TABLES

Southern Hills Lakes Preliminary Evaluation and Management Plan: Summary Report

TABLE 1

Summary of Lake Monitoring Program
(See Table 2 for Parameters)

Sample Type[1]	Type of Sample[2]
Inflow	
• Storm	G
• Baseflow	G
Springs	G
In-Lake	
• Water quality	C
• Profile[3]	N/A
Sediment	C
Weed/Algae survey	V
Shoreline condition inventory[4]	V

1 See Figure 3 for sampling locations.

2 G=grab sample; C=composite sample; V=visual estimate or description.

3 Profiles for temperature and dissolved oxygen were collected.

4 Conducted at same time as weed/algae inventory.

TABLE 2

Parameters Measured in Water Quality Samples

Parameter	Recommended MDL[1]
pH (field)	0.2 s.u.
Total suspended solids (TSS)	5 mg/L
Fecal coliform and fecal streptococcus bacteria	1 colony/100 mL
Total phosphorus	0.005 mg/L
Orthophosphate	0.005 mg/L
Amonia-nitrogen	0.1 mg/L
Total nitrogen	0.005 mg/L
Total Kjeldahl nitrogen	0.005 mg/L
Nitrate plus Nitrite-N	0.005 mg/L
Dissolved oxygen (depth profile)[2]	0.2 mg/L
BOD_5	10 mg/L
Chlorophyll a[2]	0.005 mg/L
Water temperature (depth profile)[2]	0.1 C
Total dissolved solids	1 mg/L
Hardness	1 mg/L
Calcium	1 mg/L
Magnesium	1 mg/L

[1] MDL = minimum detection limit.

[2] In lake samples only.

TABLE 3

Physical Characteristics of Study Lakes and Their Watersheds[1]

Southern Hills Lakes	Surface Area[2] (ac)	Volume[2] (AF)	Average Depth[2] (ft)	Maximum Depth[2] (ft)	Average Depth Sediment (ft)	Estimated Volume of Sediment (cy)	Immediate Drainage Area (ac)	Estimated Runoff Coefficient
Upper	4.1	19.2	5.2	10.5	1.9 (37%)[3]	10,500	511	0.50
Middle	5.4	36.5	5.8	10.6	1.3 (22%)[3]	13,900	100	0.47
Lower	10.4	38.1	5.6	9.5	0.9 (16%)[3]	8,880	43	0.47

[1] Provided by the City of Springfield.

[2] At normal water surface (spillway crest).

[3] Percentage of average lake depth, based on cross-sections surveyed by City.

TABLE 4
SOUTHERN HILLS LAKES AND SPRINGS MONITORING DATA
1999-2000

Sample By:	City of Springfield	City of Springfield	City of Springfield	City of Springfield	City of Springfield	City of Springfield	City of Springfield	City of Springfield	Bob Smith	City of Springfield	City of Springfield	City of Springfield	City of Springfield	City of Springfield
Sample Date:	11/16/99	4/6/00	6/11/00	8/10/00	9/6/00	10/12/00	10/16/00	4/6/00	3/7/00	6/11/00	8/10/00	9/6/00	10/13/00	10/16/00
Sample Time:	2:15pm													
Weather:	Dry	Dry	Wet	Dry	Dry	Dry	Wet	Dry	Dry	Wet	Dry	Dry	Dry	Wet
Sample Name:	Upper Lake (L-1)							Spring 1 (S1) Upper Lake						
Sample Type:	grab	grab	grab/composile	composite	composite			grab	grab	grab	grab	grab		
pH	-	-	-	7.3	7.5	6.3	7.2	-	-	-	6.7	-	-	5.7
BOD_5	-	4	5	2	6	-	2	< 1	-	2	< 1	2	-	2
TSS (NFR) (mg/L)	4	5	11	4	8	-	12	< 1	22	10	3	< 1	-	5
NH3-N (mg/L)	0.11	-	-	-	-	-	-	-	-	-	-	-	-	-
NO3-N (mg/L)	0.08	0.76	0.02	0.82	-	< 0.05	0.05	2.22	5.70	2.33	3.61	-	2.35	1.70
NO3 + NO2-N (mg/L)	-	-	-	-	0.06	-	-	-	-	-	-	4.23	-	-
TKN (mg/L)	< 0.05	< 0.05	2.11	0.50	0.38	0.73	0.89	< 0.05	-	0.34	< 0.08	< 0.05	0.3	0.47
Dissolved O-PO4-P (mg/L)	0.01	0.005	< 0.01	0.02	0.02	0.003	0.01	0.02	0.14	< 0.01	0.02	0.04	0.02	0.04
SO4 (mg/L)	-	-	-	-	-	-	-	-	2	-	-	-	-	-
TP Total-P (mg/L)	0.11	< 0.05	0.33	0.20	0.43	0.03	0.07	< 0.05	-	0.33	0.17	0.46	0.03	0.06
TDS (mg/L)	173	-	-	-	-	-	-	-	-	-	-	-	-	-
Fecal Coliform (colony / 100mL)	92	10	1273	40	100	64	2900	< 10	-	26550	130	1175	300	13700
Fecal Strep (colony / 100mL)		< 10	1620	10	20	10	1500	20	-	58300	423	60	92	20000
Chlorophyll-a (ppb)	4	-	< 5	-	-	7	26	-	-	> 5	-	-	2	2
Hardness (mg equivalent $CaCO_3$/L)	145	-	-	170	98	-	149	-	-	154	262	281	-	196
Ca (mg/L)	54.5	-	43.3	64.9	35.9	-	-	-	-	59.9	101	108	-	-
Mg (mg/L)	2.1	-	1.69	1.88	2.04	-	-	-	-	1.09	2.36	2.67	-	-
Fe (mg/L)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (mg/L)	-	-	-	-	-	-	-	-	-	-	-	-	-	-

TABLE 4
SOUTHERN HILLS LAKES AND SPRINGS MONITORING DATA
1999-2000

Sample By:	City of Springfield	City of Springfield	City of Springfield	City of Springfield	City of Springfield	City of Springfield	City of Springfield	City of Springfield	City of Springfield	City of Springfield	City of Springfield
Sample Date:	11/16/99	4/6/00	8/10/00	9/6/00	10/12/00	10/16/00	4/6/00	8/10/00	10/13/00	9/6/00	10/16/00
Sample Time:	1:42pm										
Weather:	Dry	Dry	Dry	Dry	Dry	Wet	Dry	Dry	Dry	Dry	Wet
Sample Name:	Middle Lake (L-2)						Spring 2 (S2) Middle Lake				
Sample Type:	grab	grab	composite	composite			grab	grab		grab	
pH	-	-	7.6	7.1	6.2	7.3	-	6.8	-	-	6.2
BOD_5	-	3	< 1	8	-	2	< 1	< 1	-	2	3
TSS (NFR) (mg/L)	2	3	4	8	-	6	< 1	< 1	-	5	6
NH3-N (mg/L)	0.10	-	-	-	-	-	-	-	-	-	-
NO3-N (mg/L)	0.10	0.74	0.90	-	0.21	0.20	1.57	2.10	0.56	-	1.00
NO3 + NO2-N (mg/L)	-	-	-	< 0.005	-	-	-	-	-	2.12	-
TKN (mg/L)	< 0.05	< 0.05	0.36	0.55	0.61	0.55	< 0.05	< 0.08	0.27	0.26	0.47
Dissolved O-PO4-P (mg/L)	< 0.01	0.005-received & analyzed after 24hr hold time	0.03	0.01	0.002	0.006	0.023	0.01	0.02	0.04	0.02
SO4 (mg/L)	-	-	-	-	-	-	-	-	-	-	-
TP Total-P (mg/L)	0.11	< 0.05	0.23	0.46	0.02	0.03	< 0.05	0.23	0.03	0.34	0.05
TDS (mg/L)	200	-	-	-	-	-	-	-	-	-	-
Fecal Coliform (colony / 100mL)	46	< 10	< 10	80	73	3900	< 10	20	510	250	2900
Fecal Strep (colony / 100mL)		10	10	30	8	1960	10	10	240	150	3460
Chlorophyll-a (ppb)	4	-	-	-	3	3	-	-	1	-	5
Hardness (mg equivalent $CaCO_3$/L)	166	-	147	126	-	183	-	216	-	183	191
Ca (mg/L)	62.1	-	55.5	46.4	-	-	-	82.3	-	68.9	-
Mg (mg/L)	2.77	-	2.05	2.39	-	-	-	2.43	-	2.55	-
Fe (mg/L)	-	-	-	-	-	-	-	-	-	-	-
Mn (mg/L)	-	-	-	-	-	-	-	-	-	-	-

TABLE 4
SOUTHERN HILLS LAKES AND SPRINGS MONITORING DATA
1999-2000

Sample By:	City of Springfield	City of Springfield	City of Springfield	City of Springfield	City of Springfield	City of Springfield	City of Springfield	City of Springfield	City of Springfield	City of Springfield	City of Springfield
Sample Date:	11/16/99	4/6/00	8/11/00	9/6/00	10/12/00	10/16/00	4/6/00	8/11/00	10/13/00	9/6/00	10/16/00
Sample Time:	1:10pm										
Weather:	Dry	Dry	Dry	Dry	Dry	Wet	Dry	Dry	Dry	Dry	Wet
Sample Name:	Lower Lake (L-3)						Spring 3 (S3) Lower Lake				
Sample Type:	grab	grab	composite	composite			grab	grab		grab	
pH	-	-	7.8	7.2	6.3	7.6	-	6.9	-	-	6.2
BOD_5	-	2	< 1	8	-	3	< 1	< 1	-	2	2
TSS (NFR) (mg/L)	3	3	4	12	-	19	< 1	20	-	17	68
NH3-N (mg/L)	< 0.1	-	-	-	-	-	-	-	-	-	-
NO3-N (mg/L)	0.02	0.63	0.62	-	0.10	0.18	1.04	1.70	1.45	-	0.05
NO3 + NO2-N (mg/L)	-	-	-	0.13	-	-	-	-	-	0.80	-
TKN (mg/L)	< 0.05	< 0.05	0.33	0.89	0.76	0.85	< 0.05	0.13	0.25	< 0.05	0.31
Dissolved O-PO4-P (mg/L)	< 0.01	0.026	0.01	0.01	0.003	0.005	0.022	0.03	0.02	0.05	0.03
SO4 (mg/L)	-	-	-	-	-	-	-	-	-	-	-
TP Total-P (mg/L)	0.10	< 0.05	0.25	0.35	0.05	0.07	< 0.05	0.20	0.02	0.40	0.07
TDS (mg/L)	160	-	-	-	-	-	-	-	-	-	-
Fecal Coliform (colony / 100mL)	10	10	60	75	260	9900	60	145	550	500	7100
Fecal Strep (colony / 100mL)	-	20	20	40	20	6060	40	140	523	80	3460
Chlorophyll-a (ppb)	2	-	-	-	10	16	-	-	4	-	3
Hardness (mg equivalent $CaCO_3$/L)	146	-	156	126	-	182	-	222	-	161	214
Ca (mg/L)	46.1	-	57.5	43.4	-	-	-	78	-	51.5	-
Mg (mg/L)	7.6	-	3.01	4.18	-	-	-	6.61	-	7.86	-
Fe (mg/L)	-	-	-	-	-	-	-	-	-	-	-
Mn (mg/L)	-	-	-	-	-	-	-	-	-	-	-

TABLE 4
SOUTHERN HILLS LAKES AND SPRINGS MONITORING DATA
1999-2000

Sample By:	City of Springfield	City of Springfield	City of Springfield	City of Springfield	City of Springfield
Sample Date:	11/16/99	12/3/99	10/16/00	12/3/99	12/3/99
Sample Time:	11:45pm	8:00am		8:00am	8:00am
Weather:	Dry	Dry	Wet	Dry	Dry
Sample Name:	Seep at L-3	Downstream of L-1 at Glenwood	Glenwood	L-2 Spillway	L-3 Spillway
Sample Type:	grab	grab		grab	grab
pH	6.82	-	7.6	-	-
BOD_5	-	-	3	-	-
TSS (NFR) (mg/L)	-	42	6	< 1	2
NH3-N (mg/L)	-	<0.10	-	<0.10	<0.10
NO3-N (mg/L)	-	0.46	0.05	0.36	0.05
NO3 + NO2-N (mg/L)	-	-	-	-	-
TKN (mg/L)	-	<0.01	0.79	<0.01	<0.01
Dissolved O-PO4-P (mg/L)	-	0.04	0.01	0.05	0.05
SO4 (mg/L)	-	-	-	-	-
TP Total-P (mg/L)	-	0.24	0.07	0.18	0.17
TDS (mg/L)	-	133	-	187	173
Fecal Coliform (colony / 100mL)	-	2815	3900	100	90
Fecal Strep (colony / 100mL)		-	3880		
Chlorophyll-a (ppb)	-	-	21	-	-
Hardness (mg equivalent $CaCO_3$/L)	-	122	151	188	174
Ca (mg/L)	-	45.9	-	70.4	57.5
Mg (mg/L)	-	1.69	-	2.99	7.33
Fe (mg/L)	12.2	-	-	-	-
Mn (mg/L)	14.7	-	-	-	-

TABLE 5

Summary of Lake and Spring Water Quality Data (Ambient Conditions)[1]

		Upper Lake			Upper Lake Spring			Middle Lake		
Parameter	**Units**	**Avg**	**Min**	**Max**	**Avg**	**Min**	**Max**	**Avg**	**Min**	**Max**
Total suspended solids	mg/L	5	4	5	7	<1	22	4	2	8
Nitrate/Nitrogen	mg/L	0.55	0.075	0.82	3.47	2.22	5.70	0.49	0.10	0.89
Total Kjedahl nitrogen	mg/L	0.24	<0.05	0.73	0.12	<0.05	0.3	0.32	<0.05	0.61
Orthophosphate	mg/L	0.01	0.005	0.02	0.04	0.01	0.14	0.01	0.005	0.02
Total phosphorus	mg/L	0.16	<0.05	0.43	0.18	0.02	0.46	0.17	<0.05	0.45

		Middle Lake Spring			Lower Lake			Lower Lake Spring		
Parameter	**Units**	**Avg**	**Min**	**Max**	**Avg**	**Min**	**Max**	**Avg**	**Min**	**Max**
Total suspended solids	mg/L	2	<1	5	6	3	12	13	<1	20
Nitrate/Nitrogen	mg/L	1.41	0.56	2.10	0.34	0.02	0.63	1.40	1.04	1.7
Total Kjedahl nitrogen	mg/L	0.16	<0.05	0.27	0.41	<0.05	0.88	0.12	<0.05	0.25
Orthophosphate	mg/L	0.02	0.01	0.04	0.01	0.003	0.02	0.03	0.02	0.05
Total phosphorus	mg/L	0.16	<0.05	0.33	0.16	<0.05	0.35	0.16	<0.05	0.39

[1] Data collected by City used. Detection limit used to calculate the average when value less than detection limit.

TABLE 6

Evaluation of Nutrient Levels

Parameter	Upper Lake	Middle Lake	Lower Lake
Ratio of total nitrogen to total phosphorus[1]	4.9	4.8	4.7
Phosphorus loading (grams $TP/M^2/year$)[2]	17.0	12.7	8.5
Average concentration of total phosphorus in lake (mg/L)[3]	0.16	0.17	0.16
Average concentration of total nitrogen in lake (mg/L)[4]	0.79	0.81	0.75

[1] Value of 10 or less typical of "eutrophic lake," and may indicate nitrogen limitations.

[2] Value of greater than 0.13 considered excessive (Vollenweider 1975).

[3] Value of greater than 0.035 indicates eutrophic lake; greater than 0.100 indicates hypertrophic lake.

[4] Value of greater than 0.30 indicates eutrophic lake.

TABLE 7
SOUTHERN HILLS LAKES SEDIMENT QUALITY 2000

Sample By:	City of Springfield	City of Springfield	City of Springfield	City of Springfield	City of Springfield	City of Springfield	City of Springfield	City of Springfield	City of Springfield	City of Springfield	City of Springfield	City of Springfield	City of Springfield
Sample Date:	8/10/00	9/6/00	8/10/00	9/6/00	8/11/00	9/6/00	8/14/00	8/10/00	9/6/00	8/10/00	9/6/00	8/11/00	9/6/00
Sample Time:													
Weather:	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
Sample Name:	L-1 (Upper)		L-2 (Middle)		L-3 (Lower)		Sequiota Main	Spring 1 (S1) North Lake		Spring 2 (S2) Middle Lake		Spring 3 (S3) South Lake	
Sample Type:	grab	grab	grab	grab	grab	grab	grab	grab	grab	grab	grab	grab	grab
Total Solids-Grab%	29.20	11.80	3.35	39.80	42.90	20.60	3.34	35.40	28.10	20.40	22.70	56.00	47.6
NO3-N mg/kg	15.70	-	81.30	-	11.30	-	338.00	28.00	-	7.42	-	10.40	-
TKN mg/kg	3.21	1314.00	8.83	1386.00	746.00	2004.00	2634.00	1.70	1259.00	1.22	2159.00	480.00	204
TP mg/kg	719.00	625.00	31.69	373.00	245.00	465.00	998.00	511.00	673.00	895.00	1692.00	262.00	349

TABLE 8

SOUTHERN HILLS LAKES STORMWATER (INFLOW) MONITORING DATA

1999-2000

Sample By:	City of Springfield	City of Springfield	City of Springfield	City of Springfield	City of Springfield	City of Springfield	Bob Smith	Bob Smith	Bob Smith	City of Springfield	City of Springfield	City of Springfield
Sample Date:	12/3/99	12/3/99	12/3/99	6/11/00	6/11/00	6/11/00	6/14/00	6/14/00	6/14/00	10/16/00	10/16/00	10/16/00
Sample Time:	2:00am	2:00am	2:00am									
Weather:	Wet	Wet	Wet	Wet	Wet	Wet	Wet	Wet	Wet	Wet	Wet	Wet
Sample Name:	West Branch at Hansen Driveway	East Branch below Topping Circle on Hansen Property	Concrete Channel at LaMonta	First Peak from S. Hills Shopping (ST1)	Second Peak from Sunshine/65 (ST2)	Goose Contaminated (GP)	Southern Hills Spring	Above LaMonta Bridge	Storm Drain	North of LaMonta	Arlington Terrace	Hanson North
Sample Type:	grab	grab	grab	grab	grab	grab	grab	grab	grab			
pH	-	-	-	-	-	-	-	-	-	6.3	-	-
BOD_5	-	-	-	5	4	-	-	-	-	-	8	6
TSS (NFR) (mg/L)	56	160	92	18	13	-	-	-	-	-	20	66
NH3-N (mg/L)	0.16	0.11	0.18	-	-	-	-	-	-	-	-	-
NO3-N (mg/L)	0.01	0.01	0.01	0.51	0.39	-	1.8	0.5	1.8	-	0.33	0.29
TKN (mg/L)	0.43	0.48	0.19	1.37	1.37	-	-	-	-	-	0.64	0.82
Dissolved O-PO4-P (mg/L)	0.14	0.13	0.14	0.17	0.05	-	-	-	-	-	0.18	0.13
PO4 (mg/L)	-	-	-	-	-	-	1.4	2.8	1.6	-	-	-
SO4 (mg/L)	-	-	-	-	-	-	0	1	0	-	-	-
TP Total-P (mg/L)	0.31	0.25	0.28	0.43	0.43	-	-	-	-	-	0.22	0.23
TDS (mg/L)	27	13	13	-	-	-	-	-	-	-	-	-
Fecal Coliform (colony / 100mL)	9800	24200	11200	60600	59400	46000	24192	-	-	-	23800	31800
Fecal Strep (colony / 100mL)	-	-	-	187000	72300	180000	-	-	-	-	60000	40000
E. Coli	-	-	-	-	-	-	5794	-	-	-	-	-
Hardness (mg equivalent $CaCO_3$/L)	27.6	19.2	32.2	-	-	-	-	-	-	-	31	34
Chlorophyll A (µg/L)										-	1.7	6.7
Ca (mg/L)	10.3	6.86	12	9.56	11.8	-	-	-	-	-	-	-
Mg (mg/L)	0.448	0.496	0.543	0.419	0.698	-	-	-	-	-	-	-

TABLE 9

Comparison of Stormwater Quality Data From This Study With Other Data

Parameter	Units	This Study			Previous Sampling by City of Springfield[1]		NURP[2]
		Avg	Min	Max	Residential	Commercial	Residential
Total suspended solids	mg/L	60	13	160	49	32	220/101
Ammonia	mg/L	0.15	0.11	0.18	0.40	0.45	NA
Nitrate/Nitrogen[3]	mg/L	0.26	0.01	0.51	1.88	2.66	NA/0.74
Total Kjedahl nitrogen	mg/L	0.76	0.19	1.37	0.84	0.72	4.0[4]/1.90
Orthophosphate	mg/L	0.13	0.05	0.17	—	—	NA
Total phosphorus	mg/L	0.31	0.25	0.43	0.14	0.13	1.64/0.38

[1] From 1992-1993 sampling for City's stormwater NPDES permit.

[2] Data from USEPA Nationwide Urban Runoff Program (NURP). Average for Kansas City/national median shown for residential land use.

[3] $NO_2 + NO_3 - N$.

[4] Value for Champaign/Urbana, Illinois shown (no data for Kansas City).

TABLE 10

Summary of Dominant Algae Types in Lakes[1]

In-lake Algae	Upper Lake	Middle Lake	Lower Lake
Hydrodictyon	X		
Oedogonium	X	X	
Zygnema	X		
Spirogyra			X

[1] From November 16-17, 1999 and July 21-August 6, 2000, algae classifications by Dr. Rhoads and Dr. Stauffer, respectively.

TABLE 11

Estimated Annual Water Balance for Lakes[1]

	Upper Lake		Middle Lake		Lower Lake	
	(AF/Year)	(%Total Inflow)	(AF/Year)	(%Total Inflow)	(AF/Year)	(%Total Inflow)
Runoff from immediate watershed[2]	626	76	115	9	50	3
Flow from upstream lake[3]			807	62	1283	74
Flow from spring at lake[4]	181	22	361	28	361	21
Direct precipitation on lake[5]	14	2	19	1	36	2
Total inflow	821	100	1302	100	1730	100
Evaporation[6]	14		19		36	
Net	+807		+1283		+1694	
Average hydraulic retention time (days)[7]	9		10		8	

[1] Based on climatological data from Springfield Regional Airport weather station. See text for additional explanation.

[2] 3.5 feet of precipitation/year x acres x 0.7 x runoff coefficient, C.

[3] Assumed (total inflow)-(evaporation) would be available to next downstream lake.

[4] Assumed that only groundwater entering lakes is flow from defined springs at each lake. Assumed 0.25 cfs from upper lake spring and 0.5 cfs from middle and lower lake springs for total of 1.25 cfs. These projections were arrived at by repeated field observations by City staff, including dry weather conditions when flow over the spillways was entirely attributable to groundwater inflows.

[5] 3.50 feet x lake surface area.

[6] 3.50 feet of annual evaporation x lake surface area.

[7] (Lake Volume) ÷ (Annual Inflow) x (365 days/year).

TABLE 12

Summary of Estimated Nutrient Loading to Lakes From Surface Water and Springs[1]

	Total Phosphorus	Ortho-phosphate	Nitrate Nitrogen	Total Kjedahl Nitrogen	Total Nitrogen[3]	Total Suspended Solids
UPPER LAKE						
• **Runoff (lbs/yr)**						
Avg. concentration (mg/L)[2]	0.31	0.13	0.26	0.76	1.0	60
Load (lbs/yr)	530	220	440	1290	1700	102,000
• **Upper Spring**						
Avg. concentration (mg/L)[4]	0.18	0.04	3.47	0.12	3.39	7
Load (lbs/yr)	90	20	1710	60	1770	3450
Total Load (lbs/yr)	620	240	2150	1350	3470	105,450
MIDDLE LAKE						
• **Runoff (lbs/yr)**	100	40	80	240	310	18,770
• **Middle Spring**						
Avg. concentration (mg/L)[4]	0.16	0.02	1.41	0.16	1.57	2
Load (lbs/yr)	160	20	1380	160	1540	1960
• **From Upper Lake**						
Avg. concentration (mg/L)[4]	0.16	0.01	0.55	0.24	0.79	5
Load (lbs/yr)	350	20	1205	525	1730	10,980
Total Load (lbs/yr)	610	80	2665	925	3580	31,710
LOWER LAKE						
• **Runoff (lbs/yr)**	40	20	35	100	140	8,600
• **Lower Spring**						
Avg. concentration (mg/L)[4]	0.16	0.03	1.40	0.12	1.52	13
Load (lbs/yr)	160	30	1370	120	1490	12,770
• **From Middle Lake**						
Avg. concentration (mg/L)[4]	0.17	0.01	0.49	0.32	0.81	4
Load (lbs/yr)	590	30	1710	1115	2825	13,960
Total Load (lbs/yr)	790	80	3115	1335	4455	34,890

[1] Loads from precipitation, groundwater (other than the springs at each lake), sediment, and waterfowl wastes are not included. Loads calculated from estimates of inflows (Table 11) and average concentrations.

[2] From Table 9.

[3] Sum of nitrate plus total Kjedahl nitrogen.

[4] From Table 5.

TABLE 13

Breakdown of Nutrient Loading to Lakes From Surface Water and Springs[1, 2] (% of Estimated Average Annual Contribution)

	Upper Lake			Middle Lake			Lower Lake		
Nutrients	**TP**	**TN**	**OPO_4**	**TP**	**TN**	**OPO_4**	**TP**	**TN**	**OPO_4**
Runoff	85	49	92	16	9	50	5	3	25
Upstream lake	NA	NA	NA	57	48	25	75	64	37
Spring near lake	15	52	8	27	43	25	20	33	38

[1] See Table 12 for loads (lbs/year).

[2] Does not include loading from precipitation, waterfowl, sediment or groundwater in addition to monitored springs.

TABLE 14

Inventory of Potential Weed and Algae Management Techniques for Lakes

Method	Filamentous Algae
Nutrient Management	
Stormwater BMPs	X
Stream channel stabilization	X
Fertilizer controls	X
Waterfowl deterrents	X
Flushing/recirculation	
Reduction in wastewater	X
Dilution/flushing	
Biofixation	
Dredging (full or partial)	X
Alum/lime treatments	X
Sediment oxidation	
Bio-removal (bacteria)	
Sediment forebay	X
Spring flow and low flow bypass	X
Create littoral zones	X
Biocontrols	
Herbivorous fish (grass carp)	X
Fungal pathogens	
Bacterial pathogens	
Crayfish	
Nutripods	X
Herbicide/Algaecide	
Herbicide	
Algaecide	X
Mechanical harvesting	X
Mowing/sickling	
Mechanical derooting	
Dredging (full or partial)	X
Frothing/foaming	
Centrifugation	
Destratification	
Aeration/circulation	
Hypolimnetic withdrawal	
Shading	
Physical	X
Chemical	X
Bottom Barrier	
Miscellaneous	
Public education	X
Construction of outlet structure to drain lakes and pull water off bottom	X
Raising of lake levels	X

TABLE 15

Evaluation of Potential Lake Management Options
(Note: Conceptual level; costs could change substantially with additional engineering analysis)

OPTION	CONTROLS	ADVANTAGES	DISADVANTAGES	RECOMMENDED DOSAGE RATE	CONCEPTUAL UNIT COST	CONCEPTUAL COST FOR LAKES ($)	COMMENTS
Algaecides							
a) Copper Sulfate	Algae, filamentous algae	Relatively inexpensive	Reacts with water hardness forming an insoluble salt	10 lbs per surface acre	$5.00 per 50 lb bag	$4,000/application	Inactivation by water hardness and need for repeated applications argue against.
		Ease of application	Effectiveness significantly reduced by hard water				
			Potential toxicity to aquatic life				
			Copper carbonate build-up				
			Likely requires numerous applications				
b) Cutrine-Plus	Filamentous algae, chara, nitella	More effective in hard water (chelated copper)	May require numerous applications (roughly every month in peak season)	0.6 gallons per ac-ft, 60 lbs/ac for filamentous algae	$39.00 per gallon or $80.00 per 30 lb bag	$7,000/application	Preferred over copper sulfate.
		Long contact time (8-10 hours)	Moderately toxic				
		Low rates of application	Some water-use restrictions apply				
		Less corrosive					
		Liquid or Granular form					

TABLE 15 (continued)

Evaluation of Potential Lake Management Options

OPTION	CONTROLS	ADVANTAGES	DISADVANTAGES	RECOMMENDED DOSAGE RATE	CONCEPTUAL UNIT COST	CONCEPTUAL COST FOR LAKES ($)	COMMENTS
c) Weed-trine (Diquat dibromide)	Specific filamentous algae	Fast Absorbing	Not effective in muddy water	1 gallon per 4000 sq. ft.	$70.50 per gallon	$16,000/application	More applicable to aquatic weeds.
	Aquatic weeds	Chemical structure not changed or degraded within plants	Moderately toxic				
		Removed from water in 2-4 weeks	Need to apply before algae reaches surface				
			Expensive				
			Water-use restrictions apply				
d) Herbivorous Fish (Grass Carp)	Aquatic weeds, filamentous algae	Inexpensive	Potential environmental harm due to overstocking	15-25 fish per surface acre	$10.00 per fish	$4,000 - $6,000 (initial cost)	No stocking permit required for private pond.
		Non-chemical					Fish prefer aquatic weeds but will eat filamentous algae.
		Low Maintenance	Periodic re-stocking				
Sediment Removal							
Selective sediment removal (dozers, loaders, etc. after water has been removed from lakes)	Aquatic weeds, filamentous algae	Reduces shallow areas for algae and weed growth, long-term solution, multiple benefits	Expensive, creates large disturbance, potential to break current bottom "seal"	Focus on inlets where sediment has accumulated and on excavating to depth of at least 6 to 7 feet	$15/cy with offsite disposal; assume no restrictions apply. Assume cost covers water inflow management	$150,000 - $400,000 without permanent outlet structures included	Preferred over hydraulic ("wet") dredging.

TABLE 15 (continued)

Evaluation of Potential Lake Management Options

OPTION	CONTROLS	ADVANTAGES	DISADVANTAGES	RECOMMENDED DOSAGE RATE	ESTIMATED UNIT COST	ESTIMATED COST FOR LAKES ($)	COMMENTS
Forebay (at inlet to upper lake)	Settles out large sediment and debris, filamentous algae, overall nutrient load	Long-term solution, proven effective	Inadequate space may exist, potential shallow bedrock, private property, flood hydraulics, etc.	5 – 10 minutes of residence time for 80th % annual storm; say 2 – 3 AF of capacity	$50,000 - $100,000	$50,000 - $100,000 (upper lake only)	Must be designed for easy sediment removal.
		Reduces overall sediment and nutrient load	Could be unsightly				
			Routine maintenance required				
			Relatively expensive				
Partial or total conversion of upper lake to wetland	Sediment, nutrients, algae	Would provide excellent protection for middle and lower lakes	Relatively expensive	N/A	$5,000 - $10,000/ac, plus cost of bypass channel and dredging cost	$20,000 - $40,000 for wetland only: additional costs would increase by $20,000 to $40,000	Would "sacrifice" upper lake to benefit of lower lakes. Cost highly variable.
		Could look more appealing than existing lake	Would eliminate lake				
		Good long-term sediment and nutrient control	Could wash-out during large floods				
			Potentially negative homeowner reaction				

TABLE 15 (continued)

Evaluation of Potential Lake Management Options

OPTION	CONTROLS	ADVANTAGES	DISADVANTAGES	RECOMMENDED DOSAGE RATE	ESTIMATED UNIT COST	ESTIMATED COST FOR LAKES ($)	COMMENTS
Watershed Controls							
• Stormwater BMPs/channel stabilization	Overall water quality	Long-term sediment and nutrient control	Difficult to implement, may only be able to control part of land	Variable			Continuation of use of stormwater BMPs in watershed.
			Relatively expensive				
• Fertilizer controls (around lakes)	Overall water quality	Long-term nutrient control	Only controls part of nutrient load	N/A			Requires public education and commitment of homeowners.
		Inexpensive					
• Waterfowl deterrents	Overall water quality	Reduce nutrients and damage from waterfowl	May be difficult to achieve long-term	N/A			
		Inexpensive	Waterfowl may be desirable to homeowners	N/A			
			May require reconfiguration of shorelines				
Miscellaneous							
Outlet works to drain lakes	Aquatic weeds allow for dredging	Would help to prevent oxygen depletion near bottom	May still need to pump to dry lake	N/A	N/A	$20,000 - $30,000/lake	Costs for basic siphon-type outlet, over the top of dam. Concrete outlet works tower with weir not included.
		Water level control					
		Allows for dredging in "dry"					

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TABLE 16

Recommended Lake Management Plan for Years 2001 – 2003 (Years 1 – 3) [1] [2]
(See Report for Detail)

Management Action	Upper Lake	Middle Lake	Lower Lake
Recommended Short-Term Control Measures			
1. Algaecides	Years 1-3	Years 1-3	Years 1-3
2. Stocking of grass carp	Year 1	Year 1	Year 1
Recommended Long-Term Control Measures			
1. Partial dredging	[3]	[3]	[3]
2. Outlet structure installation	[3]	[3]	[3]
3. Raise lake normal water surface elevation	[3]	[3]	[3]
4. Construction of a forebay	[3]	NA[4]	NA[4]
5. Conversion of some of the Upper Lake into a wetland	[3]	NA	NA
6. Continued monitoring of sanitary sewer system by city, with repairs and upgrades as necessary	Years 1-3	Years 1-3	Years 1-3
7. Waterfowl deterrents, including littoral zone establishment	Years 1-3	Years 1-3	Years 1-3
8. Stormwater quality control practices including structural BMPs, public education and stream channel stabilization	Years 1-3	Years 1-3	Years 1-3

[1] Program will need to be adjusted each year based on monitoring.

[2] Three-year timeframe provided to initiate lake management plan. Plan will eventually need to be extended beyond 2003. Plan assumes start-up in 2001.

[3] Further feasibility/financial analysis required to determine whether technically and/or financially feasible. Should be assessed after initial controls are implemented. See report for more information.

[4] Forebays in the middle and lower lakes are not necessary based on current analysis.

NA—Not applicable