APPENDIX C. (Continued)

Chemical tests: total phosphorus concentrations in China Lake for summer and fall 2005, at different sites and levels within the lake.

Site	Date	Sample Type [a]	Concentration (ppb)	Quality Control [b]
1	7-Jun-05	S	13.4	-
1	7-Jun-05	M	15.8	-
1	7-Jun-05	B	16.7	-
1	7-Jun-05	B	23.1	Duplicate
1	7-Jun-05	E	18.4	-
2	7-Jun-05	S	18.3	-
2	7-Jun-05	M	14.5	-
2	7-Jun-05	B	23.4	-
2	7-Jun-05	E	15.4	-
3	7-Jun-05	S	17.5	-
3	7-Jun-05	M	14.2	-
3	7-Jun-05	B	27.4	-
3	7-Jun-05	E	18.8	-
1	22-Jun-05	M	14.3	-
1	22-Jun-05	B	13.1	-
1	22-Jun-05	B	16.2	Duplicate
1	22-Jun-05	E	15.5	-
2	22-Jun-05	S	16.6	-
2	22-Jun-05	M	17.6	-
2	22-Jun-05	B	23.2	-
2	22-Jun-05	E	15.6	-
3	22-Jun-05	S	17.6	-
3	22-Jun-05	S	18.0	Split
3	22-Jun-05	M	20.6	-
3	22-Jun-05	B	46.8	-
3	22-Jun-05	E	14.1	-
4	11-Jul-05	St-C	16.5	-
4	11-Jul-05	St-S	21.3	-
1	3-Aug-05	S	16.1	-
1	3-Aug-05	M	11.4	-
1	3-Aug-05	M	11.9	Duplicate
1	3-Aug-05	B	25.3	-
1	3-Aug-05	E	19.7	-
2	3-Aug-05	S	12.9	-
2	3-Aug-05	M	13.1	-
2	3-Aug-05	B	59.2	-
2	3-Aug-05	B	58.1	Split
2	3-Aug-05	E	16.8	-
3	3-Aug-05	S	13.3	-
3	3-Aug-05	M	16.1	-
3	3-Aug-05	M	26.5	10 ppb Spike
3	3-Aug-05	B	81.7	-
3	3-Aug-05	E	14.1	-
1	16-Aug-05	S	15.4	-
1	16-Aug-05	M	12.9	-
1	16-Aug-05	M	12.6	Duplicate
1	16-Aug-05	B	34.7	-

APPENDIX C. (Continued)

Site	Date	Sample Type [a]	Concentration (ppb)	Quality Control
1	16-Aug-05	E	17.2	-
2	16-Aug-05	S	17.1	-
2	16-Aug-05	M	14.6	-
2	16-Aug-05	M	22.6	10 ppb Spike
2	16-Aug-05	B	32.9	-
2	16-Aug-05	E	15.3	-
3	16-Aug-05	S	18.2	-
3	16-Aug-05	M	14.5	-
3	16-Aug-05	B	111.1	-
3	16-Aug-05	B	105.5	Split
3	16-Aug-05	E	17.4	-
1	19-Sep-05	S	16.6	-
1	19-Sep-05	M	17.8	-
1	19-Sep-05	B	25.0	-
1	19-Sep-05	B	35.1	10 ppb Spike
1	19-Sep-05	E	20.8	-
2	19-Sep-05	S	21.5	-
2	19-Sep-05	M	21.3	-
2	19-Sep-05	B	22.5	-
2	19-Sep-05	E	22.7	-
3	19-Sep-05	S	18.8	-
3	19-Sep-05	S	18.1	Duplicate
3	19-Sep-05	M	19.9	-
3	19-Sep-05	M	20.1	Duplicate
3	19-Sep-05	B	199.3	-
3	19-Sep-05	B	197.1	Split
3	19-Sep-05	E	25.4	-
4	19-Sep-05	S	20.4	-
5	19-Sep-05	S	18.1	-
6	19-Sep-05	S	20.8	-
6	19-Sep-05	S	31.2	10 ppb Spike
7	19-Sep-05	S	21.0	-
8	19-Sep-05	S	18.0	-
9	19-Sep-05	S	32.7	-
10	19-Sep-05	S	63.3	-
11	19-Sep-05	S	44.7	-
11	19-Sep-05	S	42.5	Split
2	6-Oct-05	S	19.5	-
2	6-Oct-05	S	13.8	Duplicate
2	6-Oct-05	M	12.1	-
2	6-Oct-05	M	15.7	10 ppb Spike
2	6-Oct-05	B	115.2	-
2	6-Oct-05	B	102.9	Split
2	6-Oct-05	E	15.8	-
9	6-Oct-05	St-C	25.3	-
9	6-Oct-05	St-S	46.1	-
11	6-Oct-05	St-C	16.7	-
11	6-Oct-05	St - S	20.9	-

[a] S = Surface, M = Middle, B = Bottom, E = Epicore, St–C = Storm water - Continuous, and St–S = Storm water – Staggered
[b] See Appendix B

APPENDIX C. (Continued)
Biotic measurements: chlorophyll-*a* concentration in China Lake, for summer and fall 2005.

	Concentration (ppb)			
Depth	22-Jun-05	3-Aug-05	16-Aug-05	19-Sep-05
Site 1				
0	-	0.9	1.4	1.3
1	-	2.4	2.0	2.6
2	-	1.9	1.8	3.7
3	-	2.7	1.9	3.6
4	-	2.2	2.9	4.4
5	-	2.1	1.3	4.8
6	-	1.1	1.6	4.6
7	-	0.7	0.8	2.8
8	-	0.2	0.0	2.6
9	-	0.3	0.5	1.0
10	-	0.0	0.2	0.2
11	-	1.0	0.7	0.1
12	-	0.3	0.3	0.6
13	-	1.2	0.0	2.0
14	-	0.8	0.0	0.1
15	-	0.3	0.1	0.4
16	-	-	-	0.4
17	-	-	-	0.2
18	-	-	-	0.7
19	-	-	-	0.0
20	-	-	-	0.6
21	-	-	-	0.5
22	-	-	-	0.0
23	-	-	-	0.2
24	-	-	-	1.2
25	-	-	-	0.1
26	-	-	-	0.0
Site 2				
0	2.1	1.0	1.2	2.7
1	2.6	1.5	1.4	4.3
2	3.0	2.3	2.0	4.5
3	3.0	1.7	3.6	5.8
4	3.1	1.4	2.1	5.6
5	3.9	1.0	1.9	5.4
6	3.6	0.8	0.6	5.2
7	3.7	0.5	0.1	3.3
8	2.4	0.5	0.7	2.3
9	1.5	0.2	0.2	0.8
10	1.7	0.5	0.5	0.5
11	1.2	0.0	0.2	0.6
12	1.7	0.3	0.6	0.9
13	1.1	0.2	0.5	0.4
14	1.5	0.6	0.5	0.9
15	1.9	0.3	0.5	0.6

Appendix C. (CONTINUED)

	Concentration (ppb)			
Depth	**22-Jun-05**	**3-Aug-05**	**16-Aug-05**	**19-Sep-05**
Site 3				
0	3.4	0.7	1.8	1.8
1	2.8	1.6	3.2	2.8
2	3.7	1.6	3.0	3.8
3	3.9	2.0	3.1	3.6
4	6.5	2.0	3.2	3.3
5	4.4	2.1	1.5	4.3
6	3.3	1.0	1.0	3.4
7	2.1	1.1	0.6	2.6
8	2.0	1.4	0.8	3.7
9	1.3	1.0	0.7	1.8
10	1.9	0.6	0.5	1.1
11	1.4	1.0	0.6	0.7
12	1.7	1.1	0.8	1.0
13	1.6	1.4	1.0	1.2
14	1.1	1.3	0.6	0.9
15	2.9	0.9	0.9	0.4
16	-	-	-	1.0

APPENDIX D. WATER BUDGET FOR CHINA LAKE

1. Calculating Net Inputs (m^3/ year)

I_{net} = (runoff* land area) + (precipitation* lake area) – (evaporation* lake area)

2. Calculating Flushing Rate (flushes/year)

F.R. = (I_{net} Lake 1) + (I_{net} Input 2) +…(I_{net} Input *n*) / (mean depth* lake area)

3. Physical Parameters of China Lake Used in The Water Budget

Physical Parameter	**Value**	**Units**
Runoff	0.622	meters/yr.
Precipitation	1.003	meters/yr.
Evaporation	0.560	meters/yr.
Land Area	6.87×10^7	square meters
Lake Area	1.60×10^7	square meters
Average Depth	8.534	meters

4. Water Budget

- The net input to China Lake is 59,300,000 cubic meters per year.
- I_{net}= (0.622x $6.87*10^7$) + (1.003x $1.6*10^7$) –(0.560x $1.6*10^7$)
- Flushing rate = ($5.935x10^6$/ (8.53x $1.6*10^7$)
- The flushing rate of China Lake is 0.35 flushes per year.

APPENDIX E. PHOSPHORUS MODEL EQUATION AND COEFFICIENTS

The following coefficients are based on past studies of lakes in central Maine (CEAT 2001, 2003, 2004, and 2005), in addition to other sources that are specifically cited. These export coefficients were estimated using several factors that influence the movement of phosphorus into China Lake, including land use patterns, soil type and quality, land area, population size, and characteristics of residential development. All coefficients represent the mass of phosphorus exported from a particular source into the lake in kg/ha/yr unless otherwise noted.

Ec_a = export coefficient for atmospheric input

Estimated Range = 0.10 - 0.25 Best Estimate = 0.15

This coefficient was estimated based on past studies of central Maine lakes. The very low level of industry producing airborne particulates in the area would decrease potential phosphorus deposition. Additionally, China Lake is farther from cities than Togus Pond; the best estimate of the export coefficient is lower in comparison (CEAT 2005).

Ec_{mf} = export coefficient for mature forest

Estimated Range = 0.05 - 0.15 Best Estimate = 0.10

The majority of the forested area in the China Lake watershed is comprised of a mix of coniferous and deciduous species with slightly more coniferous areas than deciduous areas, so a relatively low export coefficient was estimated. Coniferous forests contribute less phosphorus than deciduous forests because they produce less leaf litter. In general, mature forests have a low phosphorus export coefficient because they reduce runoff and soil erosion as the canopy reduces velocity of rain and roots hold the soil in place.

Ec_{cp} = export coefficient for cropland

Estimated Range = 0.10 - 3.00 Best Estimate = 1.50

The estimated range for the phosphorus export coefficient for cropland was taken from Reckhow and Chappra (1983). The 2001 Total Maximum Daily Load Report (TMDL) for China Lake also used the coefficient of 1.50 as a best estimate for cropland in the China Lake watershed (MDEP 2001). These values are relatively high because there is generally little cover to reduce the velocity of rain and reduce soil erosion on cropland, and runoff can contain high levels of nutrients from fertilizers. Additionally, crops planted in rows can form channels for water to flow through, carrying soil with it.

Ec_p = export coefficient for pasture

Estimated Range = 0.35 - 1.35 Best Estimate = 0.55

The range for pasture phosphorus export coefficient was taken from a TMDL study for Threemile Pond (MDEP 2003). Pastures and hayfields retain phosphorus better than cropland because of their thick grass cover.

Ec_g = export coefficient for grassland

Estimated Range = 0.25 - 0.90 Best Estimate = 0.50

Grasslands are open areas dominated by grass that have no association with agriculture (e.g., lawns). The export coefficient was estimated to be slightly lower than that of pasture because there is no association with grazing animals that can contribute nutrients to the land and runoff. Grass cover helps to prevent soil erosion. However, if grasslands are treated with fertilizers, nutrients can be washed into the lake during heavy precipitation.

Ec_w = export coefficient for wetland

Estimated Range = 0.02 - 0.08 Best Estimate = 0.04

The phosphorus export coefficient for wetlands is very low, since wetlands act as phosphorus sinks during the summer when there is active plant growth. Some phosphorus, however, may be released from wetlands during periods of runoff (CEAT 2005; See Watershed Land Use Patterns: Comparison of 1965 and 2003: Wetlands).

Ec_r = export coefficient for reverting land

Estimated Range = 0.20 - 0.80 Best Estimate = 0.30

The export coefficient for reverting land is higher than mature forest because the vegetation is dominated by grasses and shrubs with less than 50% canopy cover. There is well developed ground cover that helps to reduce runoff and prevent erosion.

Ec_{cm} = export coefficient for commercial and municipal land

Estimated Range = 0.50 - 3.00 Best Estimate = 1.30

Commercially developed land contributes more phosphorus to the watershed than undeveloped areas because of the increased runoff from impervious surfaces such as parking lots and the roofs of buildings

Ec_{sr} = export coefficient for state and municipal roads

Estimated Range = 0.70 - 6.00 Best Estimate = 1.80

The impervious surface of state and municipal roads increases runoff, and as the roads wear down, phosphorus is released in the dust. The state and municipal roads were assigned a lower export coefficient than the camp roads because most of the paved roads in the China Lake watershed are well maintained and generally have better crowns than dirt roads. Our best estimate was slightly higher than for other lake watersheds in the region because of the close proximity of Lakeview Drive to the shoreline (CEAT 2004, 2005).

Ec_{cr} = export coefficient for camp roads

Estimated Range = 1.00 - 7.00 Best Estimate = 3.40

The export coefficient for camp roads is higher than that of state and municipal roads because they are unpaved and prone to erosion, generally not as well maintained, and closer in proximity to the lake (often leading directly to the lake shore).

Ec_{s} = export coefficient for shoreline development

Estimated Range = 0.50 - 3.00 Best Estimate = 1.80

Development within 200 ft of the shoreline impacts water quality significantly because water can run directly off lawns, roofs, and other exposed surfaces into the lake. Shoreline areas that are developed are relatively densely developed and there are areas of clustered older residences that are grandfathered. These characteristics can lead to increased phosphorus loading from residences, and are reflected in the high export coefficient.

Ec_{n} = export coefficient for non-shoreline development

Estimated Range = 0.20 - 1.50 Best Estimate = 0.30

Non-shoreline development (greater than 200 ft from the shore) impacts water quality far less than shoreline development because the soil absorbs more runoff over a greater distance, and a wider buffer exists between the homes and the lake.

Ec_{ss} = export coefficient for shoreline septic systems

Estimated Range = 0.40 - 0.90 Best Estimate = 0.60

Many of the septic systems along the shoreline of China Lake were built before the implementation of current standards for these systems, and there are many septic systems built close to the edge of the water or in soil that is not ideal for septic systems. The high export coefficient reflects the potential of these systems to export phosphorus into the lake

Ec_{ns} = export coefficient for non-shoreline septic systems

Estimated Range = 0.30 - 0.90 Best Estimate = 0.50

The estimated export coefficients for non-shoreline septic systems were slightly lower than the shoreline septic coefficients for the reasons discussed under non-shoreline development.

I_A = export coefficient and number capita years for China Primary and Middle Schools

Estimated Range = 203.72 - 509.30 kg/yr Best Estimate = 305.58 kg/yr

I_B = export coefficient and number capita years for Erskine Academy

Estimated Range = 227.01 - 557.52 kg/yr Best Estimate = 340.51 kg/yr

I_C = export coefficient and number capita years for Friends Camp

Estimated Range = 18.10 – 36.20 kg/yr Best Estimate = 24.13 kg/yr

The estimated export coefficients and number capita years for China Primary and Middle Schools, Erskine Academy, and the Friends Camp represent the number of kilograms of phosphorus per year released by each institution, respectively. These values were calculated using the following factors: (a) number of students and faculty at each institution; (b) the number of days of operation per year; (c) a high, low, and best estimate of the number of gallons of water used per day per person based on reported estimates in a 1980 USEPA report, current code regulations for water fixtures, and other factors specific to the institution; and (d) an average phosphorus concentration of institutional wastewater reported by the U.S. Environmental Protection Agency (USEPA 1980). China Primary

School and China Middle School were treated as one large school for the purpose of the model due to their close proximity to the lake and to each other. Erskine Academy was accounted for separately because it is located much farther from the lake and operates for a different number of days per year in comparison to the other two schools. The Friends Camp was also considered separately since it is a residential summer camp and has different characteristics from the schools.

SR_1 = soil retention coefficient for shoreline residences

Estimated Range = 0.65 - 0.35 Best Estimate = 0.55

The majority of soil types along the shoreline of China Lake are drained well or moderately well (USDA 1978). Well drained soil allows water to percolate through at a slow rate that allows the soil to capture nutrients such as phosphorus. This characteristic is reflected in the relatively high soil retention coefficient, which indicates the ability of the soil to hold nutrients.

SR_2 = soil retention coefficient for non-shoreline residences

Estimated Range = 0.90 - 0.75 Best Estimate = 0.80

There are large areas of excessively drained soil interspersed with areas of well or moderately well drained soil, and areas of poorly or very poorly drained soil within the China Lake watershed. Excessively drained soil allows water to percolate very quickly, carrying nutrients with it. Poorly drained soil does not allow water to percolate, trapping water where it can be flushed out during heavy precipitation. These retention coefficients are slightly higher than for shoreline residences because water travels a greater distance through the soil before reaching the lake, allowing for the soil to retain a greater amount of nutrients.

SR_{3A} = soil retention coefficient for China Primary and Middle Schools

Estimated Range = 0.65 - 0.35 Best Estimate = 0.55

Due to the close proximity of China Primary and Middle Schools to the lake, the shoreline soil retention coefficient estimates were used.

SR_{3B} = soil retention coefficient for Erskine Academy

Estimated Range = 0.90 - 0.75 Best Estimate = 0.80

Non-shoreline soil retention coefficient estimates were used because Erskine Academy is located at the edge of the China Lake watershed.

SR_{3C} = soil retention coefficient for the Friends Camp

Estimated Range = 0.90 - 0.75 Best Estimate = 0.80

Non-shoreline soil retention coefficient estimates were used because the Friends Camp is located greater than 200 ft from the shore of China Lake.

Sd = internal sediment release coefficient

Estimated Range = 1.00 - 1.60 Best Estimate = 1.40

The amount of phosphorus released from sediments was estimated by subtracting the export coefficient terms from the observed concentration of phosphorus in China Lake during the summer and fall (see Phosphorus Budget). Our results are supported by previous estimates of sediment release in China Lake, reported in the 2001 China Lake TMDL (MDEP 2001).

Calculations for Total Phosphorus Loading

The total phosphorus loaded into China Lake from the watershed per hectare per year **(L)** was calculated by dividing the annual phosphorus inflow by the surface area of the lake:

$$\mathbf{L = W/A_s}$$

W = annual phosphorus inflow in kg/yr

A_s = surface area of the lake = 16,041,650 m^2

Annual atmospheric water loading **(q_s)** was calculated by dividing the total volume of water inflow by the surface area of China Lake:

$$\mathbf{q_s = Q_{total}/A_s}$$

Q_{total} = total volume of water inflow in m^3/yr= 59,356,148 m^3/yr

The predicted ranges of phosphorus concentration **(P)** were calculated by dividing annual phosphorus loading by the settling velocity of phosphorus and the areal water loading in a lake:

$$P = L/(11.6 + 1.2q_s)$$

L = phosphorus loading (m/yr)

$(11.6 + 1.2q_s)$ = settling velocity of phosphorus and areal water loading in a lake

q_s for China Lake = 3.70 m/yr

Phosphorus Budget Estimates

Low estimate:

W = 1209.9 kg/yr

L = 0.075 kg/ha/yr

P = 4.70 ppb

Low estimate with sediment release:

W = 2814.1 kg/yr

L = 0.175 kg/ha/yr

P = 10.94 ppb

Best estimate:

W = 2597.0 kg/yr

L = 0.162 kg/ha/yr

P = 10.09 ppb

Best estimate with sediment release:

W= 4842.8 kg/yr

L = 0.302 kg/ha/yr

P = 18.82 ppb

High estimate:

W = 5716.1 kg/yr

L = 0.356 kg/ha/yr

P = 22.21 ppb

High estimate with sediment release:

W = 8282.7 kg/yr

L = 0.516 kg/ha/yr

P = 32.19 ppb