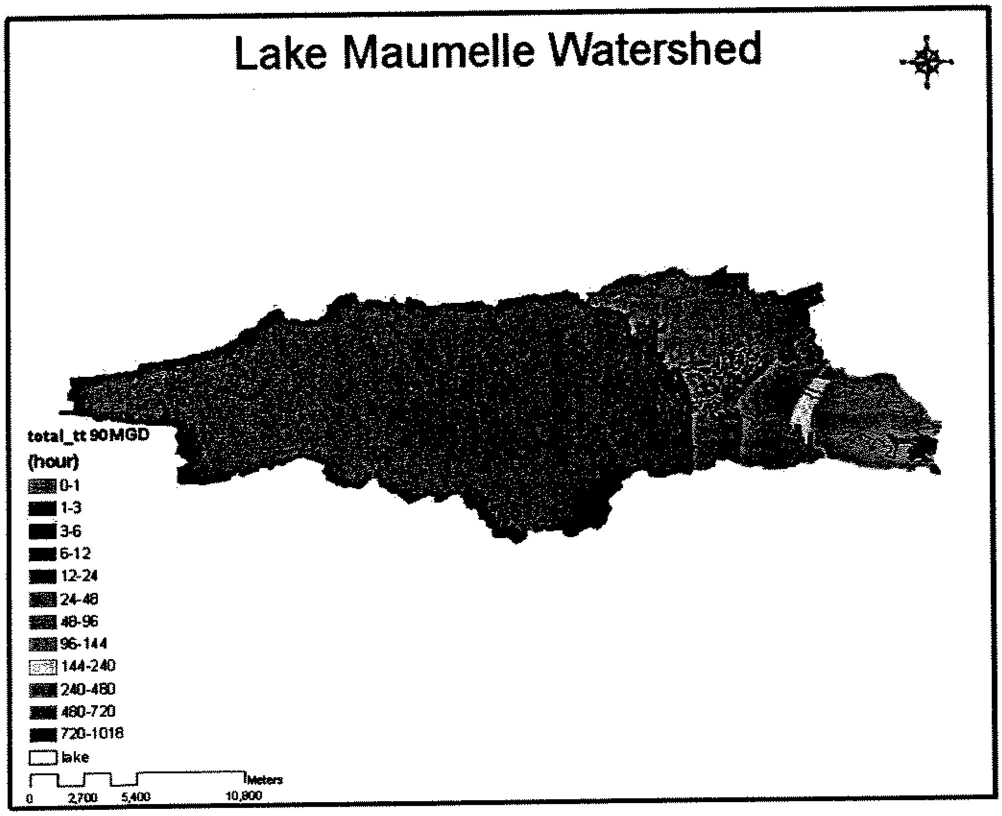


Figure 59. Total Travel Time Grid of the Lake Maumelle Watershed for the 90 MGD Withdrawal Scenario

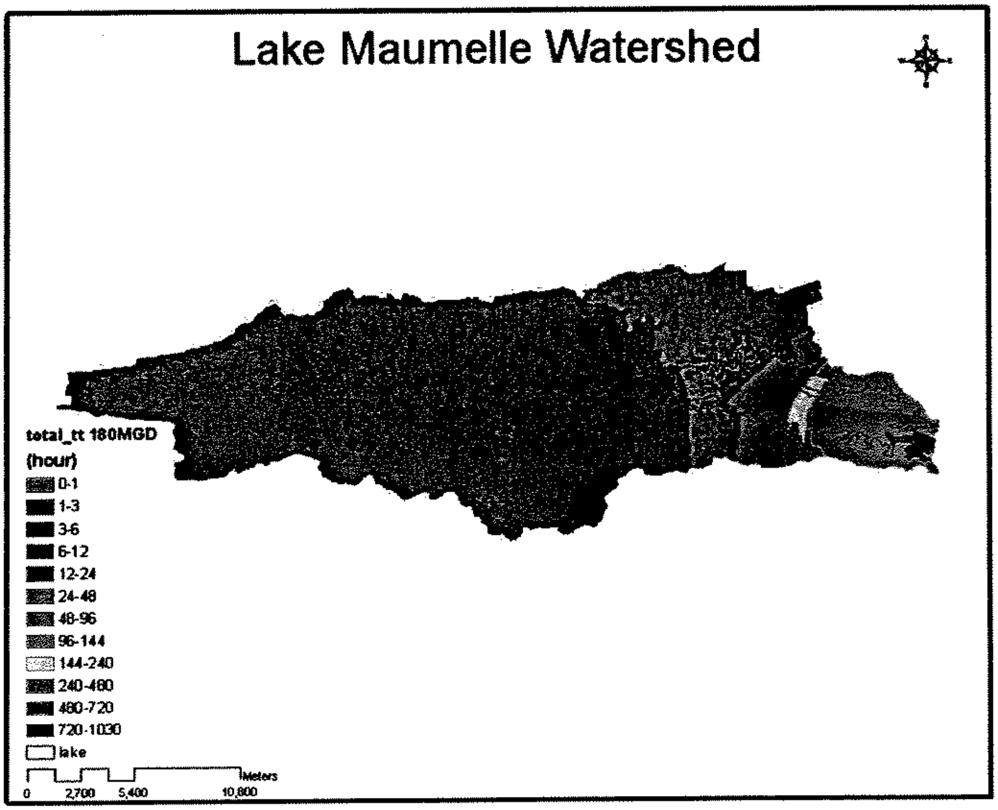


Figure 60. **The Total Travel Time Grid of the Lake Maumelle Watershed for the 180 MGD Scenario**

The total flow travel time in the Lake Maumelle watershed ranges from 0-43 days, which is the time taken by a flow from any point in the study area including overland, streams, and lake to the intake point. The lake component of the watershed travel time takes much longer (up to 42 days) than those of the overland, tributary, and mainstem components of the watershed (usually less than 1 day) under the condition specified in this study. The total flow travel time is almost the same in both the 90 MGD and 180 MGD withdrawal scenarios.

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6 Conclusions

Existing water quality in Lake Maumelle is excellent; however, at this time the watershed is largely undeveloped. Significant development pressure is expected, and the resulting addition of residences, commercial buildings, and new roads will increase pollutant loading to the lake. This increased loading may in turn cause degradation of the water quality in the lake. The Baseline Analysis was undertaken to investigate the magnitude of the potential impacts.

The Baseline Analysis evaluates the potential water quality impacts from several different potential development scenarios for the Lake Maumelle watershed. As the name implies, the analysis establishes a "baseline" by examining potential impacts without any additional management efforts (beyond those in current regulations) to protect water quality in Lake Maumelle. The exercise provides an intentional worst case (but realistic) analysis of what *could* happen. The results are not expected to reflect what *will* happen, as additional management requirements are expected to be adopted as a result of this study. Rather, the Baseline Analysis provides a reference point on which to calculate the needed level of additional management.

Four future land use scenarios were developed with input from local planners, realtors, and engineers, as well as the members of the TAC. Approximately 52,000 acres of land in the watershed are privately owned and feasible for development. Four different baseline buildout scenarios were developed. These add between 8,350 and 15,360 new households to the watershed. Each household will be associated with impervious surfaces and managed land areas, both of which contribute higher rates of pollutant loading to the tributaries of Lake Maumelle than the existing land cover, which is primarily forest. In addition, the households generate wastewater. Under current regulations, wastewater could be disposed of by conventional subsurface (septic) systems, individual surface discharge systems, and package plants with surface discharges. Because many of the soils of the watershed are of low suitability for subsurface wastewater disposal, a significant fraction of the wastewater is likely to be treated and discharged into streams that drain to Lake Maumelle.

Each of the future buildout scenarios was analyzed using the calibrated watershed and lake response models. The scenarios are compared with one another and to existing conditions using a set of key indicators and associated target values associated with the management objectives for Lake Maumelle endorsed by the PAC. For example, there is a target to keep the summer median concentration of chlorophyll *a* (a measure of algal density) below 3.5 μg/L and as close as 3.0 μg/L as possible at the water supply intake to prevent problems associated with blue-green algal toxins, clogging of filters, excess demand for treatment chemicals, and unpleasant taste and odor in the finished water.

All four future land use scenarios result in significant increases in pollutant loading to Lake Maumelle. For instance, loads of phosphorus (a key nutrient that promotes algal growth) could increase by up to 1,419 percent of existing levels. As expected, these large increases in pollutant loads result are predicted to result in degraded water quality in the lake. All four scenarios fail to meet most of the water quality targets by substantial amounts. Algal concentrations near the water intake could increase by up to more than 5 times current levels (and up to 13 times current levels in the upstream portion of Lake Maumelle), leading to conditions in which visible algal blooms are frequent and the quality of finished water is compromised. Turbidity, organic carbon, and bacterial levels are also predicted to increase.

Based on the results reported here, it is clear that additional management measures will be necessary to protect water quality in Lake Maumelle. An important finding of this investigation is that the major part of the projected increases in most pollutant loads is attributed to wastewater discharges, and prevention of surface discharges of wastewater will need to be a key consideration for attaining objectives. However, even if surface discharges are entirely omitted, reductions in loading from the land surface will also be needed. Examples of potential management measures include non-engineering/conservation options such as reducing the number of houses that can be built (or allowable imperviousness percentage for development) and engineering controls such as vegetated filters, water quality swales and detention basins that trap and treat pollutant runoff from such developments.

It is important to note that for the analyses presented here new roads were assumed to be paved. Information received subsequently suggests that many of the new roads are likely to be unpaved. Unpaved roads typically generate much higher loads of sediment and sediment-associated pollutants (such as phosphorus) than paved roads – leading to even worse conditions than currently predicted. As all the buildout baseline analyses (with paved roads) yield results well in excess of in-lake targets, it was not essential to revise this assumption at this time. However, future scenario runs will need to explicitly account for the creation and management of new unpaved roads.

The Baseline Analysis also demonstrates that delivery of contaminants to the water supply intake is not uniform. Pollutants in the Upper Watershed area are expected to take much longer, on average, than pollutants in the Lower Lake zone to reach the water intake. For pollutants that break down or die off in transit, such as many forms of bacteria, this means that sources in the upper watershed pose less threat than those in the lower watershed. For other contaminants that are not as easily lost in transit, such as total organic carbon, management should focus on watershed-wide controls. Time-of-travel and relative loading analysis results can be used to help established different management zones with separate performance standards or loading allocations that recognize these differences in risk and relative impact.

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Appendix A. Baseline Scenario Land Use Distribution for the Lake Maumelle Watershed

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Table A-1. Land Use Areas by Subbasin under Baseline Scenario 1 (acres excluding water)

Subbasin	Deciduous Forest	Evergreen Forest	Mixed Forest	Grass & Pasture	Developed	Roads	Total
1	112	1,215	3,037	219	520	171	5,273
2	313	2,537	3,017	106	295	120	6,387
3	98	1,869	918	228	375	97	3,585
4	218	1,344	792	34	257	67	2,712
5	434	2,847	3,004	407	125	63	6,881
6	196	1,325	1,553	78	96	53	3,301
7	179	806	751	43	70	21	1,869
8	608	1,877	1,667	504	490	111	5,257
9	406	2,461	1,860	1,542	750	198	7,217
10	225	1,082	1,012	237	520	136	3,212
11	539	1,241	761	267	311	81	3,201
12	119	1,427	1,174	30	307	79	3,136
13	225	1,136	1,044	319	497	127	3,348
14	200	815	489	0	162	37	1,704
15	18	36	22	0	4	2	82
16	4	11	28	0	9	4	56
17	103	509	322	64	311	65	1,374
18	91	239	182	0	81	24	617
19	168	724	795	97	621	124	2,529
20	41	298	237	15	152	30	772
21	80	861	505	38	266	66	1,815
22	59	415	461	11	279	53	1,278
24	114	629	1,099	432	1,245	249	3,768
25	52	768	534	46	452	88	1,940
26	13	182	161	0	32	6	395
27+28	61	851	501	15	387	81	1,896
29	43	196	103	3	138	24	507
30	100	670	480	0	277	64	1,592
31	242	727	406	206	187	37	1,804
32	74	394	623	0	133	22	1,245
Total	5,135	29,492	27,538	4,941	9,349	2,300	78,753

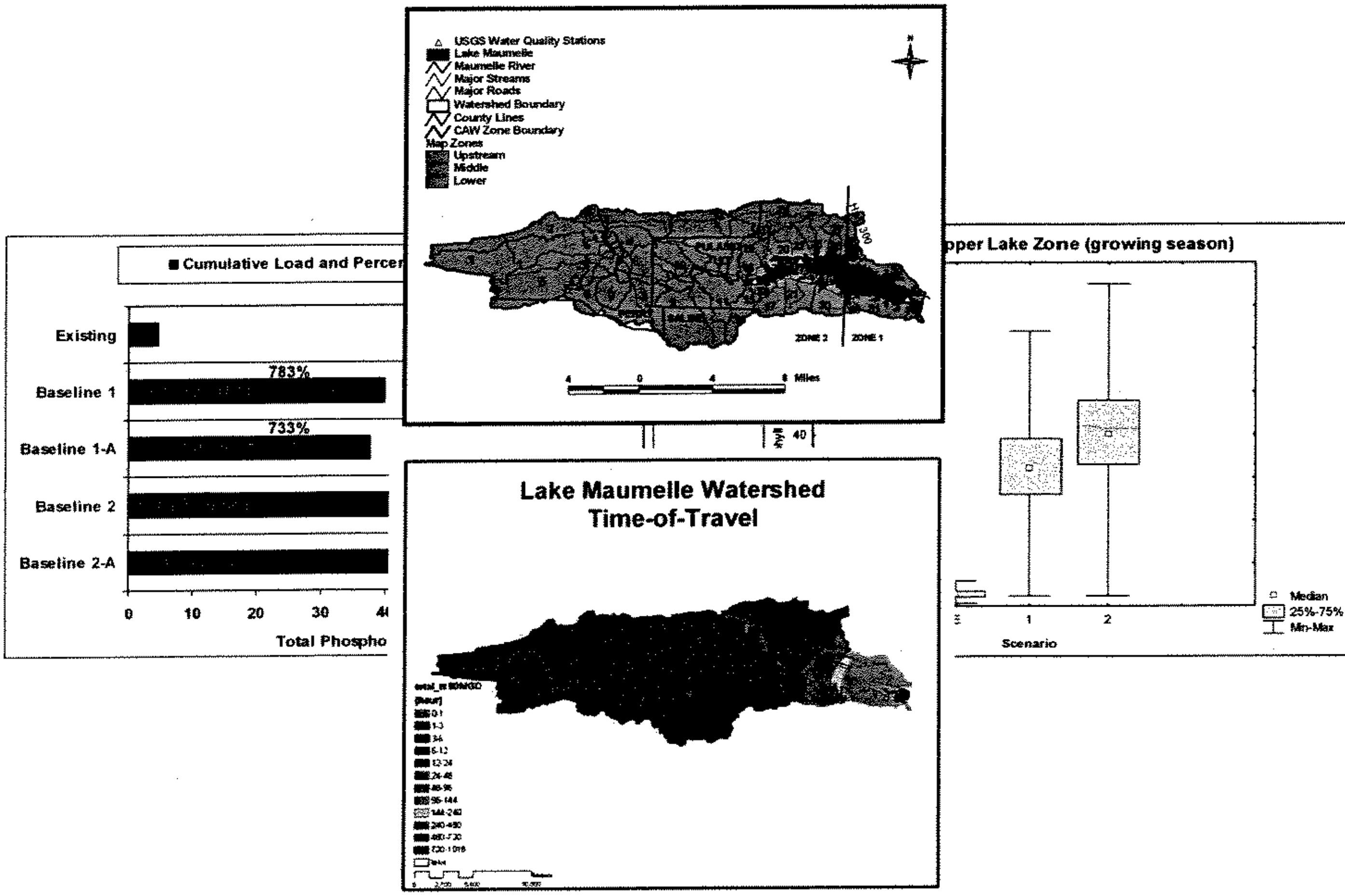
Table A-2. Land Use Areas by Subbasin under Baseline Scenario 2 (acres excluding water)

Subbasin	Deciduous Forest	Evergreen Forest	Mixed Forest	Grass & Pasture	Developed	Roads	Total
1	112	1,215	3,037	219	520	171	5,273
2	313	2,537	3,017	106	295	120	6,387
3	98	1,869	918	228	375	97	3,585
4	219	1,344	792	34	257	67	2,712
5	434	2,847	3,004	407	125	63	6,881
6	196	1,325	1,553	78	96	53	3,301
7	179	806	751	44	69	21	1,869
8	608	1,877	1,669	504	488	111	5,257
9	406	2,461	1,860	1,542	750	198	7,217
10	225	1,082	1,011	236	523	135	3,212
11	538	1,230	754	253	346	80	3,201
12	119	1,427	1,174	30	307	79	3,136
13	225	1,134	1,041	297	526	125	3,348
14	200	815	489	0	162	37	1,704
15	18	35	22	0	5	2	82
16	4	11	28	0	9	5	56
17	90	450	285	54	422	72	1,374
18	81	226	171	0	113	26	617
19	147	642	707	80	817	135	2,529
20	37	264	218	14	205	34	772
21	74	793	479	33	366	71	1,815
22	53	365	419	10	373	59	1,278
24	95	526	924	358	1,591	273	3,768
25	46	675	477	39	605	98	1,940
26	13	176	156	0	43	7	395
27+28	57	760	463	13	512	90	1,896
29	37	170	95	3	176	26	507
30	93	607	445	0	375	71	1,592
31	240	699	395	179	250	41	1,804
32	73	372	610	0	168	24	1,245
Total	5,030	28,740	26,964	4,761	10,869	2,391	78,753

EXHIBIT F5

BASELINE MODELING ANALYSIS

Lake Maumelle Water Quality Management Plan: Baseline Modeling Analysis



Prepared for:

Central Arkansas Water

Prepared by:

TETRA TECH. INC.
PO Box 14409
3200 Chapel Hill-Nelson Hwy.
Research Triangle Park, NC 27709

May 2006

Table of Contents

List of Tables

List of Figures

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1 Introduction/Purposes of the Baseline Analysis

As a part of the process to develop a comprehensive, scientifically based watershed management plan for the Lake Maumelle watershed, Tetra Tech performed a baseline modeling analysis. The purpose of the baseline analysis is to establish points of reference to guide plan development. This was accomplished by comparing existing conditions in the lake and watershed to potential future conditions, assuming that no additional management policies or programs are established (i.e., existing management policies and programs continue to be applied without change in the future). Through this comparison, stakeholders will be able to see what impacts might occur if no action is taken and to better understand the magnitude of what should be addressed by the management plan to achieve the established goals and objectives.

After consultation with the Technical Advisory and Policy Advisory Councils and other stakeholders, Tetra Tech decided to analyze two scenarios describing potential future development: Scenario 1 – characterized by large lot development and, Scenario 2 – characterized by denser development near the lake. Differences between the two scenarios provide stakeholders with an understanding of the sensitivity of lake water quality response to different levels of pollutant loading reflective of different development density levels.

Three lake zones were used for summarizing the baseline analysis results: upper, middle, and lower (Figure 1). These correspond to significantly different response areas in the lake that also have USGS monitoring data available for ease of comparison. Lake response is shown for the key indicators previously selected by Tetra Tech with input from the councils: chlorophyll *a* concentration, total organic carbon (TOC) concentration, Secchi disk depth, and fecal coliform concentration. Predictions were made using the CE-QUAL-W2 model calibrated and validated for Lake Maumelle by Tetra Tech. Hydrology conditions to drive the model reflected the period of January 2002 through September 2004 (end date of available USGS sub-daily flow data).

The lake response is linked to the watershed modeling analysis performed using the HSPF model calibrated and validated to the Lake Maumelle watershed by Tetra Tech. Watershed loading indicators previously selected with input from the councils include sediment, total phosphorus (TP), total nitrogen (TN), total organic carbon (TOC), and fecal coliform. Delivered loads for each indicator were aggregated by subbasin according to the subbasin's geographic location relative to the three lake zones. Therefore, loads reported for the upper lake zone reflect the aggregation of delivered loads from subbasins 1–16 in the watershed model, and subbasins 17–25 and 26–32 for the middle and lower lake zones, respectively.

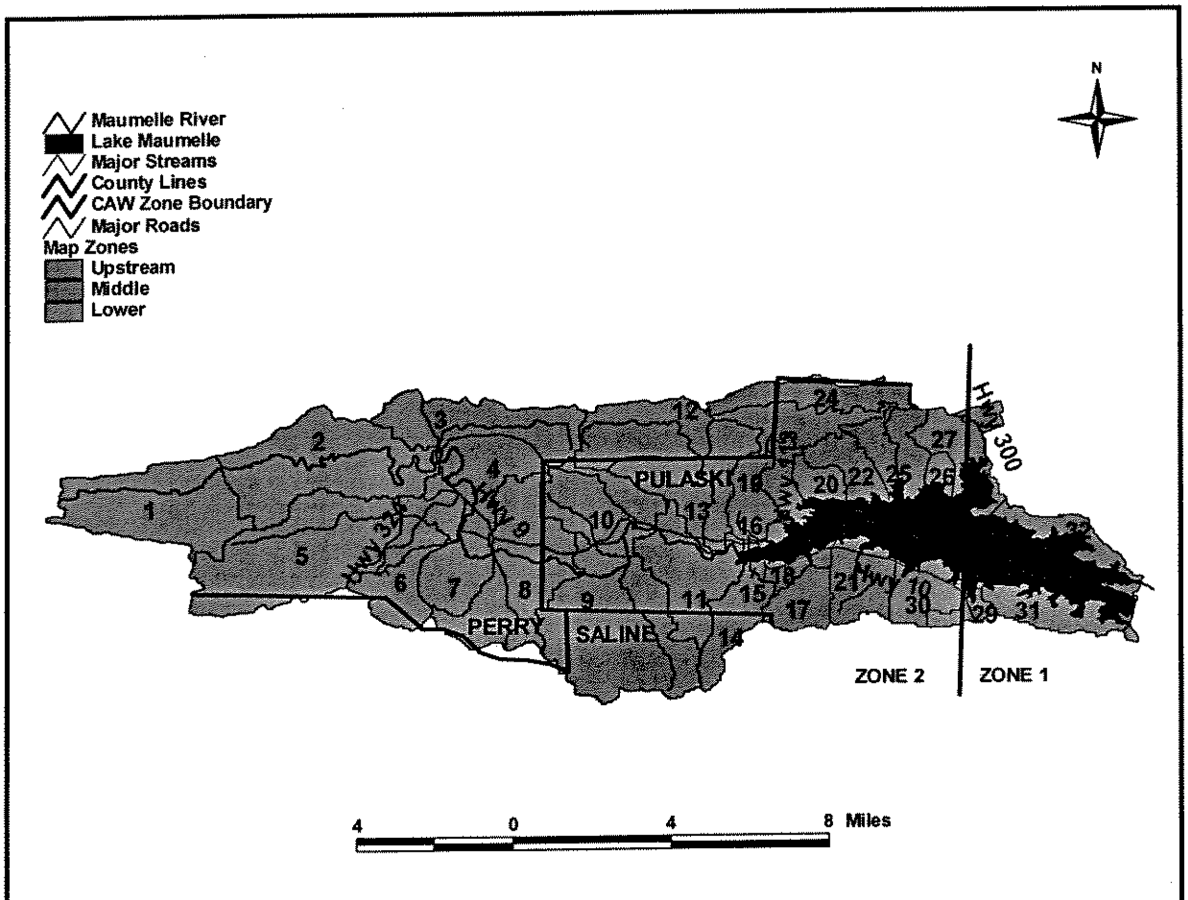

Figure 1. Map Illustrating Lake Zones and Contributing Modeling Subbasins

Figures summarizing watershed load results display estimates of both point and nonpoint sources for each indicator. For the purposes of the baseline analysis, the conservative assumption was made that all wastewater would be handled inside the watershed (i.e., treated and discharged to the subsurface or surface as opposed to being pumped out of the watershed). This reflects the fact that current regulations would not prohibit discharge in the watershed, and that pumping wastewater out of the watershed would reflect a management option that could be tested later as part of the potential management scenarios for the watershed plan. Estimates of point source loads were generated based on assumptions of population to be served by the future development, gallons of wastewater generated per person, and expected average pollutant concentrations for the different types of waste treatment and discharge systems (a more detailed summary of these assumptions is provided in Attachment 2). Nonpoint source loads are summarized for the same January 2002 through September 2004 hydrology conditions as used to drive the lake response, varying land use conditions to reflect the different scenarios.

In addition to understanding the response of the lake to potential unmanaged buildout contaminant loads, it is informative to examine relative travel time of pollutant loads through the watershed. Areas with shorter travel time to the intake present a greater potential risk to the water supply because response time will be short and the opportunity for dilution and decay of a contaminant spill will be reduced. Thus, areas with shorter travel times should be subject to more stringent management to prevent introduction of contaminants into the water supply. To estimate total travel time to the water supply intake, Tetra Tech linked results of models for the three components of travel: overland, instream, and inlake. The approach examines conditions that present a higher level of risk: rapid runoff from the watershed, which decreases loading time, coupled with lake levels a little below full pool, so that the load is not washed over the dam. These are conditions that might arise in response to a summer thunderstorm mobilizing a contaminant spill.

Overland time-of-travel (including flow through small and ephemeral channels not explicitly represented in the HSPF model) was estimated using the Grid-Based Mercury Model 2.0 (GBMM) model, a grid-based model that uses TR55 and Manning's equation to calculate overland travel time before the runoff enters the modeled stream reaches. The 2-year 24-hour rainstorm was used to drive the overland analysis. An instream reach travel time grid was generated by assigning each subbasin the travel time obtained from the corresponding HSPF reach to the lake boundary using the 95th percentile of average daily velocities simulated in HSPF from 10/1/96 to 9/30/04. Lake travel times were estimated using the EFDC three-dimensional model and a conservative tracer from the inflow point to the lake for each tributary reach. Preliminary results reflect an assumption of a 90 MGD water supply withdrawal. An additional analysis is being conducted at a withdrawal rate of 180 MGD to test the sensitivity of the travel time estimates to the theoretical maximum of planned pump capacity.

Results of the baseline analysis are briefly summarized below and in the attached graphics, beginning with watershed loads, moving to lake response, and finishing with the initial time-of-travel analysis.

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2 Modeling Tools – Baseline Analysis Framework

2.1 Summary of Calibrated Models

The primary modeling tools employed in the baseline analysis are a linked watershed model (HSPF) and lake response model (CE-QUAL-W2). The watershed model predicts flows and conveyance loads to the lake, while the lake model simulates lake response. Additional tools include a time-of-travel model to evaluate risk of delivery of spills to the lake.

2.1.1 HSPF Watershed Model

The HSPF model (Bicknell et al., 2001) provides a continuous simulation of flow and pollutant delivery within the watershed and stream network leading to the lake at an hourly time step. Development and calibration of the watershed model is described in detail in the Lake Maumelle Watershed and Lake Modeling – Model Calibration Report (Tetra Tech, 2006). The model was calibrated to observations for 1997-2004 and model performance validated to observations for 1989 to 1996.

2.1.2 CE-QUAL-W2 Lake Model

The CE-QUAL-W2 model (Cole and Wells, 2005) simulates the movement and quality of water within Lake Maumelle on a daily time step. The model operates in two spatial dimensions: longitudinal and vertical. Calibration (1991–1992) and validation (2002–2004) of this model is also described the Lake Maumelle Watershed and Lake Modeling – Model Calibration Report (Tetra Tech, 2006). The lake model uses input from the HSPF watershed model and predicts variation in management targets, such as algal concentration, within the lakes. Together, the HSPF and CE-QUAL-W2 models provide a comprehensive simulation of loads from the watershed and in-lake impacts.

2.1.3 EFDC Lake Model

A separate, three-dimensional hydrodynamic model of Lake Maumelle was created using EFDC (Hamrick, 1992). While it was impractical to develop and calibrate a fully three-dimensional model of water quality within the schedule for the project, there are important management concerns that require finer spatial resolution than is provided by CE-QUAL-W2, such as the potential transport of spills of toxic material. This need was satisfied, while maintaining the project schedule, by implementing EFDC in hydrodynamic-only mode parallel to the development of the CE-QUAL-W2 model. Hydrodynamic calibration of EFDC is also described in the Lake Maumelle Watershed and Lake Modeling – Model Calibration Report (Tetra Tech, 2006).

2.2 Development of Time-of-Travel Model

A Time-of-Travel (TOT) model was constructed to evaluate the risk posed to the water supply intake of spills or other pollutant loads occurring at any point in the watershed. Time-of-travel from the point of a spill to the intake is important for two reasons. First, larger time of travel provides a greater opportunity for emergency response measures. Second, most pollutants attenuate, dilute, or decay during transit. Thus longer time-of-travel is likely to reduce concentrations present at the intake. Results of the TOT modeling provide a basis to assign restrictions on hazardous material use, transport, or storage in different zones of the watershed based on relative risk.

The complete travel time analysis includes several components. Flow travel time is the time water takes to travel from a location in the watershed to a terminal point – in this case the water supply intake. Water moves through a watershed as sheet flow, shallow concentrated flow, open channel flow, or some combination of these. For the Lake Maumelle watershed, a grid-based time of travel estimation approach (TTEA) was developed to compute the flow travel time for each grid cell over land, in tributaries, in the mainstem, and in the lake. The methodology used to compute flow travel time for each component is described in this section.

2.2.1 Overland Travel Time

Overland flow travel time (T_{ov}) was computed for each land-grid using the GBMM. GBMM uses the TR55 (USDA-NRCS, 1986) approach to calculate the sheet flow travel time (Equation 1).

$$T_{ov} = \frac{0.0289 \cdot (n \cdot L)^{0.8}}{P_2^{\,0.5} \cdot S^{0.4}} \qquad \textbf{Equation 1}$$

where

T_{ov} = overland flow travel time (hr),

n = Manning's roughness coefficient,

L = flow length (m),

P_2 = 2-year, 24-hour rainfall (cm), and

S = land slope (m/m).

Overland flow travel time (hours) was computed for surface runoff (sheet flow) up to the point where it reaches the streams, which were represented using the medium resolution National Hydrography Dataset (NHD). A 2-year 2-hour rainstorm of 2 inches was used in this calculation (Browne, 1998).

2.2.2 Low-order Tributary Travel Time

Travel time within larger streams is provided daily by the HSPF watershed model. The smallest tributary streams are not explicitly represented in HSPF, but provide an important part of the overall travel time.

Low-order tributary flow travel time (T_{trib}) was computed for each tributary-grid using GBMM. GBMM uses the following equations to calculate the concentrated flow travel time (Equation 2 and 3).

$$T_{trib} = \frac{L}{3600 \cdot V} \qquad \textbf{Equation 2}$$

where

T_{trib} = tributary flow travel time (hr),

L = flow length (m), and

V = flow velocity (m/sec).

Flow velocity is calculated by Manning's equation.

$$V = \frac{1}{n} R^{2/3} \cdot S^{1/2} \qquad \textbf{Equation 3}$$

where

V = flow velocity (m/sec),

n = Manning's roughness coefficient,

R = hydraulic radius (m), and

S = channel slope (m/m).

Tributary flow travel time (hours) was computed in NHD streams before water entered the major streams defined in HSPF model. The tributary flow travel time is an important link between land and the main reaches. The channel (tributary) roughness of 0.04 was used in this calculation.

TTEA makes the following assumptions to calculate overland and tributary time of travel:

1. Flow directions can be approximated by the eight discrete flow directions as assumed in the GIS software (ArcGIS 9.x).
2. Overland roughness varies based on land type.
3. Stream roughness is assumed to be constant for all NHD streams.
4. The overland runoff moves as a sheet flow before it enters the NHD streams.

Data required to calculate overland and tributary time of travel are:

1. Elevation grid (m)
2. Land use grid
3. Stream shape file
4. Roughness for each land type
5. 2-year, 24-hour rainfall (cm)
6. Manning's stream roughness coefficient.

2.2.3 Major Stream Travel Time

Major streams are explicitly simulated in the HSPF watershed model. Flow travel time (T_{rch}) was computed for each subbasin reach using the HSPF model. Average daily velocities in each reach were output from 10/1/96 to 9/30/04. The reach flow travel time was calculated using the 95th percentile of average daily velocities and the reach length (Equation 4).

$$T_{rch} = \frac{L}{3600 \cdot V} \qquad \textbf{Equation 4}$$

where

T_{rch} = tributary flow travel time (hr),

L = flow length (m), and

V = 95th percentile flow velocity (m/sec).

The 95th percentile was selected to provide a conservative estimate of risk consistent with the use of a storm event for overland and low order reach. This scenario is consistent with a spill being washed into the stream systems by a storm event

2.2.4 Lake Travel Time

The calculation of time of travel inside the lake (T_{lake}) was conducted using the calibrated EFDC model. The description of the EFDC for Lake Maumelle including grid generation, model configuration, and calibration is presented in the calibration report (Tetra Tech, 2006). The lake is a dynamic system under the impacts of various factors such as wind speed and direction, watershed inflows, spillway release of water, and withdrawal rate. The travel time for contaminants and nutrients may vary depending on these impact factors. Several modifications from the calibration run were made to calculate the time of travel in Lake Maumelle as explained below.

For the lake, maximum risk does not occur under the highest flow conditions, as these increase dilution and result in contaminants being washed over the dam. Rather, high risk conditions are associated with an inflow event from an isolated storm entering the lake in a period in which water is not flowing over the dam.

The EFDC model was run from Julian Date 170 to 200 as the model spin-up time period using the actual driving force data in the year of 1991 to build up a realistic flow field. On Julian Date 200, the storm of August 5, 1992 was inserted and corresponding watershed inflows were specified. The total rainfall from that storm was 2.75 inches. The water surface elevation increases 0.1 m in the lake and is still below the spillway elevation. Therefore, the withdrawal from the intake is the only sink of water from the lake in addition to evaporation loss. After Julian Date 200, the watershed inflows were set to 0. Two water withdrawal scenarios with 90 MGD and 180 MGD were used in the calculation of travel time after Julian Date 200. These represent anticipated future average and maximum withdrawal demands, and increase the rate of transport to the water supply intake. All the other conditions such as wind speed and direction were identical to those in the calibration. The total model simulation period was from Julian Date 170 to Julian Date 320.

Simulated tracers were used to determine the time of travel in the lake from various points. Fifty-one distinct tracers were "released" to 17 cells that receive watershed inflows and 34 cells within the lake (Figure 2). In general, more tracers were specified near the intake to obtain a finer resolution of travel time in this critical area. Tracer concentrations were then recorded at the intake cell, which is indicated with a solid triangle in Figure 2. Tracers move within the lake due to both advection and diffusion mechanisms. The average grid cell size is 480 x 270 meters.

The input files for the EFDC lake travel time model are:

1. aser.inp: weather data including air temperature, dew point temperature, precipitation, and solar radiation.
2. wser.inp: wind data including wind speed and direction.
3. qser.inp: flow data including inflows from the watershed and outflow at the withdrawal intake.
4. tser.inp: water temperature time series associated with inflows.
5. txser.inp: concentration time series of tracers.

In addition to the assumptions made in the model calibration (Tetra Tech, 2006), assumptions were made specifically for the computation of in-lake travel time:

1. Tracers are conservative, and the only sink of the tracers is the intake withdrawal.
2. Tracers are completely mixed with water once they enter the model cells.
3. Different types of tracers do not mix.
4. Tracers do not change the density of water.
5. The small flows for releasing tracers in lake cells do not change the hydrodynamics.

6. No watershed inflows are received after tracers are released on Julian date 200.
7. The withdrawal rate is constant at either 90 MGD or 180 MGD after tracers are released.

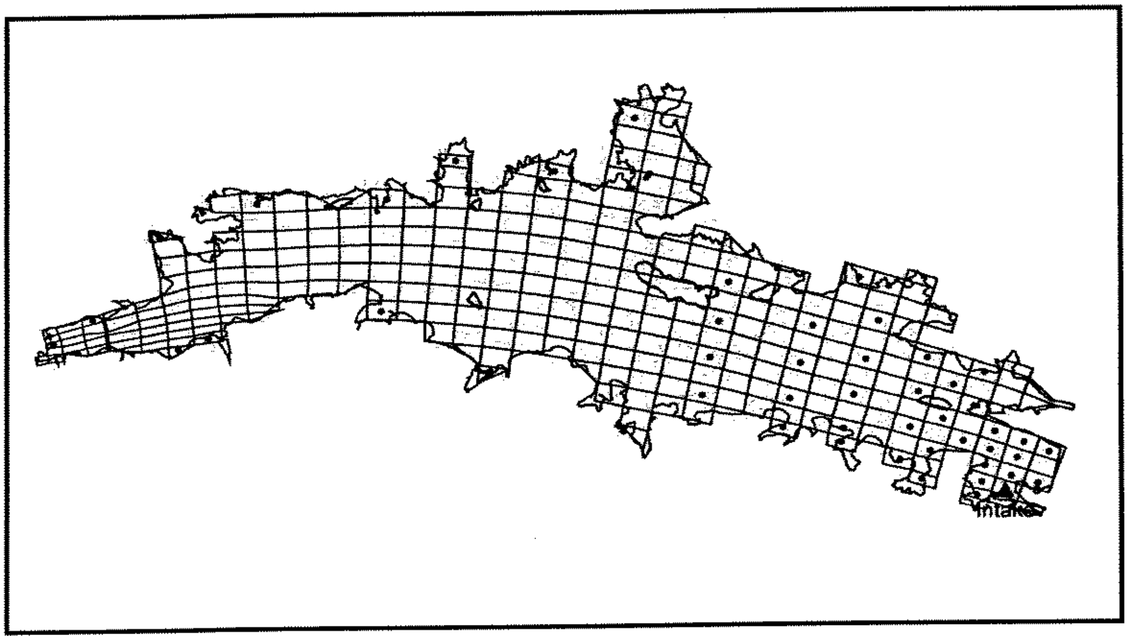


Figure 2. Distribution of Tracer Release Locations in Lake Maumelle

At the end of the simulation, the travel time from each cell was defined as the time required for the concentration at the intake to be at 75 percent of the maximum recorded (Figure 3). The concentrations of tracers generally increased due to the advection and diffusion toward the intake cell from the releasing cells. During the entire simulation period, concentrations might also decrease or fluctuate due to the complex circulation pattern associated with the changes of wind speed and direction. Generally, there are two types of tracer concentration time series curves, as shown in Figure 3 and Figure 4. Tracers from the upper portion of the lake were well mixed when they reach the intake cell (Type 1 in Figure 3). The tracer concentrations reached a pseudo-steady-state condition that increased in the intake cell only due to the decrease of water volume in the lake. For the tracers from the cells near the intake, a peak or multiple peaks existed in the time series curves (Type 2 in Figure 4 and Figure 5). When multiple peaks existed such as in Figure 5, the travel time was determined using 75 percent of the first peak value.

2.2.5 Total Flow Travel Time

Total travel time (T_{tot}) was computed by adding the above four travel time components (Equation 5).

$$T_{tot} = T_{ov} + T_{trib} + T_{rch} + T_{lake} \qquad \textbf{Equation 5}$$

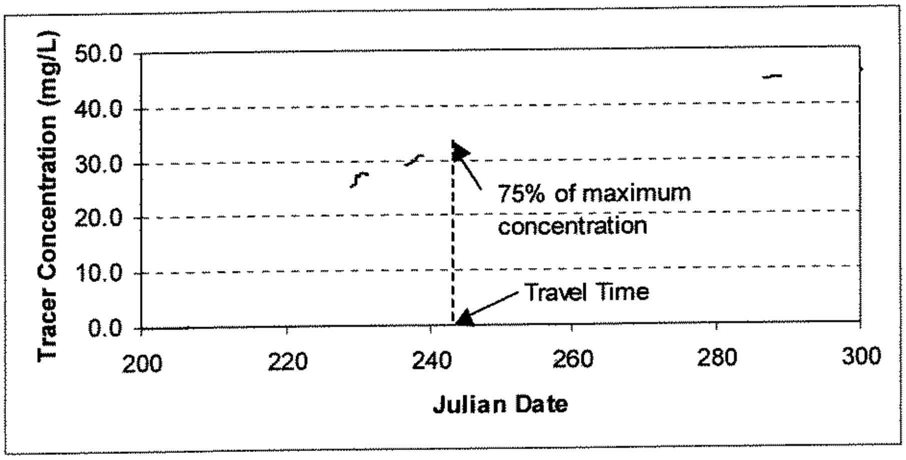


Figure 3. Approach to Determine the Travel Time Using the 75 Percent Maximum Concentration Rule for the Type 1 Curve

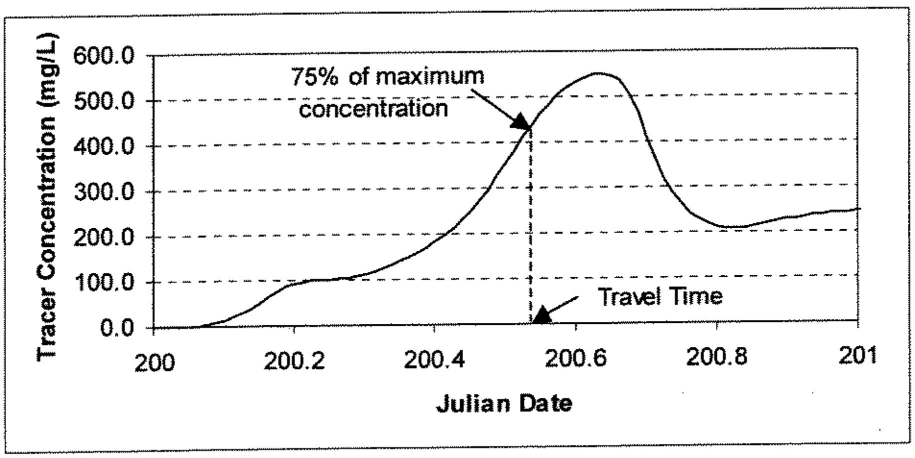


Figure 4. Approach to Determine the Travel Time Using the 75 Percent Maximum Concentration Rule for the Type 2 Curve

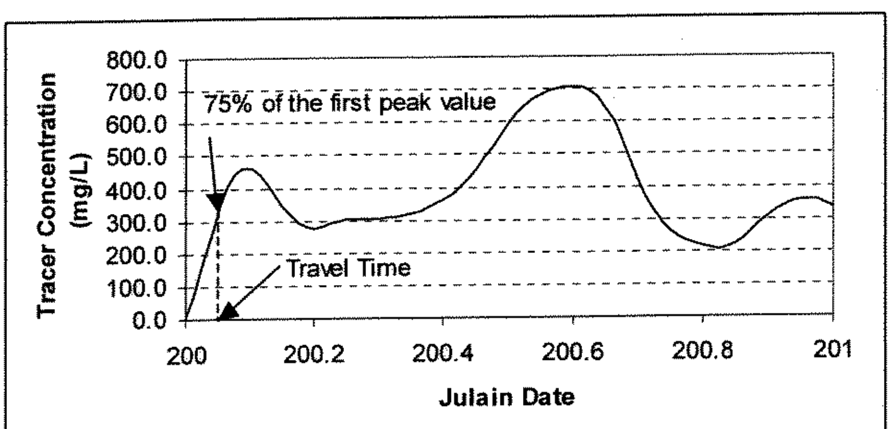


Figure 5. Percent Maximum Concentration Rule for a Curve with Multiple Peaks

3 Baseline Modeling Analysis Assumptions

The calibrated HSPF watershed model was used to compare pollutant loading to Lake Maumelle and to drive the CE-QUAL-W2 lake response model under four development scenarios. The underlying assumptions for these scenarios are described in this section.

3.1 Land Use Scenarios

To conduct the baseline analysis, Tetra Tech required an estimate of future land use in the watershed. Forecasting future land use is a challenging task because so many different factors can affect how an area develops such as development demand, water and waste treatment availability, population growth, road development and congestion, proximity to desirable areas, etc. There is no absolute definition because of the uncertainty associated with many of these figures. All that is needed, however, is a reasonable approximation of what the future may hold so that the relative magnitude of impact that should be managed can be better understood to guide management plan development.

3.1.1 Existing Land Use

The estimates of existing developed land use from the February 2006 Model Calibration Report were used to estimate the amount of land that was already developed versus the amount of land that was available for future development. Preliminary estimates of land use and land cover in the Lake Maumelle watershed are based on 1999 Landsat TM5 satellite imagery processed and ground-truthed by the Center for Advanced Spatial Technologies at the University of Arkansas at 30-meter resolution (Figure 6). This provides recent, high quality information on land cover (the vegetation covering the land surface), but is not of sufficient resolution to show dispersed rural residences or roads. Indeed, there are no developed land categories classified in the watershed. To account for residences, other developed land uses, and roads, Tetra Tech updated this coverage as described below.

The TIGER roads coverage maintained by the US Census Bureau was used along with the Arkansas Forest Service road coverage to create a comprehensive road coverage (Figure 7). The forest service database contains road surface type information (paved, gravel, native soil, or improved native soil). Unpaved roads that were not identified in the forest service coverage were conservatively assigned a surface type of native soil. Road widths were assigned by measuring widths of various road classifications detected in year 2004 digital orthophotos obtained from Jos Bell, GIS Manager, Central Arkansas Water. The total impervious area associated with a road includes compacted shoulders, ditches, and banks in addition to the road surface. However, significant portions of road imperious surface are not directly connected to the stream network, but rather are diverted onto adjacent pervious surfaces (especially true for maintained Forest Service roads). It is this connected impervious area (also known as effective impervious area) that is required for input to HSPF. Lacking detailed road survey data at this time, we assume that these two factors cancel out, and the effective impervious area of roads and their margins is equal to the area of the road surface. Areas of each road surface type within each subwatershed were subtracted from the underlying Landsat land cover and then added as a separate impervious land use to the HSPF model.

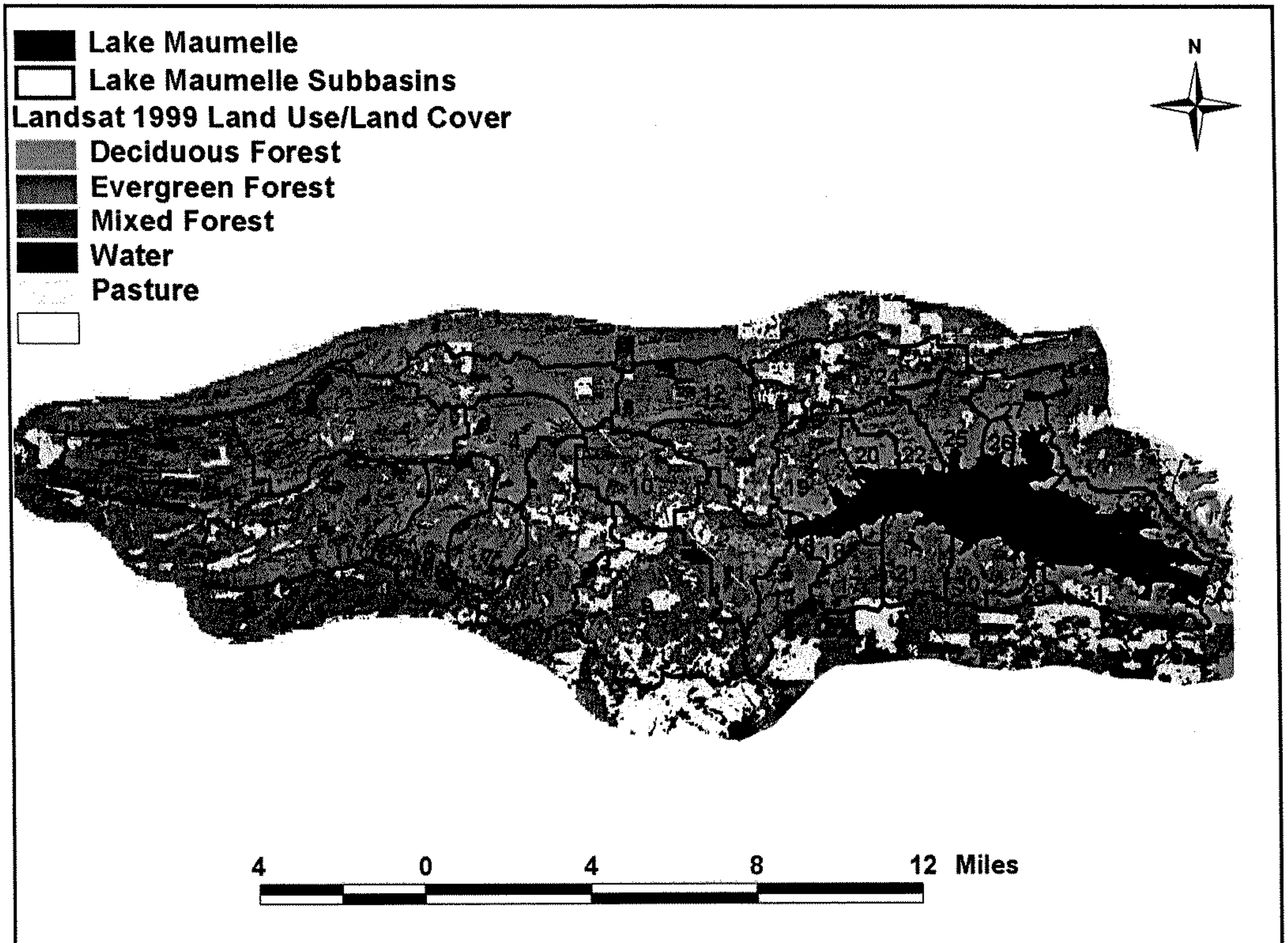


Figure 6. Landsat 1999 Land Use/Land Cover Data for the Lake Maumelle Watershed

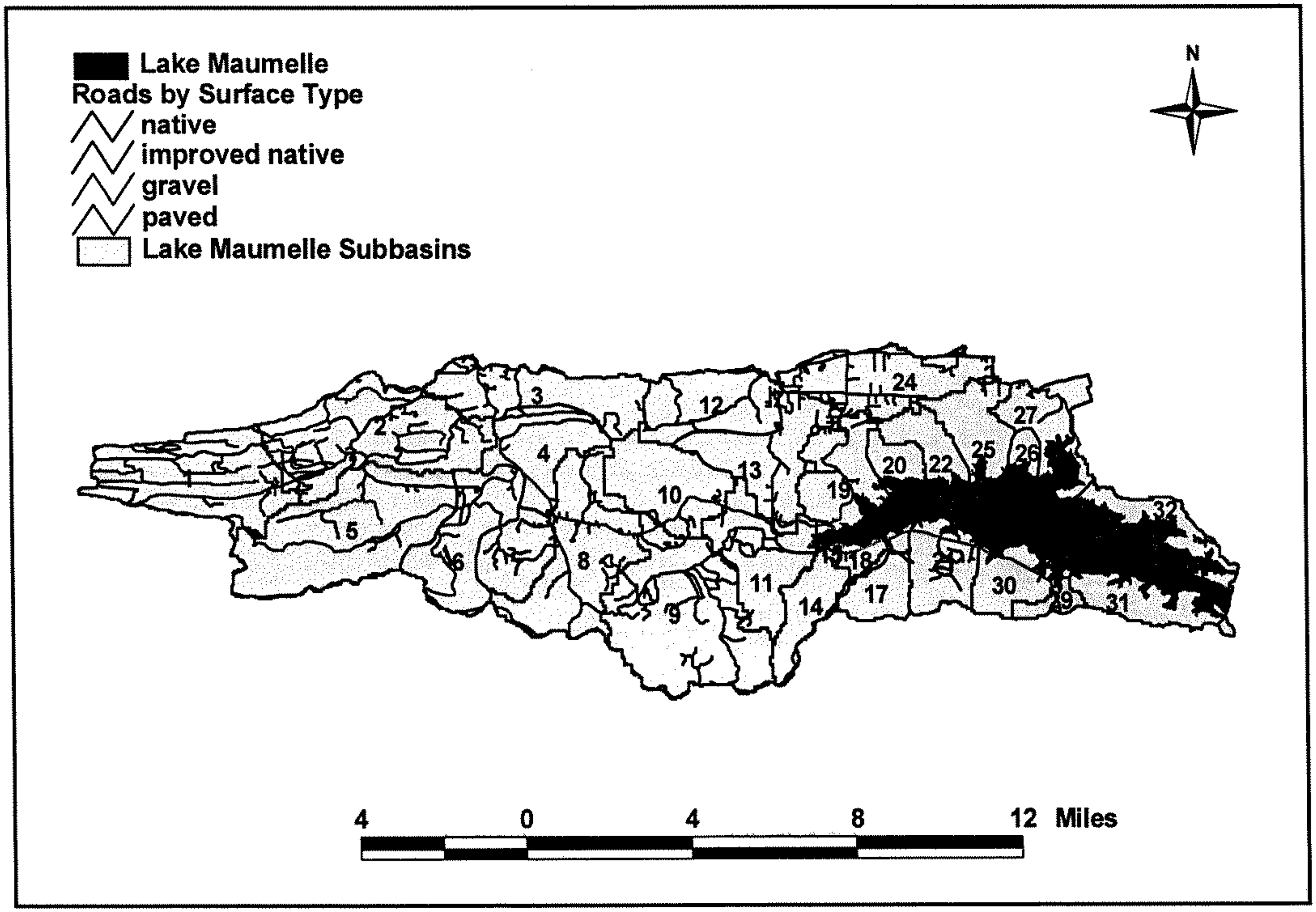


Figure 7. Road Coverage by Surface Type in the Lake Maumelle Watershed

The Landsat coverage does not show rural residences or other developed land in the watershed; however, information on the location of residential, commercial, and industrial parcels is available from county tax data. Pulaski County provided detailed spatial coverage of tax parcel boundaries and associated information, while Perry County provided parcel centroids, but not lot boundaries. The small portion of the watershed lying in Saline County does not have visible buildings on low altitude digital orthophotography. Parcels with buildings were identified through a combination of information on tax class and improvement value. In most cases, the situation is clear: for instance, Residential Improved and Commercial Building classes can be assumed to have buildings, while Residential Vacant lots are unlikely to have a significant amount of building. For other classes, such as the agricultural class, significant development was assumed to be present on a lot if the assessed improvement value was greater than $25,000.

Because Perry County provided only parcel centroids, it is not possible to exactly extract residential lots as a separate land use. In addition, there are commonly cases in which a residence is located on a large lot, but only a small portion of that lot is cleared and developed with the rest remaining in forest. In such cases, it is preferable to simulate the majority of the lot as forest.

To combine the disparate types of information available, we assumed for existing conditions that each residence or small commercial building was associated with approximately 1 acre of cleared land and ¼ acre of effective impervious surface area (roofs, drives and other paved or compacted areas). The existing conditions simulation assumes that these areas are laid out to optimize drainage, and that most of the impervious surface on existing developed lots is directly connected to the stream network. In situations in which a house is surrounded by larger amounts of cleared land (e.g., horse pasture), it is assumed that the cleared land cover would be detected by the Landsat interpretation. The resulting pervious and impervious land uses were located at the parcel centroid (as this was the only location information available from Perry County), and used to replace the underlying Landsat land use (Figure 8).

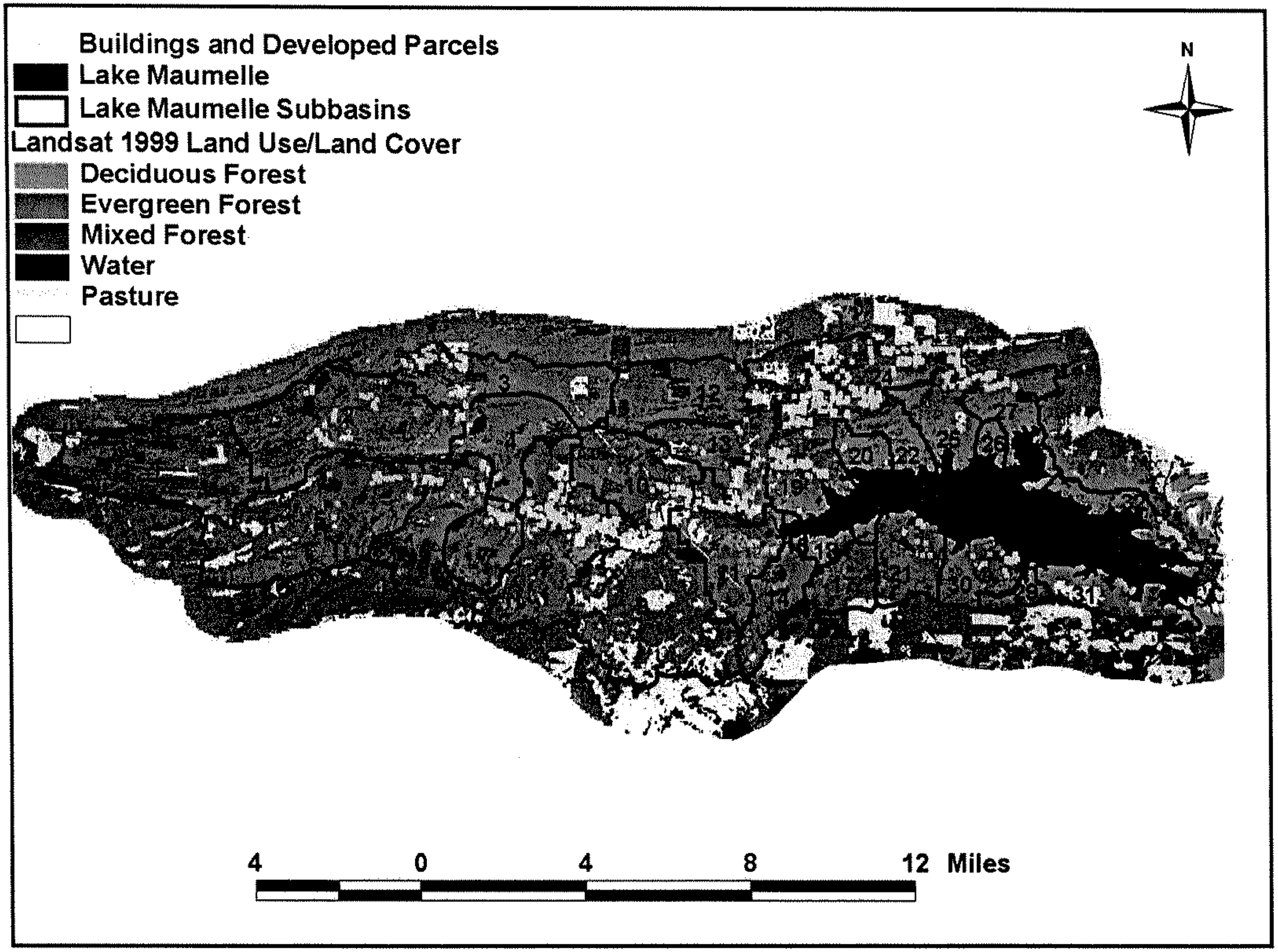


Figure 8. Approximate Location of Buildings and Developed Parcels in the Lake Maumelle Watershed

3.1.2 Input from Local Planners, Realtors, and Engineers on Future Land Use

Tetra Tech determined that a realistic forecast of future land use could best be determined by obtaining input from local planners, realtors, and engineers. Planners on the Technical Advisory Council were contacted to obtain input on regulations and policies that could shape how and where development would occur. Additionally, Tetra Tech worked with staff from the Metroplan Council of Governments to review available population and household projections for the watershed. Next, Tetra Tech met with the following group of realtors and engineers with extensive experience in western Pulaski County including the portion extending into the watershed: Tim Daters with White-Daters Engineering, Bill Dean with Civil Design, Lolly Honea and Wally Loveless with Adkins, McNeill, Smith & Associates, and Debbie Moreland with Pinnacle Realty. The group discussed many topics including availability of water and wastewater treatment, the effect of slope on development types, expected demand over a range of lot sizes, and how development would likely occur in the watershed given transportation corridors and other factors.

Based on the initial discussion with local realtors and engineers, the following key assumptions were made to help drive the development of a future land use database:

- Water and wastewater treatment availability, while a problem in some locations now, will be resolved in the next 10 years and will not be a significant long-term constraint on development.
- Steep slopes do not eliminate much land from development; rather they affect how the land will develop. For slopes < 15 percent, land can be developed at higher densities (e.g., 1- to 2-acre lot sizes) and can be serviced by a community or package plant wastewater treatment system. For slopes ≥ 15 percent, land will tend to be developed at lower densities (> 5-acre lot size) and be serviced by onsite waste treatment.
- The area around the lake will develop faster than land further to the west because of the proximity to Little Rock and the lake as an attractive feature.
- The majority of development will be residential. A small amount of commercial development (e.g., small grocery store, gas station) may occur along the main transportation routes and intersections (e.g., Hwy 10 and Route 113).

From a demand standpoint, the realtors and engineers thought that the majority (~ 70 percent) of development would be in the 3- to 5-acre lot-size range in the near lake zone. They also estimated that about 15 percent would be developed in higher density (1- to 2-acre lot sizes and possibly a small number of multi-family dwellings) and about 15 percent would be developed with lot sizes > 5 acres. The consensus was that this would be a starting point, but that Tetra Tech would use slope information and historical demand information to adjust these as appropriate.

Based on the input from local representatives, Tetra Tech developed a preliminary approach to estimating future baseline land use for two separate zones (near-lake and remainder of watershed). Then the Technical Advisory Council (TAC) and a group of local realtors reviewed the results and recommended revisions that led to the development of four baseline scenarios: 1, 1A, 2, and 2A. Scenario 1 represents a reasonable estimate of future, baseline conditions, and Scenario 2 assumes higher densities near Lake Maumelle to provide a sensitivity analysis. Scenarios 1A and 2A test how the planned developments near the intake will affect water quality if the land is not acquired by CAW. The details of the approach, assumptions, and findings are provided herein.

3.1.3 Preliminary Approach and Methods

The Baseline Buildout Analysis was developed to produce future land use data for the baseline modeling analysis. To estimate the extent of future development at buildout, Tetra Tech took the following steps:

- Estimated developable land.
- Distributed developable land into slope categories.
- Estimated the future lot size distribution in the watershed.
- Separated new road area from developable land according to the expected lot size distribution.

Tetra Tech assumed that the impact of future non-residential development would be negligible, and, therefore, developed the buildout assumptions for residential development. After future developable land was estimated, the number of households associated with the buildout assumptions was calculated.

3.1.3.1 GIS Analysis of Developable Land

As the first step in estimating future land use, Tetra Tech estimated the extent of developable land in the watershed. The following land was not considered developable:

- Land owned by a public entity. (The majority of the public land in the watershed is owned by CAW and USFS. It was assumed that this land would remain in similar uses and not be developed in the future.)
- Land in existing buildings, roads, and other development, as described in Section 3.1.1.
- Land classified as water in the 1999 Arkansas Land Use/ Land Cover dataset.

The developable land was estimated for each modeling Hydrologic Reference Unit (HRU). Tetra Tech established the HRUs for watershed modeling.

Local representatives projected that the densest development would occur on the land around the lake out to the western, or upstream, edge of the lake. This part of the watershed will be referred to as the Near Lake Zone for the purposes of the baseline modeling analysis. The HRUs that approximately corresponded with the western edge of the lake were used to estimate developable land in the Near Lake Zone (yellow boundary of zone is shown in Figure 9).

3.1.3.2 Slope Categories

Based on input from local representatives, as discussed in Section 3.1.2, Tetra Tech divided developable land into two slope categories: 1) land < 15 percent slopes, and 2) land ≥ 15 percent slopes. The average slope data were acquired from the county SSURGO data. Each average slope represents an area-weighted average of the slopes within each soil mapping unit. Figure 9 illustrates the distribution of land within the two slope categories throughout the watershed.

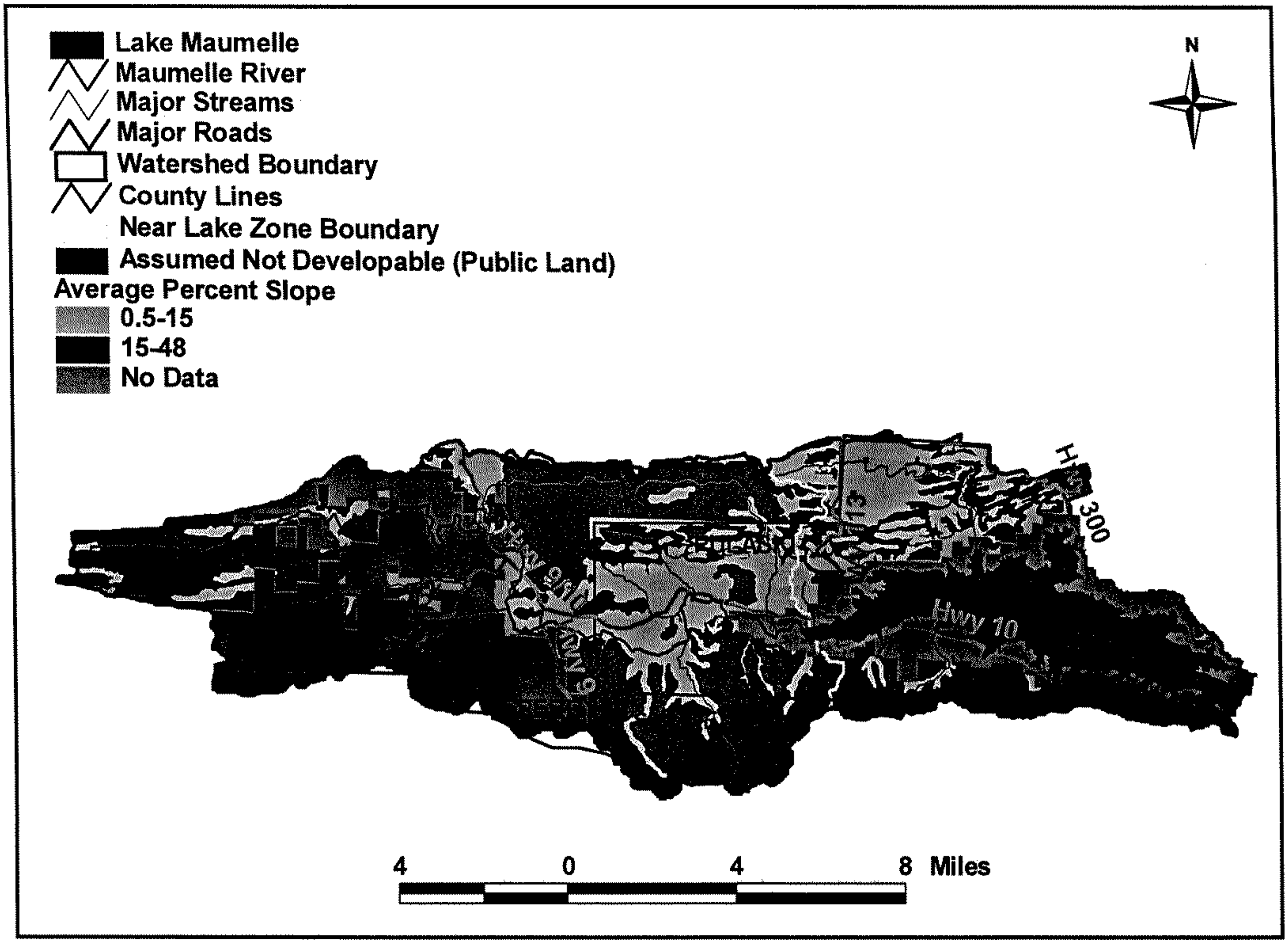


Figure 9. Distribution of Slope Categories in the Lake Maumelle Watershed

3.1.3.3 Lot Size Assumptions

Once developable land was portioned into the slope categories, the developable land was further portioned into expected lot sizes. Tetra Tech selected future lot size proportions that reflected recent realty sales as well as future projections from local realtors and engineers. The realtors and engineers provided an estimate of the distribution of lot sizes within the two slope categories. Tetra Tech developed separate lot size assumptions for 1) the Near Lake Zone and 2) the remainder of the watershed.

Lot Size Distribution for the Near Lake Zone

Within the Near Lake Zone, the realtors and engineers projected that the developable land would have the following distribution at buildout:

- 15 percent of the developable land in less than 3-acre lots
- 70 percent in 3- to 5-acre lots
- 15 percent in greater than 5-acre lots

The realtors subsequently provided Tetra Tech with data on realty sales from 2001 through 2005 in western Pulaski County. Tetra Tech used the sales distribution for lots ranging from 1 to 11 acres as an indicator of future realty sales distributions in the watershed (Figure 10).

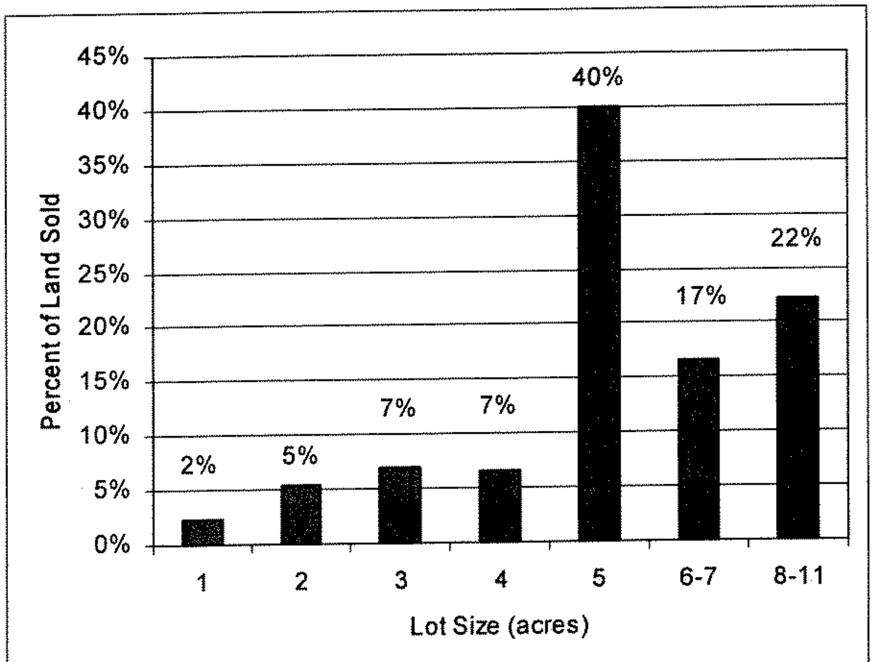


Figure 10. Proportion of Homes and Lots Sold in 2001 through 2005 in Western Pulaski County for Lot Sizes Ranging from 1 to 11 Acres

The historical sales indicate that a substantially higher proportion of land has been sold for lots larger than 5 acres than projected for the future by the group (39 percent versus 15 percent). Therefore, Tetra Tech used the recent realty sales distribution to further proportion future development among lot sizes. For example, in the 1- to 2-acre lot category (15 percent of developable land), 2 out of 7 acres were assigned to 1-acre lots and 5 out of 7 acres were assigned to 2-acre lots. These proportions were then converted to the percent of developable land in each soil slope category, as shown in Table 1.

Table 1. Proportion of Developable Land Assumed for Each Slope Category and Lot Size

Lot Size (acres)	Percent of Developable Land
For developable land with an average slope of less than 15 percent:	
1	5%
2	13%
3	11%
4	11%
5	60%
For developable land with an average slope of greater than or equal to 15 percent:	
6.5	44%
9.5	56%

The proportion of land in the slope categories will differ from the projected distributions due to the distribution of land in the slope categories. If 15 percent of the developable land were in slopes equal to or greater than 15 percent, then the lot size proportions would perfectly match the local projections. However, the soils data show that 60 percent of the developable land in the Near Lake Zone is in slopes greater than or equal to 15 percent, so the modeled future lot size proportions using the aforementioned assumptions will result in 60 percent of the developable land in lots greater than 5 acres.

During the first analysis iteration, all land at or above 15 percent average slopes was assumed to be in either 6.5- or 9.5-acre lots (i.e., the midpoints of the sales ranges displayed in Figure 10). All land with less than 15 percent average slopes was assumed to be in less than 5-acre lots. Once the land was separated into the slope categories, then the lot size proportions in Table 1 were applied.

Lot Size Distribution for the Remainder of Watershed

For the remainder of the developable land in the watershed outside of the Near Lake Zone, a lower density of households was assumed for buildout as follows:

a. For soils with average slopes < 15 percent: average lot size = 5 acres.

b. For soils with an average slope ≥ to 15 percent: average lot size = 10 acres.

A lower density of development was assumed for the remainder of the watershed because this area is farther from highly developed areas (e.g., Little Rock and North Little Rock) than the Near Lake Zone. Although actual lot sizes will likely vary from relatively small to relatively large, average lot sizes were applied to cover the ranges.

3.1.3.4 Estimate of Future Roads in New Residential Development

Tetra Tech estimated the area of future roads corresponding to the expected range of lot sizes. The proportion of road for each lot size was approximated from the ratios of road area to development area in existing and future planned developments near Lake Maumelle. The ratios were extrapolated for 1- and 2-acre lots, since development examples were not available for these lot sizes. Table 2 shows the results of this analysis. The estimated area of future roads was removed from the developable land area prior to estimating the number of households.

Table 2. Ratio of Road Area to Residential Development Area Based on Existing and Planned Residential Developments Near Lake Maumelle

Lot Size (acres)	Ratio of Road Area to Development Area
1	0.080
2	0.075
3	0.065
4	0.060
5	0.050
6.5	0.040
9.5-10	0.020

For the baseline analyses, new roads were assumed to be paved. Information received subsequently suggests that many of the new roads are likely to be unpaved. Unpaved roads typically generate much higher loads of sediment and sediment-associated pollutants than paved roads. As both baseline analyses yield results well in excess of in-lake targets, it was not essential to revise this assumption at this time. However, future scenario runs will need to explicitly account for the creation and management of new unpaved roads.

3.1.3.5 Estimation of Households

The developable land (minus future road area) was portioned into expected lot sizes based on the percentages in Table 1. Then, the number of houses represented in each lot size was summed to achieve a total number of households. This process was performed for the Near Lake Zone and the entire watershed. The approximate number of existing households was estimated from the parcel data and added to the household totals (300 and 400 for the Near Lake Zone and entire watershed respectively).

3.1.4 Preliminary Estimates of Buildout

Table 3 displays the results of the preliminary estimates of buildout for the baseline analysis. The preliminary analysis produced an estimated acreage of future development for lot sizes ranging from 1 to 10 acres. The distribution of developable land among the lot sizes provides a likely distribution of development densities in the watershed.

The results of this analysis reflect the distribution of average slopes as well as the lot size assumptions originally obtained from local realtors and engineers. The high proportion of large lot sizes estimated in the preliminary analysis reflects that a majority of the developable land has average slopes at or greater than 15 percent, as estimated from the SSURGO soils data. Of the developable land allocated to 1- to 5-acre lots, the majority is in 3- to 5-acre lots, which agrees with the recommendations of local realtors and engineers.

The count of households provides an estimate of the expected growth occurring over the years leading to buildout.

Table 3. Preliminary Estimates of Buildout

Location	Lot Size	Acres of Developable Land	Households
Near Lake Zone	Future < 3-acre lots	1,000	600
	Future 3- to 5-acre lots	4,700	1,000
	Future > 5 acre lots	8,500	1,100
	Existing lots	NA	300
	Total	14,200	3,000
Remainder of Watershed	Future 5-acre lots (average lot size)	5,400	1,100
	Future 10-acre lots (average lot size)	32,900	3,300
	Existing lots	NA	100
	Total	38,300	4,500
Whole Watershed	Future < 3-acre lots	1,000	600
	Future 3- to 5-acre lots	10,100	2,100
	Future > 5 acre lots	41,400	4,400
	Existing lots	NA	400
	Total	52,500	7,500

3.1.5 Scenario 1 Baseline Buildout Assumptions

The above preliminary baseline buildout analysis was reviewed by the group of local realtors and engineers and the Technical Advisory Council (TAC). The local realtor/engineering experts raised concerns that the historical realty sales data likely underestimated the future amount of development in lots less than 5 acres. They also projected that denser development will occur on the land with greater than 15 percent slopes than is reflected in the preliminary assumptions. Based on feedback from this group, Tetra Tech revised the preliminary baseline buildout assumptions as follows:

- Water and wastewater treatment availability, while a problem in some locations now, will be resolved in the next 10 years and will not be a significant long-term constraint on development.
- The majority (~ 70 percent) of development would be in the 3- to 5-acre lot size range in the Near Lake Zone (see orange area in Figure 11). One-half of these lots will be 3-acre and one-half will be 5-acre lots. For the rest of the Near Lake Zone, about 15 percent would be developed in higher density (1- to 2-acre lot size and possibly a small number of multi-family dwellings) and about 15 percent would be developed with lot sizes > 5 acres.
- The developable land in the remainder of the watershed (see light green area in Figure 11) will develop according to assumptions in the preliminary baseline buildout analysis.
- Lots ≤ three acres in size will be served with package treatment plants. Lots greater than three acres will have individual, onsite wastewater systems.

- Land with greater than 30 percent slope would be too difficult to develop and was removed from developable land, as shown in Figure 11.
- The area around the lake will develop faster than land further to the west because of the proximity to Little Rock and the lake as an attractive feature.
- The majority of development will be residential. A small amount of commercial development (e.g., small grocery store, gas station) may occur along the main transportation routes and intersections. Tetra Tech assumed that a 0.1 mile corridor of non-residential development would occur at the intersections of Highways 113 and 300 and Highways 9 and 10 and near the intersection of Highways 10 and 113.
- A 50-foot buffer around the proposed petroleum pipeline was removed from developable land, as shown in Figure 11.

Table 4 shows the proportion of developable land assumed for each lot size with the revised assumptions, termed Baseline Scenario 1. The revised assumptions resulted in a total number of households at buildout of 4,300 in the Near Lake Zone (Table 5), a near 50 percent increase from the former estimate of 3,000. Table A-1 and Table A-2 in Appendix A summarize the acres of land use by subwatershed for Baseline Scenario 1.

The Technical Advisory Council (TAC) reviewed both the preliminary and the revised baseline buildout assumptions. The TAC recommended that Tetra Tech assume a greater density for buildout than predicted in the preliminary analysis. After reviewing the Revised Baseline Analysis, members of the Council agreed that it represented reasonable assumptions for the baseline analysis, with two revisions. First the group believed that package plants would serve lots less than 5 acres (rather than 3 acres or less). Also, based on discussions with the local sanitarian, the TAC recommended that Tetra Tech clarify that onsite waste treatment for larger lots would include both subsurface discharge (e.g., septic tanks) and surface discharge (e.g., aeration systems). The latter should be applied to steep sloped areas.

With these revisions, members stressed the scenario was a good representation of future development given that Tetra Tech consulted the local engineering experts that work with the major landowners in the watershed and are familiar with the types of development envisioned or planned. If this large lot pattern of development occurs, community advisors and TAC members predicted that buildout of the Near Lake Zone of the watershed could occur within 30 to 50 years, while the balance of the watershed would build out over a longer time period.

Based on the comments from the local realtors and engineers and the TAC, Tetra Tech proposed the revised baseline buildout projection as a reasonable estimate of potential development occurring in the watershed in the future.

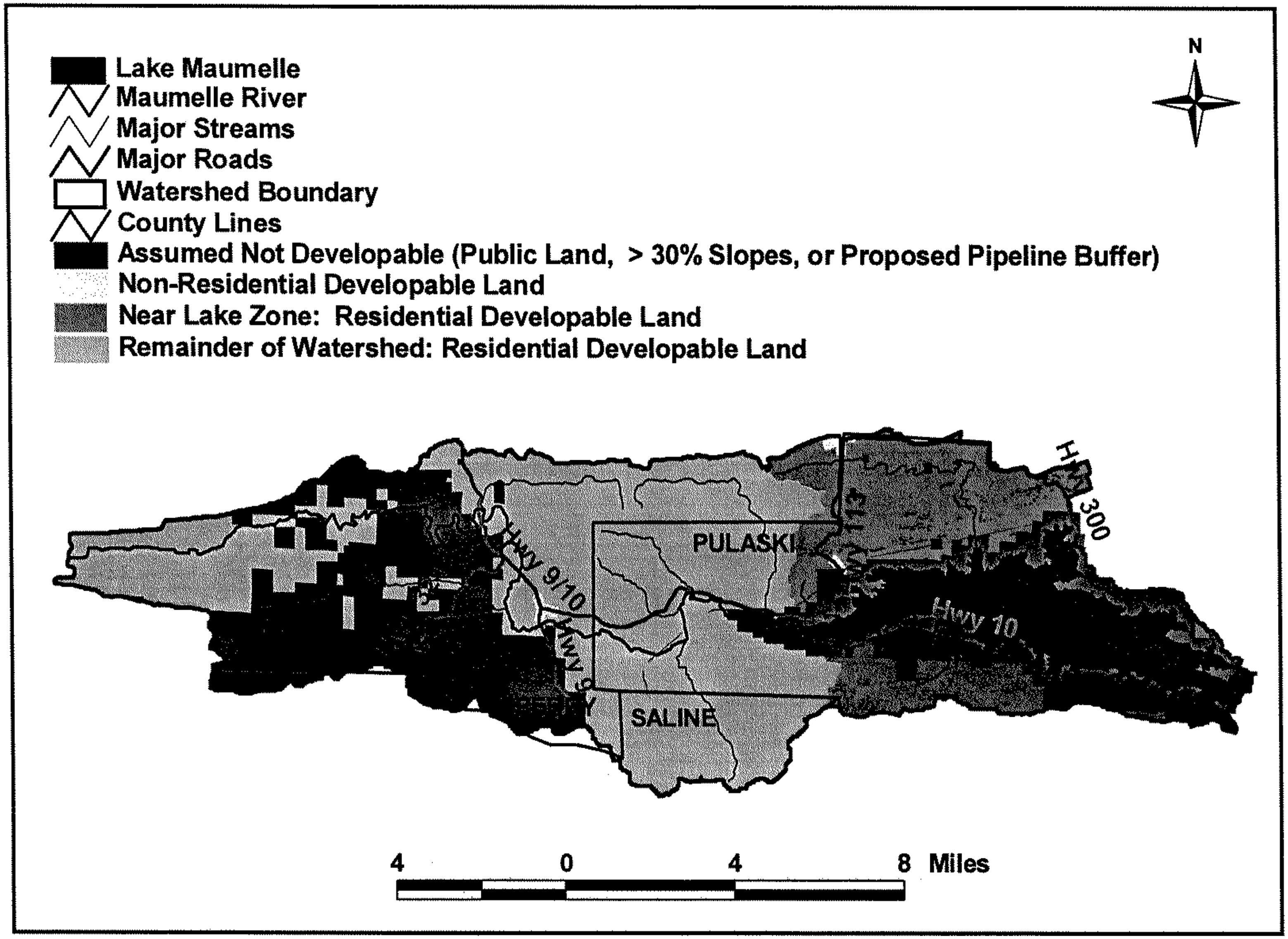


Figure 11. Baseline Scenario 1 – Developable Land in the Near Lake Zone and Remainder of the Watershed

Table 4. Near Lake Zone Revised Assumptions: Proportion of Developable Land Assumed for Each Lot Size

Lot Size (acres)	Percent of Developable Land
1.5	15%
3	35%
5	35%
6.5	7%
9.5	8%

Table 5. Baseline Scenario 1 Development Summary

Location	Lot Size	Acres of Developable Land	Percent Developable Land in Zone	Households	Percent Total Households in Zone
Near Lake Zone	Non-residential	170	1.3%	NA	NA
	Future < 3-acre lots	2,000	14.7%	1,330	30.4%
	Future 3- to 5-acre lots	9,320	68.5%	2,490	56.9%
	Future > 5-acre lots	2,100	15.5%	250	5.7%
	Existing lots	NA	NA	300	6.9%
	Total	13,590		4,370	
Remainder of Watershed	Non-residential	110	0.3%	NA	NA
	Future 5-acre lots (average lot size)	5,400	14.0%	1,080	24.1%
	Future 10-acre lots (average lot size)	32,960	85.7%	3,300	73.7%
	Existing lots	NA	NA	100	2.2%
	Total	38,470		4,480	
Whole Watershed	Total	52,060		8,850	

3.1.6 Scenario 1A Baseline Buildout Assumptions

CAW requested that Tetra Tech model a variation on Baseline Scenario 1. This variation, Scenario 1A, assumed that the remaining developable land surrounding roughly the eastern half of Lake Maumelle near the intake (CAW Zone 1) will be purchased by CAW. This change reduces developable land in the Near Lake Zone by about 1,500 acres and reduces the number of households by about 500. A comparison between Baseline Scenarios 1 and 1A will help determine how future development near the intake will impact Lake Maumelle water quality and how land acquisition could help to reduce this impact.

3.1.7 Scenario 2 Baseline Buildout Assumptions - Sensitivity Analysis

The TAC agreed that a sensitivity analysis should be conducted using an alternative baseline scenario that assumes a higher density for developable land in subwatersheds closest to the lake. This "what if" scenario is to reflect potential higher demand for condominiums and small-lot development because of changing demographics, proximity to Little Rock, and a desire to be closer to the lake.

For comparative purposes, Tetra Tech assumed that households in the Near Lake Zone would roughly double the number of households predicted in Baseline Scenario 1. Next, Tetra Tech changed the pattern of development so that the majority of households would reflect high density housing types (approximately 40 percent of the households would be condominium or apartment development and 16 percent of the households would be on ½-acre lots) despite occupying a relatively small amount of land within the zone. Table 6 shows the results of the Baseline Scenario 2 assumptions, and Table A-2, summarizes the acres of land use by subwatershed for Baseline Scenario 2. Note that while comprising only 2 percent and 5 percent of the developable land, respectively, the multifamily and small lot (0.5 acre) categories would account for over half of the total projected households in the Near Lake Zone. If this pattern of development occurs, the watershed would build out over a much longer timeframe than estimated for Scenario 1 because of the increased population needed to fill the larger number of households. Tetra Tech also assumed more additional non-residential development along Highway 10, as shown in Figure 12.

Tetra Tech used Buildout Scenario 2 to conduct a baseline sensitivity analysis, comparing the potential impacts from the larger lot development characterized in Scenario 1 to the potential impacts from higher density development in the Near Lake Zone characterized in Scenario 2.

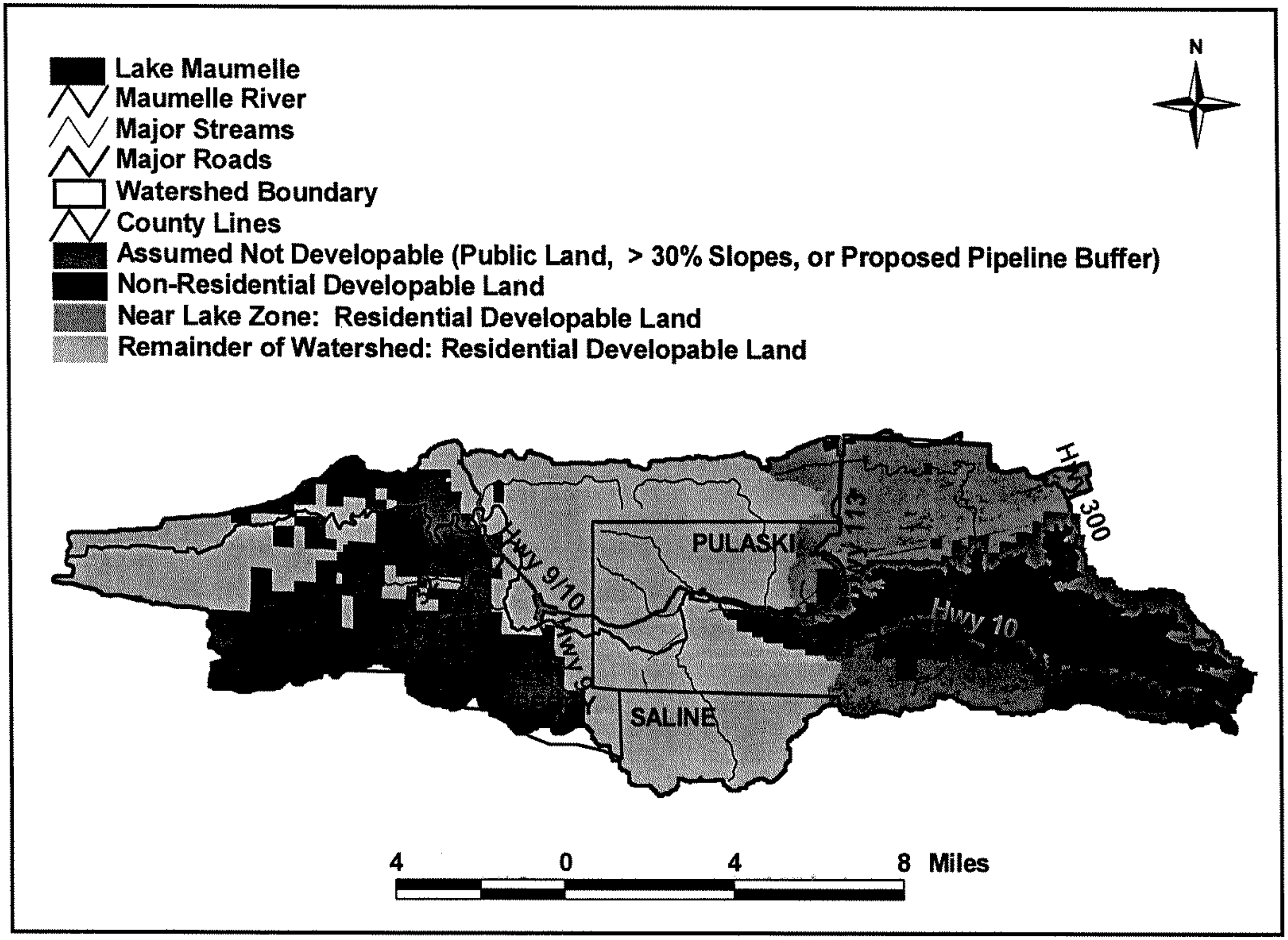


Figure 12. Baseline Scenario 2 – Developable Land in the Near Lake Zone and Remainder of the Watershed

Table 6. Baseline Scenario 2 Development Summary

Location	Lot Size	Acres of Developable Land	Percent Developable Land in Zone	Households	Percent Total Households in Zone
Near Lake Zone	Non-residential	220	1.6%	NA	NA
	Future Multifamily (condos, garden apartments)	300	2.2%	3,390	31.1%
	Future 0.5- to <1-acre lots	1,990	14.9%	3,970	36.3%
	Future 1-acre to 3-acre lots	2,680	20.0%	1,390	12.8%
	Future 3- to 5-acre lots	6,210	46.4%	1,550	14.2%
	Future > 5-acre lots	1,990	14.9%	300	2.8%
	Existing Households	NA	NA	300	2.8%
	Total	13,390		10,900	
Remainder of Watershed	Non-residential	190	0.5%	NA	NA
	Future 5-acre lots (average lot size)	5,350	13.9%	1,070	24.0%
	Future 10-acre lots (average lot size)	32,940	85.6%	3,290	73.8%
	Existing Households	NA	NA	100	2.2%
	Total	38,480		4,460	
Whole Watershed	Total	51,870		15,360	

3.1.8 Scenario 2A Baseline Buildout Assumptions

CAW requested that Tetra Tech model a variation on Baseline Scenario 2. This variation, Scenario 2A, assumed that the remaining developable land surrounding roughly the eastern half of Lake Maumelle near the intake (CAW Zone 1) will be purchased by CAW. This change reduces developable land in the Near Lake Zone by about 1,500 acres and reduces the number of households by about 1,200. A comparison between Baseline Scenarios 2 and 2A will help determine how future development near the intake will impact Lake Maumelle water quality and how land acquisition could help to reduce this impact.

3.1.9 Impervious Area Assumptions

Once the amount of developable land and projected number of households was determined, Tetra Tech developed assumptions for how much impervious surface and cleared pervious area would exist on future development. The baseline impervious surface assumptions are based on input from Tim Daters as well as USDA and USEPA estimates of typical impervious surface distributions for developments (USDA, 1986; USEPA, 2006). Table 7 lists the impervious and pervious surface assumptions for residential and non-residential land, listing the residential assumptions by lot sizes assumed in Baseline Scenarios 1, 1A, 2, and 2A.

Pervious area was divided into developed and undeveloped previous areas. Developed pervious areas represent land that has been cleared of forest and is maintained as lawn or another type of managed pervious area. Undeveloped pervious area represents land that has not been disturbed and is assumed to be forested.

The average amount of cleared area per lot was assumed to be 1 acre. Therefore, the developed pervious area for each lot size category accounts for 1 acre minus the driveway and building foot-print area. For lot sizes 1-acre or less, all pervious area was assumed to be cleared, managed pervious area. These assumptions were consistent with USEPA's assumptions based on current construction practices (USEPA, 2006). Table 7 presents the total impervious surface associated with each lot size, including the building footprint and driveway area as well as the new roads estimated in Section 3.1.3.

Table 7. Percentages of Impervious, Developed Pervious, and Undeveloped Pervious Area Assumed for Each Lot Size (Baseline Scenarios 1 and 2)

Lot Size (acres)	Impervious Surface	Developed Pervious	Undeveloped Pervious
0.1	68%	32%	0%
0.5	33%	67%	0%
1.5	19%	50%	31%
2.0	16%	38%	46%
3.0	12%	25%	62%
4.0	11%	19%	71%
5.0	9%	15%	76%
6.5	7%	12%	81%
6.7	7%	11%	82%
9.5	4%	8%	88%
10.0	4%	7%	88%
Non-Residential	70%	30%	0%

3.2 Wastewater Assumptions for Future Scenarios

Under existing conditions there are 640 residences in the watershed. These are assumed to be served by properly functioning subsurface wastewater disposal systems for the purposes of the baseline analysis. While some households may have failed systems or direct discharges, their contribution is insignificant in terms of load to the lake under the existing sparse development. Therefore, no separate wastewater load is simulated for existing conditions. This provides a conservative basis for comparison and is also consistent with the approach taken in the model calibration.

A result of the large project increase in development is the production of significant amounts of wastewater from residential and commercial land uses. Even when properly managed, this wastewater can contribute significant levels of nutrients and other pollutants. It is likely that some wastewater generated under the watershed will be pumped out and treated elsewhere. However, there are no regulations in place that guarantee that this will occur. Therefore, for the baseline analysis it is appropriate to assume that all wastewater is disposed within the watershed.

To simulate wastewater loads for the future scenarios, Tetra Tech assumed that three types of localized systems would be used in the watershed to accommodate development. Pollutant concentrations by system type were defined for nutrients, total organic carbon, biochemical oxygen demand (BOD_5), total suspended solids, and fecal coliform. Wastewater loads were calculated from the per capita wastewater flow rate suggested by ADEQ (125 gal/capita/day), the pollutant concentrations from each system, and the estimated number of people served by each type of system under the future scenarios.

Future Scenario 1 features a majority of large lot development based on stakeholder input and growth trends. For this scenario, all households situated on less than 5-acre lots were assumed to be serviced by package treatment plants (approximately 2,900). All households with greater than 5-acre lots were assumed to be serviced by subsurface systems (e.g., septic or alternative) or individual discharge units. The SSURGO soils data for the Lake Maumelle watershed provides two subsurface ratings: "somewhat limited" and "very limited." About 6 percent of developable land in the Lake Maumelle watershed is classified as "somewhat limited," and Tetra Tech assumed that these areas would be suitable for subsurface systems for lot sizes 5 acres and greater. About 600 households were assumed to be serviced by subsurface systems, and about 5,400 households were assumed to use individual discharge units under Baseline Scenario 1. Existing households were assumed to be either on subsurface or individual discharge systems depending on soil suitability.

Scenario 2 represents a buildout scenario with higher density assumed near the lake. This scenario has more high-density developments such as townhouses, condomiums, and houses on smaller lots (0.5 to 3 acres) that will contribute additional wastewater loading compared to Scenario 1. Scenario 2 assumes approximately 500 households served by subsurface systems; 6,100 households served by individual discharge systems; and 8,800 households served by package treatment plants.

Both scenarios assume some level of commercial development as well. Scenario 1 assumes approximately 280 acres of commercial development and Scenario 2 assumes approximately 410 acres of commercial development. For every one acre of impervious surface from commercial development, Tetra Tech assumed seven people per day served by package treatment plant (adapting information from USEPA, 2002).

Tetra Tech assumed an average household size of 2.5 people based on input from ADEQ. Table 8 compares the number of people served by subsurface systems, individual discharge systems, and package treatment systems (including loads from commercial development) for each of the two future scenarios.

Table 8. Number of People Served by the Three Types of Wastewater Treatment Systems Under Future Scenarios

Scenario	Subsurface Systems	Individual Systems	Package Systems	Total
1 – Large Lot	1,515	13,395	8,587	23,497
2 – Higher Density	1,312	15,225	23,893	40,431

Three types of localized wastewater treatment systems are assumed to handle wastewater loads for the future scenarios. The following sections describe the assumptions used to determine pollutant loading by system type.

3.2.1.1 Onsite Subsurface Discharge Systems

A small fraction of developed lots are located on soils that are somewhat suitable for subsurface discharge systems. Without engineering modifications to improve drainfield areas for the baseline analysis – which is intended to evaluate the reasonable maximum potential impact of development – it was assumed that onsite subsurface disposal would be employed only where native soils are suitable for such uses without modification. Subsurface systems in Arkansas are assumed to fail 15 percent of the time due to poor site characteristics and lack of maintenance (USEPA, 2000). Tetra Tech assumed that 15 percent of the per capita wastewater flow rate (18.75 gal/capita/day) will reach water pathways either by short circuiting or by surfacing and flowing over the land surface. It is assumed that failing systems are not treated in the subsurface drain field where the majority of treatment typically occurs. To estimate pollutant concentrations from failing systems, Tetra Tech gathered data from several studies that report typical ranges of pollutant concentrations measured in subsurface tank effluent before discharge to the drain field. The upper end of each concentration range was used as the pollutant concentration because minimal treatment will occur in the tank of a failing system. Table 9 lists the pollutant concentrations and assumptions used to generate the wastewater loads from subsurface discharging systems.

Table 9. Pollutant Concentrations Assumed from Failing Subsurface Systems

Parameter	Units	Value	Assumption (Reference)
Flow	gal/d	18.75	Assume 15 percent failure of subsurface systems
Solids	mg/L	100	Tank effluent concentration (Siegrist et al., 2000)
Ammonia as N	mg/L	10	Assume that 10 percent of TN will reach waterbody as ammonia
Nitrate as N	mg/L	75	Assume that majority of TN in tank effluent will be in nitrate form when it reaches waterbody
Total Nitrogen	mg/L	100	Tank effluent concentration (Siegrist et al., 2000)
Phosphate as P	mg/L	15	Tank effluent concentration (Hoover et al., 1998)
Total Phosphorus	mg/L	20	Tank effluent concentration (USEPA, 1980)
Total Organic Carbon	mg/L	70	Tank effluent concentration (Wilhelm et al., 1996)
BOD_5	mg/L	200	Tank effluent concentration (Siegrist et al., 2000)
Fecal Coliform	#/100 ml	1,000,000	Tank effluent concentration (USEPA, 1980; Hoover et al., 1998)

3.2.1.2 Individual Surface Discharge Systems Covered by General Permit

Arkansas regulations allow individual surface discharges of wastewater when subsurface disposal is not feasible. Unless restricted, such systems are likely to be seen as cost-effective options in areas of dispersed development.

Arkansas DEQ offers a general permit (Number ARG550000) for surface discharge systems that treat less than 1,000 gal/d of domestic sanitary wastewater. This permit lists monthly average concentration limits for BOD_5, TSS, and fecal coliform and states that the level of treatment should exceed secondary levels (ADEQ, 2003). Most of these systems discharge through approximately 100 ft of perforated pipe before surfacing to ground. Pollutant concentrations for the other parameters of concern were based on concentrations reported from secondary treatment systems (Table 10). Note that variability in system performance, particularly systems that are not maintained properly, may result in higher loading to the lake compared to concentrations reported below, which assume properly functioning systems.

Table 10. Pollutant Concentrations Assumed from Surface Discharging, Individual Treatment Systems

Parameter	Units	Value	Assumption (Reference)
Flow	gal/d	93.75	Assume 25% hydraulic retention as effluent passes through perforated pipe in soil
Solids	mg/L	20	General permit limit (ADEQ, 2003)
Ammonia as N	mg/L	10	Effluent concentration for onsite secondary treatment (Hoover et al., 1998)
Nitrate as N	mg/L	40	Assume majority of TN has been nitrified in aerobic unit
Total Nitrogen	mg/L	60	Aerobic Unit Effluent Concentration (Siegrist et al., 2000)
Phosphate as P	mg/L	7	Assume 70 percent of TP in secondary effluent is in phosphate form (USEPA, 1997)
Total Phosphorus	mg/L	10	Aerobic Unit Effluent Concentration (Siegrist et al., 2000)
Total Organic Carbon	mg/L	18.8	Assume total organic carbon is equivalent to 94 percent of BOD_5 (USEPA, 1997)
BOD_5	mg/L	20	General permit limit (ADEQ, 2003)
Fecal Coliform	#/100 ml	200	General permit limit (ADEQ, 2003)

3.2.1.3 Package Treatment Systems Discharging to Surface Water

In areas of sufficient housing density, local wastewater collection and treatment system (package systems) are likely to be a cost-effective alternative.

Arkansas DEQ requires an individual permit to discharge to surface water if a systems treats more than 1,000 gal/d. The Technical Advisory Committee (TAC) for the Lake Maumelle Watershed indicated that lot sizes 3 acres or less would likely be developed with package treatment systems. Individual permit limits vary, so Tetra Tech searched the EPA point source discharge database for permits assigned to subdivisions in Arkansas. Table 11 lists the upper end of pollutant concentrations found in subdivision permits. These numbers represent conservative estimates for pollutant limits that could be permitted for systems in the Lake Maumelle Watershed. Some permits listed fecal coliform limits of 1,000/100 mL, but Tetra Tech has assumed that concentrations of 200/100 mL will be required of these systems because Lake Maumelle is a water supply watershed. Note that variability in system performance, particularly systems that are not maintained properly, may result in higher loading to the lake compared to concentrations reported below, which assume properly functioning systems.

Table 11. Pollutant Concentrations Assumed for Surface Discharging, Package Treatment Systems

Parameter	Units	Value	Assumption (Reference)
Flow	gal/d	125	ADEQ recommended rate
Solids	mg/L	20	EPA PCS query for subdivisions in Arkansas
Ammonia as N	mg/L	12[1]	EPA PCS query for subdivisions in Arkansas
Nitrate as N	mg/L	40	Assume majority of TN has been nitrified in aerobic unit
Total Nitrogen	mg/L	60	Aerobic Unit Effluent Concentration (Siegrist et al., 2000)
Phosphate as P	mg/L	7	Assume 70 percent of TP in secondary effluent is in phosphate form (USEPA, 1997)
Total Phosphorus	mg/L	10	Aerobic Unit Effluent Concentration (Siegrist et al., 2000)
Total Organic Carbon	mg/L	18.8	Assume total organic carbon is equivalent to 94 percent of BOD_5 (USEPA, 1997)
BOD_5	mg/L	20	EPA PCS query for subdivisions in Arkansas; midpoint of range suggested by ADEQ
Fecal Coliform	#/100 ml	200	EPA PCS query for subdivisions in Arkansas

[1] The ammonia concentration will be decreased in future iterations based on recent conversations with ADEQ concerning toxicity in near-dry streams (ADEQ, 2006). This change will cause an increase in nitrate concentration as the overall treatment performance is assumed the same. This change in speciation is not expected to significantly impact modeling results as the predicted eutrophication in the lake depends on the total inorganic fraction, not just the ammonia.

3.3 Summary of Model Input for Baseline Analysis

Four future development scenarios were compared to existing conditions for the baseline analysis. Scenario 1 assumes that the majority of development will occur in the Near Lake Zone in 3- to 5-acre residential lots. Scenario 2 assumes more high density residential development in the Near Lake Zone. Scenarios 1A and 2A are variations on Scenarios 1 and 2, respectively, with the assumption that CAW will acquire approximately 1,500 acres of developable land near the intake to reduce the impact in that area. Table 12 summarizes the land use and wastewater assumptions for these scenarios.

Table 12. Summary of Baseline Analysis Modeling Scenarios

Scenario	Existing	1	1a	2	2a
Land Cover Type (acres)					
Pervious Area (Undeveloped)	77,580	67,100	67,650	65,490	66,210
Pervious Area (Developed)	500	7,230	6,860	8,090	7,630
Impervious Area	670	4,420	4,240	5,170	4,910
Waste Water Systems (number of households)					
Septic System	*	610	600	530	520
Package Plant	0	2,880	2,560	8,740	7,770
Individually Discharging System	*	5,360	5,240	6,090	5,890
Total Households	640	8,850	8,400	15,360	14,180

* The small number of existing households are assumed to be served by functioning septic systems for the purposes of the baseline analysis.

4 Evaluation Metrics

Conditions predicted by the baseline analysis are interpreted in relationship to management goals and objectives. Ability to achieve these objectives is analyzed through comparison to quantitative target values of selected indicators.

The Lake Maumelle Watershed Assessment is being undertaken using a structured quality objectives process, as described in Modeling quality Assurance Project Plan for Lake Maumelle Watershed Planning Project (Tetra Tech, 2005). At the most general level, Tetra Tech worked with the Policy Advisory Council (PAC) to define the overarching goals of the management plan and associated specific objectives (Table 13).

Table 13. Draft Goals and Objectives

Endorsed 12/8/05 by the Policy Advisory Council

Overarching Goals of the Watershed Management Plan

- Maintain long-term, abundant supply of high quality drinking water for present needs and continuing growth of the community.
- Provide an equitable sharing of costs and benefits for protecting Lake Maumelle.

Objectives

(Note: It is assumed that only management options that comply with environmental regulations, such as water quality standards, will be considered.)

Minimize risks to public health from: • toxic spills • pesticide/herbicide runoff • bacteria/pathogens from failing septic/community systems and animal wastes • toxins from blue-green algae	(most important)
Minimize impacts on watershed property owners and residents including: • use restrictions • cost of BMPs	(most/more important)
Minimize water supply taste, odor, and color problems associated with: • algae • iron and manganese • turbidity	(more important)
Minimize impact on the water supply intake and water treatment facility operations such as: • intake/filter clogging • excess chemical additive requirements • increased operation and maintenance (O&M)	(more important)
Minimize rate increases from: • increased treatment costs • increased O&M • land acquisition/buffer easements	(more important)

Minimize loss of reservoir water supply storage capacity from sedimentation	(important)
Minimize risk of impairment to tributary streams in the watershed for stream and lake protection from: • channel instability (erosion, sedimentation, scour) • pollution from runoff (sediment, nutrients, pesticides/herbicides, pathogens)	(important)
Allow limited recreation that reflects environmentally sound stewardship of the lake for: • fishing • sailing • boating • access (picnicking, hiking, visiting)	(important)
Meet other community values including: • Be economically competitive • Provide a strong tax base for communities in the region and minimize tax increases • Be administratively feasible	(important)

Following agreement on the goals and objectives, a series of principal study questions was developed. These study questions link stressors or sources of risk to threats to achieving objectives. For each study question a measurement endpoint or indicator was proposed as a basis for evaluation of status relative to the management objectives.

The full set of study questions and indicators will be found in Tetra Tech (2005), Table 3. Some of the indicators are addressed with the watershed-scale water quality models presented in this report. Others will need to be addressed with different types of tools (e.g., site-scale models, costing analyses, etc.) that are outside the scope of the baseline assessment report. The main study questions addressed in the baseline assessment or to be addressed during management scenario evaluations are summarized in Table 14.

Table 14. Subset of Study Questions, Indicators, and Assessment Tools Addressed in the Baseline Assessment

Threats	Sources	Analysis Questions	Indicators	Scales	Models/Methods
Toxics					
• Spills	Accidents at bridge crossings, roads, and storage areas Improper management at storage areas	• How long to reach WS intake? • How potent at intake? • How can management affect delivery or potency?	Time-of-travel Concentration - conservative - non-conservative	Watershed Lake Response	Time-of-travel model (GBMM & HSPF) EFDC & CE-QUAL-W2
• Pesticides/herbicides	Applications (forestry, turf farms, golf courses, residential/commercial landscaping)	(Screen first to determine if potential for significant threat; if yes, same questions apply as for spills)	Time-of-travel Concentration - conservative - non-conservative	Watershed Lake Response	GBMM & HSPF EFDC & CE-QUAL-W2
• Disinfection byproducts	Reaction between disinfection chemicals and TOC in raw water (affected by algae)	• How much algae or TOC change must occur in the lake to affect THM production?	Total Organic Carbon (TOC)	Watershed Lake Response	HSPF CE-QUAL-W2
• Algal toxins	Produced by some forms of blue-green algae; related to nutrient enrichment; loading from developed areas, turf farms, golf courses; waste systems	• How much nutrient loading needed before lake productivity levels exceed threshold levels? • How can management affect amount and delivery of nutrients?	Chlorophyll *a* (productivity measure) Phosphorus & Nitrogen	Watershed Lake Response	HSPF CE-QUAL-W2 w/ EFDC

Threats	Sources	Analysis Questions	Indicators	Scales	Models/Methods
Algae					
• Taste and odor, color • Impact treatment • Impact aesthetics • Impact DO/fishery	Excessive algae related to nutrient enrichment; loading from developed areas, turf farms, golf courses; waste systems	• How much nutrient loading needed before lake productivity levels exceed threshold levels? • How can management affect amount and delivery of nutrients?	Chlorophyll *a* (productivity measure) Phosphorus & Nitrogen Loads	Watershed Lake Response	HSPF CE-QUAL-W2 w/ EFDC
Pathogens					
• Impact on WS • Impact on secondary recreation	Failing septic/community systems; direct discharge; animals (livestock, wildlife, pets)	• How much loading will threaten uses? • How can management affect amount and delivery of pathogens?	Fecal coliform/E-Coli (check w/ DEQ) Cryptosporidium/ Giardia	Watershed Lake Response	HSPF CE-QUAL-W2 w/ EFDC
Sediment					
• Impacts on treatment • Impacts on storage • Impacts on water clarity • Impacts on tributary stability & habitat	Land disturbance (clear-cutting, tilling, construction, forest fires, off-road ATVs, post-construction runoff); stream channel erosion	• How much loading before thresholds exceeded? • How can management affect amount and delivery of sediment	Sediment Load Channel Instability Turbidity/Secchi Depth	Watershed Lake Response	HSPF CE-QUAL-W2 w/ EFDC

Target values of the indicators to guide management were then developed in an iterative process with the Technical Advisory Council (TAC) and the PAC. Tetra Tech summarized existing monitoring data on the indicators and presented results of preliminary baseline runs to guide the evaluation process. A list of key indicators and associated targets were then adopted at the PAC meeting of March 16, 2006. These are summarized in Table 15.

Table 15. Key Indicators and Target Values for Lake Maumelle Endorsed by the PAC

INDICATOR: Chlorophyll *a*		
Location: Mid-Lake	Target: 3.5 μg/L summer median	Existing: 2.8 μg/L summer median
Location: Lower Lake	Target: 3.0 – 3.5 μg/L summer median	Existing: 2.8 μg/L summer median
Explanation: Welch and Jacoby, renowned limnologists, indicate that the boundary between oligotrophy and mesotrophy occurs at 3.5 μg/L. To protect the water supply to oligotrophic conditions, it is recommended that a target of 3.5 μg/L chlorophyll *a* be applied at the mid-lake evaluation point, and that 3.0 to 3.5 μg/L be used as a safety factor at the lower lake evaluation point near the water supply intake (i.e., achieve as close as possible to 3.0 μg/L but do not exceed 3.5 μg/L). The summer growing season is defined as May through September.		

INDICATOR: Total Organic Carbon (TOC)		
Location: Lower Lake (Intake area)	Target: As close to existing concentrations as possible.	Existing: 2.4 mg/L annual median
Explanation: New disinfection byproducts regulations under the Safe Drinking Water Act require that Central Arkansas Water keep its annual running average (calculated quarterly) concentration of TOC under 2 mg/L in the finished drinking water. The CAW treatment system conservatively removes 35 percent of TOC from the raw water intake concentrations. Back-calculating from the finished target to the intake using the 35 percent removal rate produces an approximate target at the intake of 3.1 mg/L. Between August 1999 and January 2006, Arkansas Department of Health quarterly monitoring data indicated raw water concentrations ranged from 1.72 to 3.75 mg/L with median 2.65 mg/L. During that time frame, the highest finished water TOC concentration was 1.93 mg/L. Because the existing levels are close to the 3.1 mg/L boundary, the recommended target is to remain as close to existing levels as possible. The model-predicted annual median for existing conditions is 2.4 mg/L at the lower lake evaluation point (January 1997–September 2004 simulation). Since future evaluations will be done using the model, the 2.4 mg/L value will be used as the desired target for scenario performance comparisons.		

INDICATOR: Turbidity (use modeled Secchi depth as surrogate)		
Location: Lower Lake (Intake area)	Target: ≤ 0.2 m Secchi depth reduction in annual median	Existing: 2.5 m annual median
Explanation: The Enhanced Surface Water Treatment Rule requires that turbidity in finished filtered water be ≤ 0.3 NTU. The intent of the Enhanced Surface Water Treatment Rule is to reduce the risk of specific microbial pathogens such as *Cryptosporidium*. Current raw water turbidity ranges from 1 to 5 NTU, with an average of 2.6 NTU over the past 15 years (personal communication, Gary Hum, CAW). Increases in turbidity result in increased treatment cost (e.g., estimated increase in alum dosage = 30 percent to treat water with 9 NTU, per Gary Hum) and increased risk of other contaminants. The lake model does not directly estimate turbidity, but does predict Secchi depth which can be used as a surrogate for turbidity. The empirical relationship between Secchi depth and turbidity for the USGS data is relatively strong (0.77 r^2). Establishing a target of ≤ 0.2 m Secchi depth reduction in annual median should maintain turbidity levels within 1 NTU of existing levels.		

INDICATOR: Fecal Coliform Bacteria		
Location: Lower Lake (Intake area)	Target: < one order of magnitude increase from existing annual median concentration (interpreted as < 0.065 #/100ml)	Existing: 0.0065 #/100ml annual median
Explanation: The concentrations of fecal coliform bacteria being predicted for the future are not in and of themselves considered to be a threat. However, fecal coliform is being used as a surrogate indicator for the potential increase of other microbial pathogens such as *Cryptosporidium* and *Giardia*. These pathogens are likely present in minute amounts under current conditions, but have not been detected in CAW sampling. Health authorities typically examine risk in terms of the orders of magnitude of reduction in pathogen concentration between sources and water supply lines. By keeping the fecal coliform bacteria indicator concentration changes for future scenarios below one order of magnitude (factor of 10), the increase in risk of other microbial pathogens should also be minimized.		

Specific targets were not adopted for other indicators, such as sediment load and time of travel. However, scenarios can still be compared on a relative basis using these indicators.

5 Results of Baseline Analysis

Results of the baseline analysis are briefly summarized below and in the attached graphics, beginning with watershed loads, moving to lake response, and finishing with the initial time-of-travel analysis.

5.1 WATERSHED MODEL RESULTS

Watershed loading indicators previously selected with input from the councils include sediment, total phosphorus (TP), total nitrogen (TN), total organic carbon (TOC), and fecal coliform. This section presents the HSPF watershed loading results first as total load to the lake and then by loading zone. The loading zones correspond to subbasin groupings based on proximity to a USGS water quality gage or inlake target (Figure 13). The upstream zone, shown in tan, includes all areas draining to the lake above the Highway 10 Bridge where the Maumelle River enters the lake (Subbasins 1 through 16). Loads from this zone are expected to impact USGS water quality gage 072632966. The middle zone, shown in green, corresponds to near-lake areas draining to the western half of the lake (Subbasins 17 through 25). This drainage area is expected to influence the mid-lake target. The lower zone, shown in yellow, drains the near-lake subwatersheds on the eastern side of the lake (Subbasins 26 through 32). This area is expected to have the most direct impact on water quality at the intake target, USGS gage 072632995.

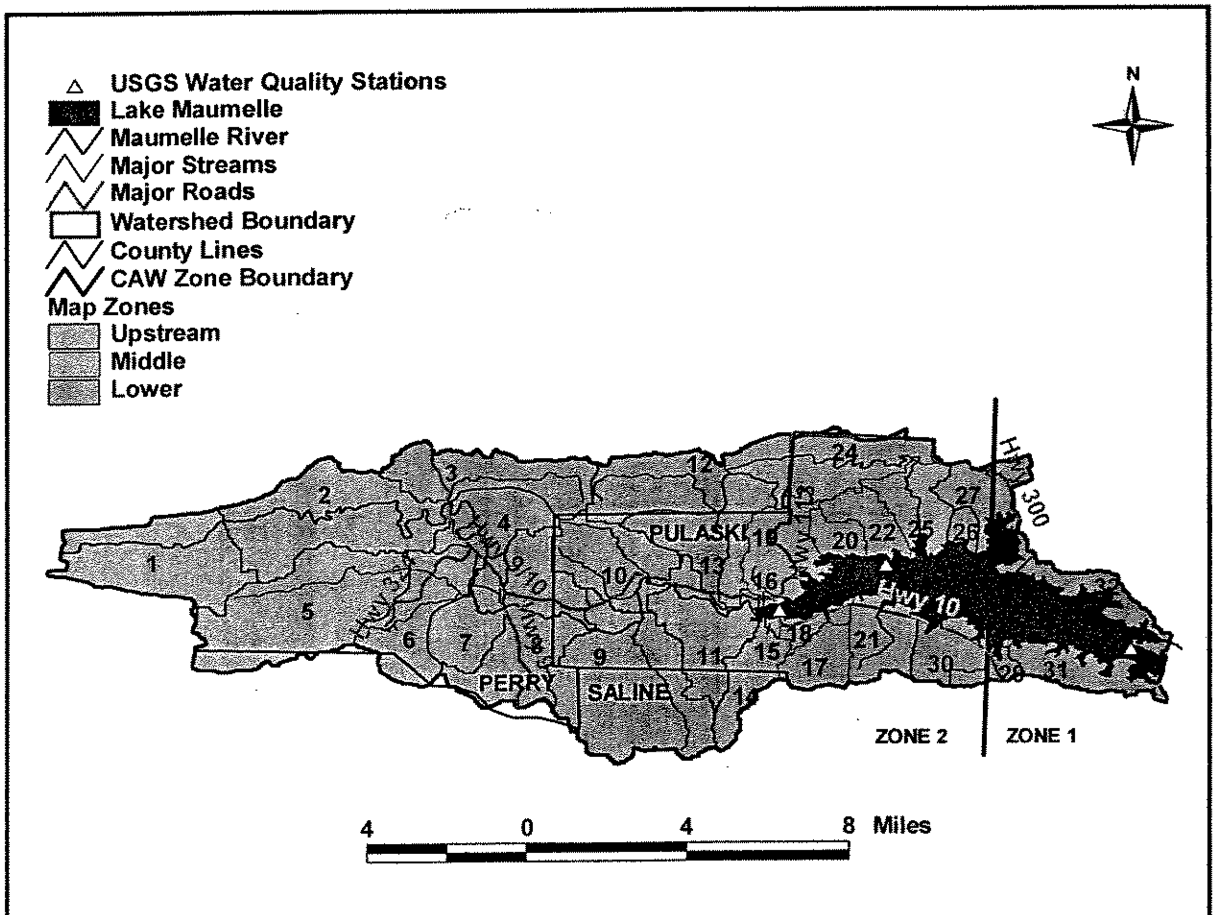


Figure 13. Lake Maumelle Watershed Loading Zones

Each loading zone graphic contains a location map showing which zone is being summarized, bar graphs comparing existing loads to future loads, and a table indicating the percent increase above the existing total load reflected by the future baseline scenarios (with the relative portion attributed to point and nonpoint sources respectively). For the Lower Zone, graphs are also shown for Scenarios 1A and 2A. These represent an alternate assumption that all remaining developable land in the currently defined CAW Zone 1 is purchased and left undeveloped (approximately 1,500 acres). [Note that this is not a comparison or test of any previously proposed developments. Rather it is a baseline analysis showing the impact of this change in zone from being developed as might occur under the Scenario 1 and 2 definitions, providing an example indication of the magnitude of potential point and nonpoint loading impact that would need to be managed under those scenarios.]

5.1.1 Sediment Loads to Lake Maumelle

Loading of sediment is of potential concern for several reasons. Deposition of sediment could, over time, decrease the storage capacity of the lake. Increased fine sediment loads will also lead to decreased water clarity. Finally, sediment transports other pollutants, such as phosphorus and metals, which tend to sorb to soil particles.

Impacts on water clarity depend on the size of sediment particles, their settling rate, and transport through the lake. These impacts are difficult to assess from gross sediment load, but can be evaluated through use of the lake model. Loading of sediment-sorbed pollutants is addressed directly through analysis of changes in those constituents.

Predicted sediment load increases above existing conditions for Baseline Scenario 1 range from 55 percent in the Upper Zone subwatersheds to 186 percent in the Middle Zone subwatersheds. The overall increase for the total watershed under Baseline 1 is 90 percent. As would be expected, the vast majority of sediment load is predicted to come from nonpoint sources (small amounts of sediments and solids are discharged by wastewater facilities). The additional increases predicted for Baseline 2 relative to Baseline 1 only occur in the near lake area (because the higher development density assumptions are only for the near lake zone under this scenario), so the predicted increase in the upper zone only rises from 55 to 56 percent, whereas the increase in the middle zone rises from 186 to 254 percent, and the increase in the lower zone rises from 142 to 193 percent.

Effects on storage capacity can be evaluated by assuming that the sediment loaded to the lake will have an approximate density of 2.2 g/cm^3, which means that one English ton of sediment load will exhaust approximately 0.41 cubic meters of lake volume if it settles out within the lake. The current full pool capacity of the lake is $2.70 \cdot 10^8$ cubic meters, so loss of capacity due to sedimentation is expected to be slow. For comparison, we can look at the total capacity loss over 100 years with the different scenarios (Table 16).

Table 16. Comparison of Capacity Loss in Lake Maumelle Under Different Baseline Scenarios

Scenario	Sediment Load (t/yr)	Capacity Loss over 100 years (m^3)	Fraction of Capacity Loss over 100 years
Existing	2,539	$1.04 \cdot 10^5$	0.04 %
Baseline 1	4,822	$1.98 \cdot 10^5$	0.07 %
Baseline 2	5,316	$2.18 \cdot 10^5$	0.08 %

While the total loss of capacity is likely to be small under all scenarios, localized effects may occur. Much of the sediment loading occurs through the Maumelle River, to the head of the lake, and much of the sedimentation will be focused in the area upstream of the Highway 10 causeway. Significant shoaling could occur in this area, as well as in some other localized inlet areas that trap incoming sediment.

Table 17 summarizes sediment loads from nonpoint and point sources in the Lake Maumelle Watershed from each loading zone. Loads are given in tons per year. The values in parentheses represent the areal loading rate from each zone in pounds per acre per year.

Table 17. Sediment Loads (t/yr) from Nonpoint and Point Sources in the Lake Maumelle Watershed by Zone (areal loading in lb/ac/yr in parentheses)

Scenario	Upstream	Middle	Lower	Total
Loads From Nonpoint Sources				
Existing	1,781 (62)	509 (72)	249 (67)	2,539 (64)
Baseline 1	2,759 (96)	1,437 (204)	591 (159)	4,788 (122)
Baseline 1A	2,759 (96)	1,437 (204)	452 (122)	4,648 (118)
Baseline 2	2,781 (97)	1,753 (249)	701 (188)	5,234 (133)
Baseline 2A	2,781 (97)	1,753 (249)	514 (138)	5,048 (128)
Loads From Point Sources				
Existing	0 (0)	0 (0)	0 (0)	0 (0)
Baseline 1	5 (0.2)	18 (2.6)	10 (2.8)	34 (0.9)
Baseline 1A	5 (0.2)	18 (2.6)	6 (1.6)	30 (0.8)
Baseline 2	6 (0.2)	50 (7.2)	26 (7)	82 (2.1)
Baseline 2A	6 (0.2)	50 (7.2)	15 (4)	71 (1.8)
Total Load				
Existing	1,781 (62)	509 (72)	249 (67)	2,539 (64)
Baseline 1	2,764 (97)	1,455 (207)	601 (162)	4,822 (122)
Baseline 1A	2,764 (97)	1,455 (207)	458 (123)	4,678 (119)
Baseline 2	2,787 (97)	1,803 (256)	727 (196)	5,316 (135)
Baseline 2A	2,787 (97)	1,803 (256)	529 (142)	5,119 (130)

Figure 14 shows the sediment load to Lake Maumelle for each baseline modeling scenario as well as the percent increase over existing conditions. Figure 15 displays the percent increase in terms of nonpoint and point source loads.

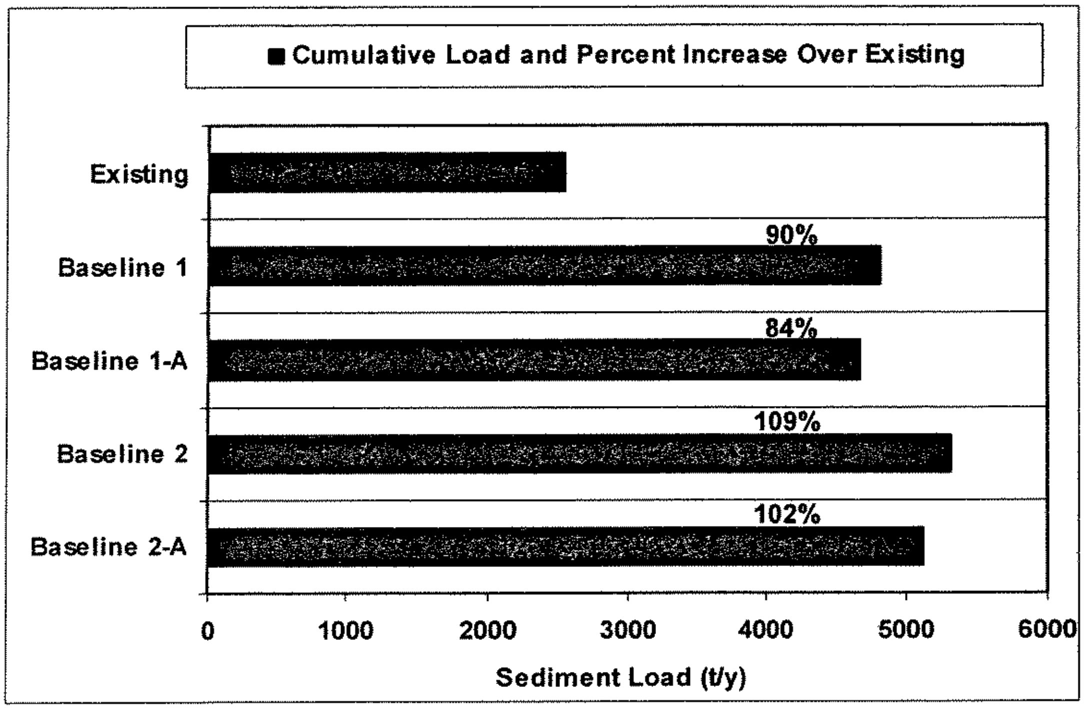


Figure 14. Total Annual Sediment Load to Lake Maumelle

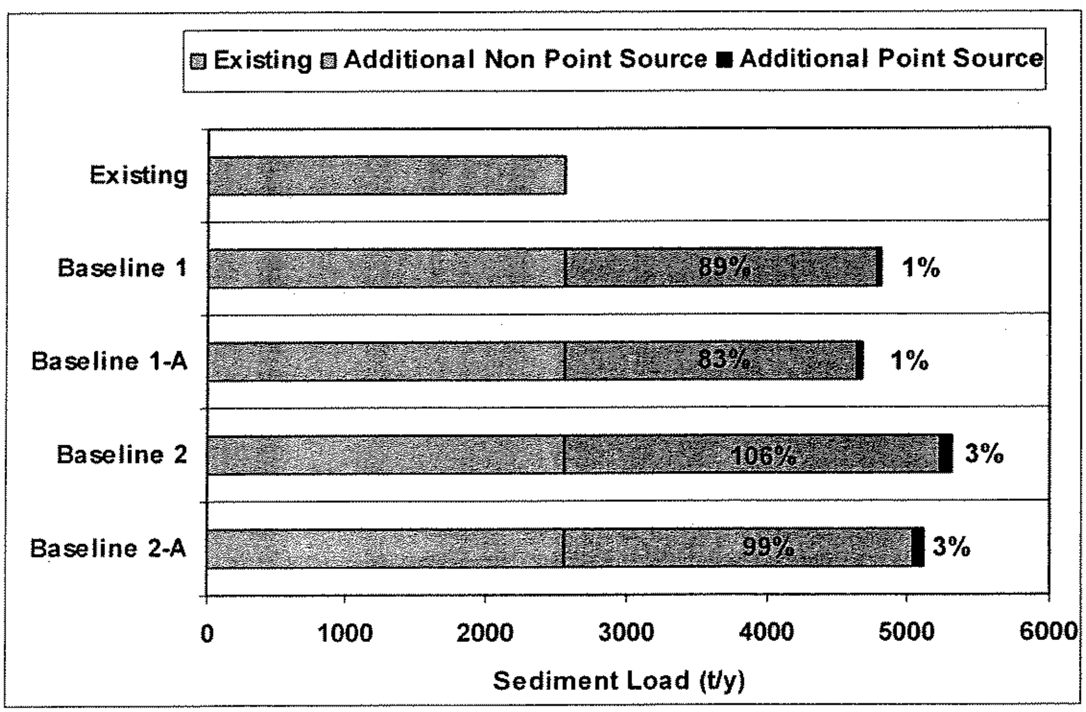


Figure 15. Point and Nonpoint Source Annual Sediment Loads to Lake Maumelle

Figure 16 through Figure 18 show the sediment load from each loading zone.

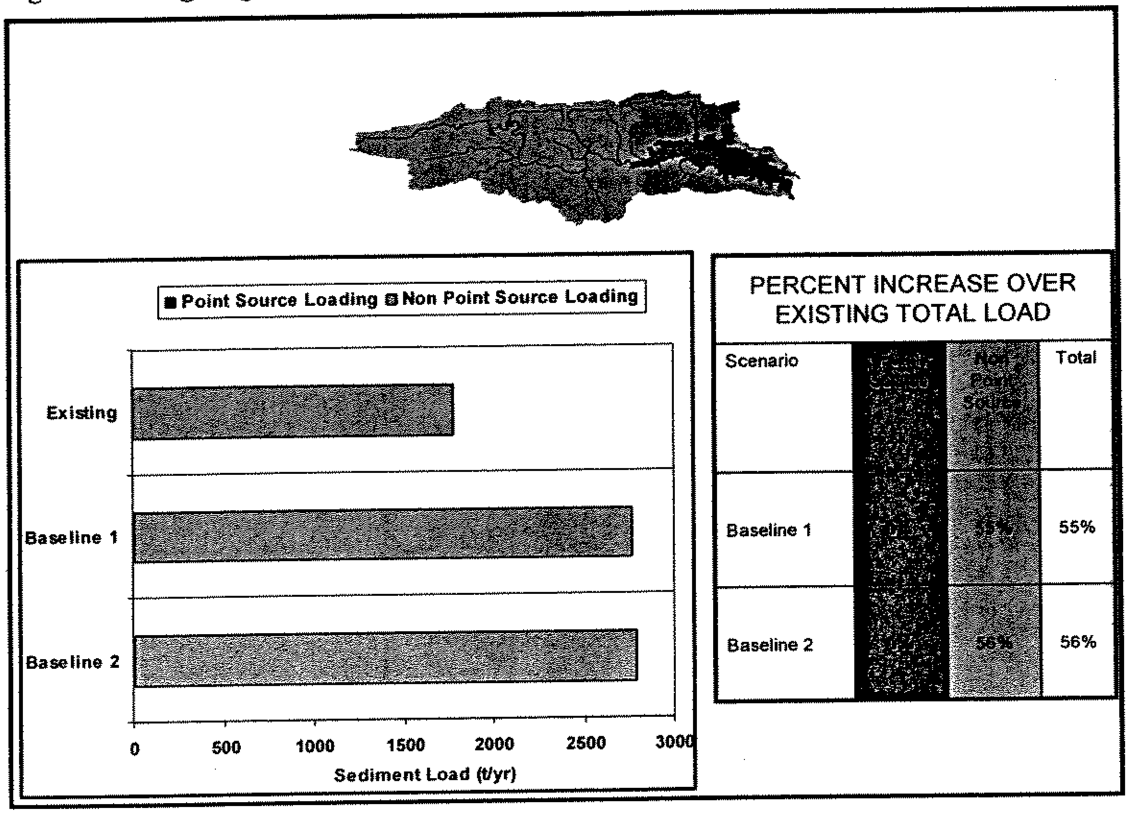
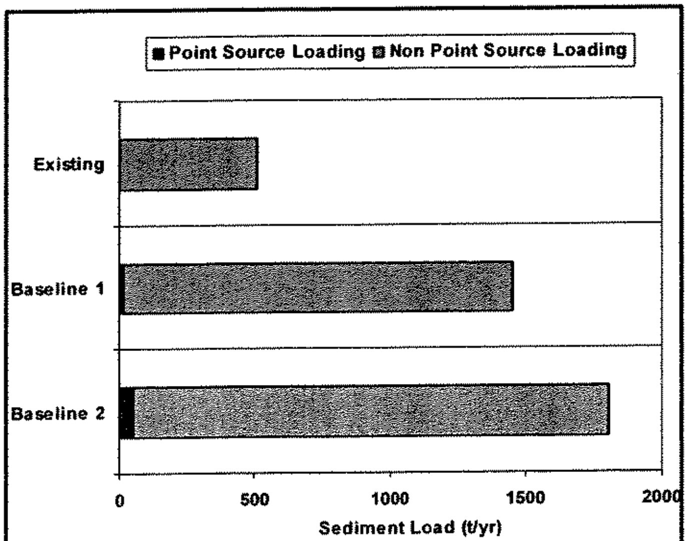


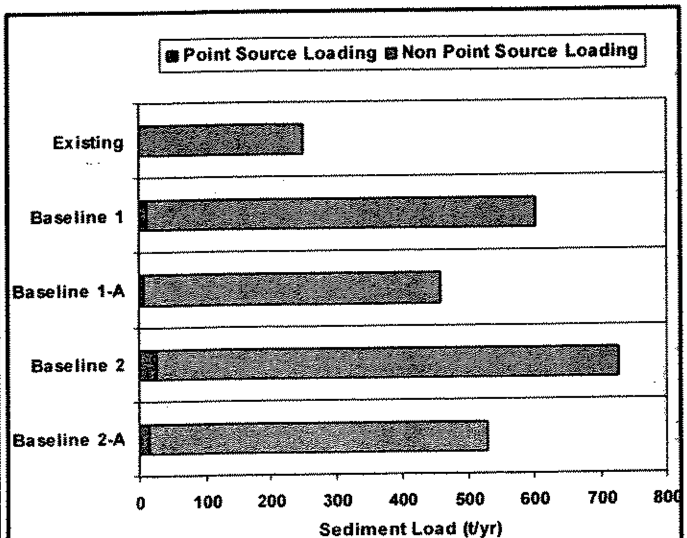
Figure 16. Annual Sediment Load from the Upstream Zone Subwatersheds



PERCENT INCREASE OVER EXISTING TOTAL LOAD

Scenario	[illegible]	Non Point Source [illegible]	Total
Baseline 1	[illegible]	[illegible]	186%
Baseline 2	[illegible]	244%	254%

Figure 17. Annual Sediment Load from the Middle Zone Subwatersheds



PERCENT INCREASE OVER EXISTING TOTAL LOAD

Scenario	[illegible]	Non Point Source	Total
Baseline 1	[illegible]	[illegible]	142%
Baseline 1-A	[illegible]	82%	84%
Baseline 2	[illegible]	182%	193%
Baseline 2-A	[illegible]	107%	113%

Figure 18. Annual Sediment Load from the Lower Zone Subwatersheds

5.1.2 Total Phosphorus Loads to Lake Maumelle

Under current conditions, Phosphorus loads to Lake Maumelle are small. Phosphorus load relative to existing conditions for the lake increased from approximately 780 percent for Baseline Scenario 1 to about 1,420 percent for Baseline Scenario 2. The vast majority of these increases are due to point source loading predictions, although nonpoint source loads account for about 80 and 100 percent increases above existing loading levels for the two scenarios, respectively.

The large increases in phosphorus loading could influence the equilibrium of nutrients in the lake, potentially shifting it from a phosphorus-limited state to a dual-limited system. Under Baseline Scenario 2, the ratio of TN to TP loading drops to 7.0 from the existing level of 14.3. This is a concern because enriched systems with low TN to TP ratios may favor the formation of blooms of cyanobacteria (blue green algae) that can produce toxins, form unsightly and filter-clogging scums, and contribute to taste and odor problems in the finished water.

Table 18 summarizes the loads from nonpoint and point sources in the Lake Maumelle Watershed from each loading zone.

Table 18. Phosphorus Loads (t/yr) From Nonpoint and Point Sources in the Lake Maumelle Watershed By Zone (Areal loading in lb/ac/yr in parentheses)

Scenario	Upstream	Middle	Lower	Total
Loads From Nonpoint Sources				
Existing	3.5 (0.1)	0.6 (0.1)	0.4 (0.1)	4.5 (0.1)
Baseline 1	5.5 (0.2)	1.9 (0.3)	0.9 (0.2)	8.3 (0.2)
Baseline 1A	5.5 (0.2)	1.9 (0.3)	0.7 (0.2)	8.1 (0.2)
Baseline 2	5.5 (0.2)	2.5 (0.3)	1.0 (0.3)	9.0 (0.2)
Baseline 2A	5.5 (0.2)	2.5 (0.3)	0.8 (0.2)	8.8 (0.2)
Loads From Point Sources				
Existing	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)
Baseline 1	13.3 (0.5)	13.2 (1.9)	5.1 (1.4)	31.6 (0.8)
Baseline 1A	13.3 (0.5)	13.2 (1.9)	3.0 (0.8)	29.5 (0.7)
Baseline 2	14.0 (0.5)	32.5 (4.6)	13.0 (3.5)	59.5 (1.5)
Baseline 2A	14.0 (0.5)	32.5 (4.6)	7.5 (2)	54.0 (1.4)
Total Load				
Existing	3.5 (0.1)	0.6 (0.1)	0.4 (0.1)	4.5 (0.1)
Baseline 1	18.8 (0.7)	15.1 (2.1)	6.0 (1.6)	39.9 (1)
Baseline 1A	18.8 (0.7)	15.1 (2.1)	3.7 (1)	37.6 (1)
Baseline 2	19.5 (0.7)	35.0 (5)	14.0 (3.8)	68.5 (1.7)
Baseline 2A	19.5 (0.7)	35.0 (5)	8.3 (2.2)	62.8 (1.6)

Figure 19 shows the phosphorus load to Lake Maumelle for each baseline modeling scenario as well as the percent increase over existing conditions. Figure 20 shows the percent contributions of point and nonpoint sources to the overall increase.

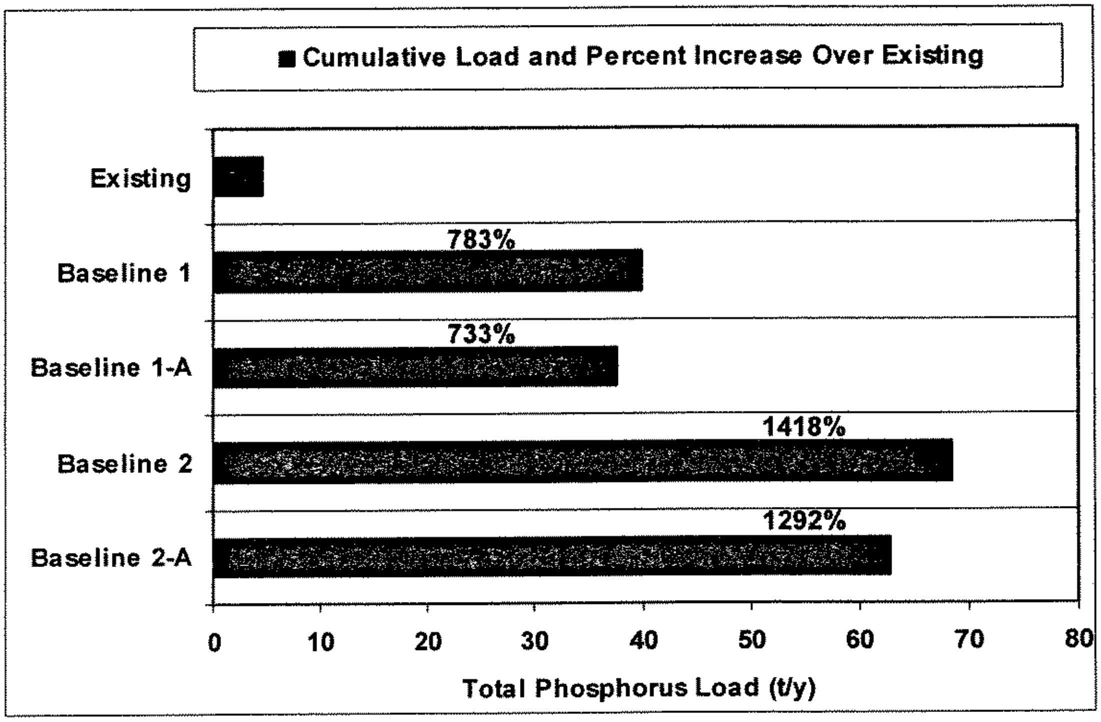


Figure 19. Total Annual Phosphorus Load to Lake Maumelle

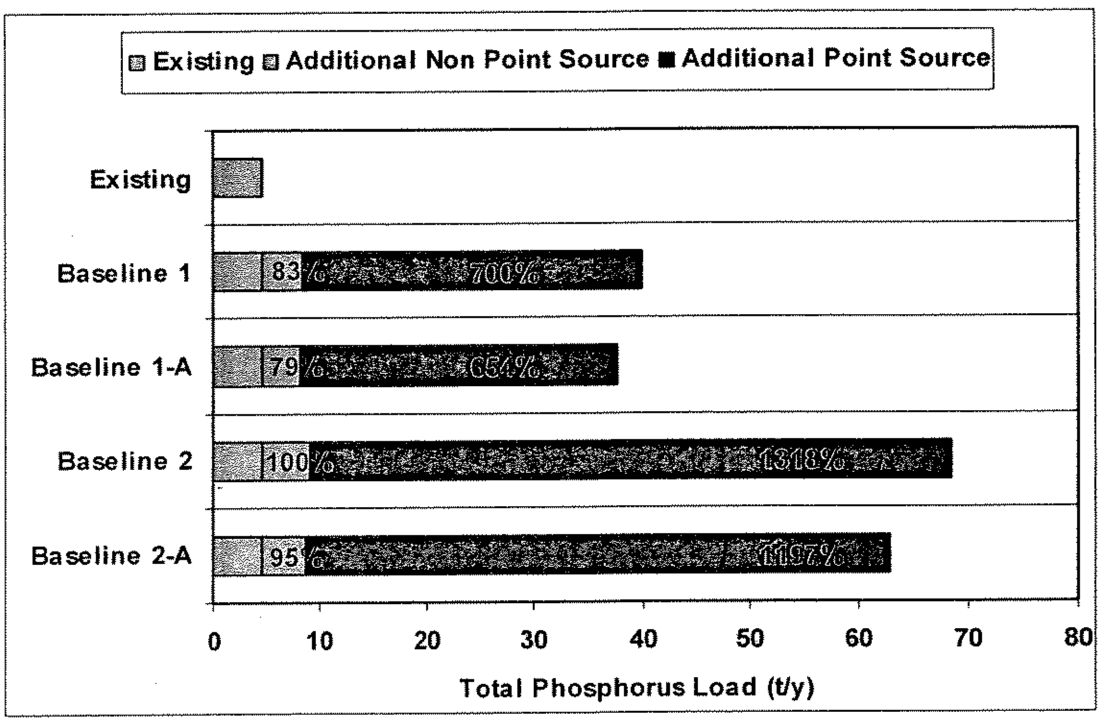
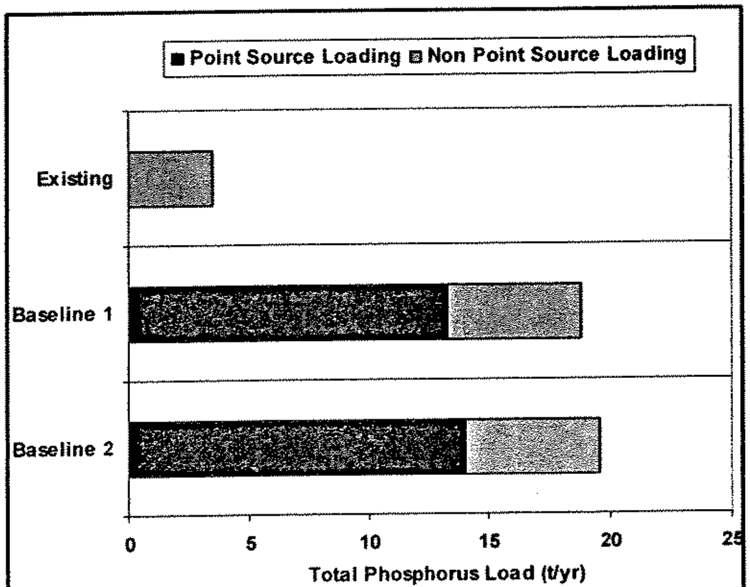


Figure 20. Point and Nonpoint Source Annual Phosphorus Loads to Lake Maumelle

Figure 21 through Figure 23 show the phosphorus load from each loading zone.



PERCENT INCREASE OVER EXISTING TOTAL LOAD

Scenario	Point Source	Non Point Source	Total
Baseline 1	[illegible]	57%	437%
Baseline 2	[illegible]	58%	457%

Figure 21. Annual Phosphorus Load from the Upstream Zone Subwatersheds