Water Quality and Nutrient Loading Summary

In the 2001 analysis, four stations were established in the main basin of the lake complex including Stump Lake, immediately north of Hwy 48 on the north end of the lake. Limnological profiling was completed in Stump Lake and in the North Basin, Central Basin, and South Basin of the Rice Lake (Map 1). Sediment cores were collected at these same stations to determine the amount of phosphorous being released from the bottom sediments of the lake. Tributary inflows and external loadings of sediment and phosphorous from Bear Creek and the Red Cedar River were evaluated.

Flow from the Red Cedar River under normal conditions (7.6 cms) is more than twice that of Bear Creek (3.4 cms). The Red Cedar River contributes >60% of the sediment and nutrients entering the system from tributaries per summer season, May-September (Table 1). Hydraulic residence time as it relates to inflow and outflow averages 15 days during normal flow. Several storm flow periods were recorded in 2001. During these times the hydraulic residence of the lake declined to <10 days; less than 5 days during large storm events (James 2001).

Table 1
Total Suspended Sediment, Nitrogen, and Phosphorous in Tons Per Summer Entering Rice Lake From Its Tributaries in 2001

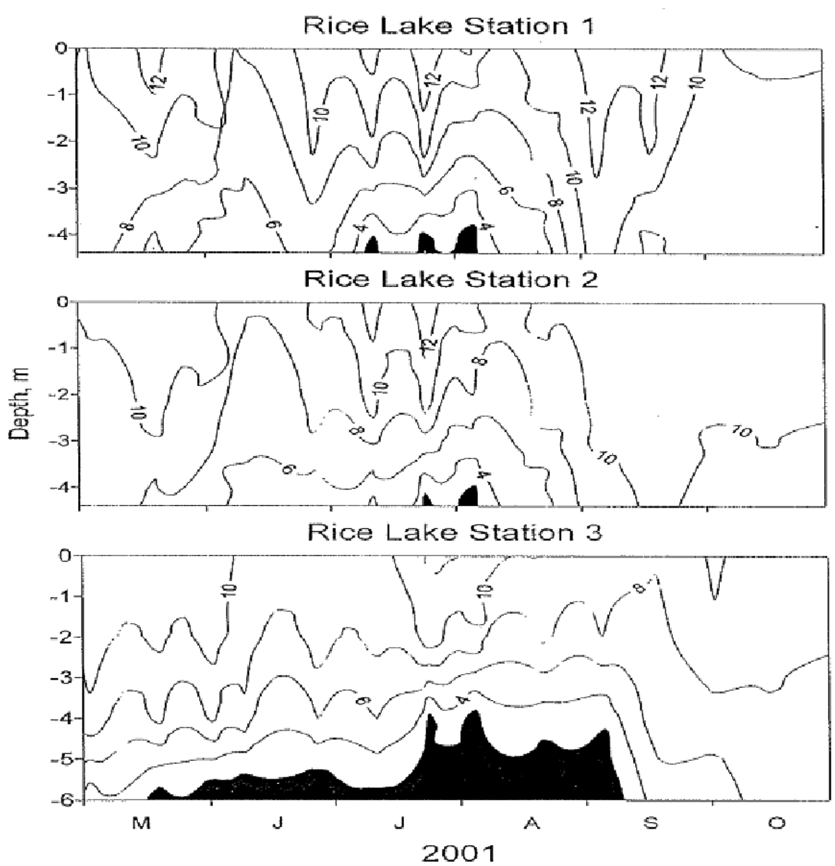
	Total Suspended Sediment (Tons/Summer)	Total Nitrogen (Tons/Summer)	Total Phosphorous (Tons/Summer)
Red Cedar River	485	99	4.2
Bear Creek	276	38	2.7
Total	**761**	**137**	**6.9**

An analysis of watershed loading was completed by Barron County (Olson & Hanson 1993) based on WINHUSLE modeling of a 4000 acre sub-watershed of Rice Lake. The area included that portion of the entire watershed above Hwy V near Lower Devils Lake to the Red Cedar River west of the intersection of Hwy 48 and M. An inventory of 46% of the study area was performed. Results of the modeling indicated that 34 tons of sediment enters the river each year from this 4000 acre area. In addition, 205 lbs of phosphorous was contributed. For extrapolation purposes, Barron County assumed the remainder of the 61,000-acre study area would yield 70% of what the 4000-acre model area did, and that the sediment entering Tuscobia Lake and Stump Lake would settle before entering Rice Lake. If this is the case, then 300 tons or more of sediment enters Rice Lake each year from crop fields. Total phosphorous loading accompanying that sediment would be around 0.9 tons/year (1800 lbs/year).

The 1993 Barron County Study also included a barnyard survey within the Rice Lake watershed. Each barnyard in the watershed (55 in total) was ranked on a scale of 1-3 based on potential for water pollution, three being the worst. 26 of the barnyards received the worst ranking, with an additional 22 receiving a ranking of 2. Only 7 were ranked a 1 or having little impact on water pollution.

Temperature and dissolved oxygen profiles are also used to help identify processes in a lake that lead to increased phosphorous and algae levels. The South Basin, also known as Station 3, exhibited an extended period of thermal stratification between mid-June and early August. Thermal stratification means that the lake separates into layers with warm water near the surface separated from colder water near the bottom by a barrier known as the thermocline. This layering is the direct result of different water density at different temperatures. Cold water is “heavier” than warm water and will sink to the bottom of a lake in the summer. Really cold water or ice is lighter than warm water so will move to the surface in the winter. In the North and Central Basins (Stations 1&2), thermal stratification was much weaker and more intermittent presumably due to the large amounts of water coming into the Upper lake from the Red Cedar River and Bear Creek. Coincident with periods of thermal stratification in the Lower lake was the occurrence of rapid dissolved oxygen (DO) depletion in the bottom waters and the development of anoxic (no oxygen) conditions. The South Basin had DO values <2 mg/L from mid-May through mid-September. By late-July anoxic conditions had extended up to the 4 meter level (Figure 1).

Figure 1 – Dissolved Oxygen (DO) Depletion at Three Rice Lake Sampling Locations

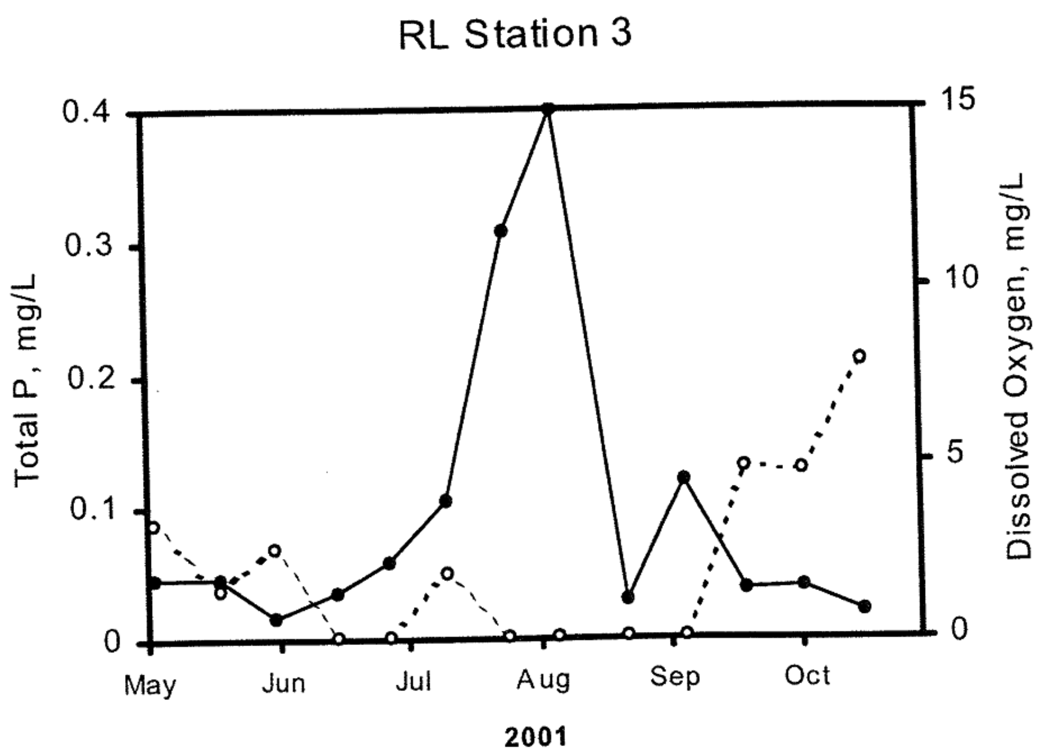


Station 1/North Basin, Station 2/Central Basin, and Station 3/South Basin
Blackened areas show periods when no oxygen was recorded

Chlorophyll levels started out low in Stump Lake and the Upper basin of Rice Lake. They remained low in Stump Lake throughout the summer season indicating that the macrophytes or large plants in this area of the lake likely used up the available nutrients before algae could. Though measurements were not made to quantify it, the same scenario likely played out in the Clearwater Bay area of the Lower basin. Relatively shallow water with extensive macrophyte growth generally remains free of algal growth throughout the summer. Though chlorophyll concentrations were low in the spring in the Upper basin of Rice Lake, they peaked in mid-July and early August. In 2001, after significant August storm events, chlorophyll concentrations declined in the Upper basin as the flushing or residence time of the lake shortened to only a few days. This suggests that the lake benefits from flushing caused by stormwater runoff from the Red Cedar River and Bear Creek, but mainly in the Upper basin as chlorophyll levels in the Lower basin did not receive as much of a benefit from the added flushing, probably due to its separation from the main body of the lake by the Narrows.

Phosphorous levels in the lake exhibited complex patterns related to storm inflows and internal loading under anoxic (no oxygen) conditions. Peaks in total phosphorous occurred after the storm inflows in early August. This signifies that even when existing algal biomass is being flushed from the system due to heavy rainfall and shortened residence times, additional phosphorous is being carried into the lake by the same event that may lead to even greater algal development later on. To complicate matters, during periods of no oxygen in the bottom waters, additional phosphorous is released from the bottom sediments via a chemical reaction. Peaks in total phosphorous often coincided with algal blooms caused by extended periods of no oxygen in the bottom waters, particularly in the Lower basin (Figure 2).

Figure 2 – Total Phosphorous Spikes as They Relate to Time of Year and Oxygen Depleted (Anoxic) Conditions in Station 3/South Basin



Actual rates of phosphorous release from the sediments were determined under lab conditions using sediment cores collected from each basin of the lake. Sediment release of phosphorous was substantial in all basins under anoxic conditions. Under oxic (dissolved oxygen is present) conditions, sediment release of phosphorous was limited in Stump Lake and the North basin, and non-existent in the Central and South basins. When pH levels were manipulated to account for increases in pH values in the lake due to plant growth, sediment release of phosphorous increased particularly in Stump Lake and in the Upper basin, even under oxic conditions. Overall there appeared to be a gradient in phosphorous release rates from the north to the south.

Externally, the Red Cedar River contributes greater than 60% of the measured total suspended sediment, total nitrogen, total phosphorous, nitrate-nitrite, and ammonium load to the lake complex.

Budgetary analysis and Bathtub modeling for the summer of 2001 suggested that external phosphorous loading appeared to dominate phosphorous dynamics in the lake complex. Modeling indicated that a 50% reduction in total phosphorous loading to the system could reduce chlorophyll (algal) concentrations by approximately 58% and Secchi reading could be increased by approximately 24%. Currently it is estimated that algal blooms can occur during approximately 23% of the summer under current phosphorous loading conditions. If a 50% reduction in phosphorous loading is achieved, than this value drops to only 2% of the summer season. Conversely if phosphorous loading were to increase by 50%, algal blooms could occur during 51% of the summer season.

Another significant source of nutrient loading to the lake is the City of Rice Lake municipal storm water sewer system. Land development in the City has been pretty extensive. In the last dozen years a Menards, a Wal-mart Super Center, a Ford Dealership, a motorcycle shop and dealer, several restaurants and fast food places, a gas station and convenience store, hotel, hospital, and several business complexes have been developed. The total impervious surface area in the City has increased at a rate greater than population growth. Much of this area does not drain directly into Rice Lake, but rather goes into the Red Cedar River directly impacting an already impacted river system. Development in the northwestern part of the City, specifically that area at the intersection of Hwy 48 and 53 does drain directly into the lake. Most of the development in the last ten years has included on-site stormwater treatment via retention ponds and other best management practices, so total impacts have been minimized to some degree.

Work completed by SEH in 2008 estimated phosphorous loading from 18 different sub-basins within the Rice Lake city limits leading to outfalls into the lake or the Red Cedar River below the dam (Map 2) (Appendix A). Sub-basins 3, 13, and 18 totaling 787 acres drain into the Red Cedar River below the dam (Map 3). These three basins account for 48% of the total nutrient loading attributed to the City of Rice Lake storm sewer system. Though important to the overall health of the Red Cedar River Basin, they are not included in the immediate calculations associated with the lake itself. The remaining 15 sub-basins cover 1051.84 acres within the city limits (Table 2). Total phosphorous loading to the lake from this area is approximately 1364.73 lbs/year, or about 2.2 lbs of phosphorous/acre/year.

Table 2
2008 Phosphorous loading Data from the 15 Sub-basins That Drain Directly Into Rice Lake

Basin	Total Acres	% of total acreage	Total Loading (lbs)	% of total loading	lbs/acre
1	128.55	12.22	184.39	13.51	1.43
2	698.91	66.45	725.81	53.18	1.04
4	1.43	.14	3.17	.23	2.21
5	1.70	.16	4.08	.30	2.4
6	24.67	2.35	76.65	5.62	3.11
7	29.76	2.83	57.72	4.23	1.94
8	22.70	2.16	23.88	1.75	1.05
9	64.06	6.09	119.12	8.73	1.86
10	11.33	1.06	10.54	.77	.93

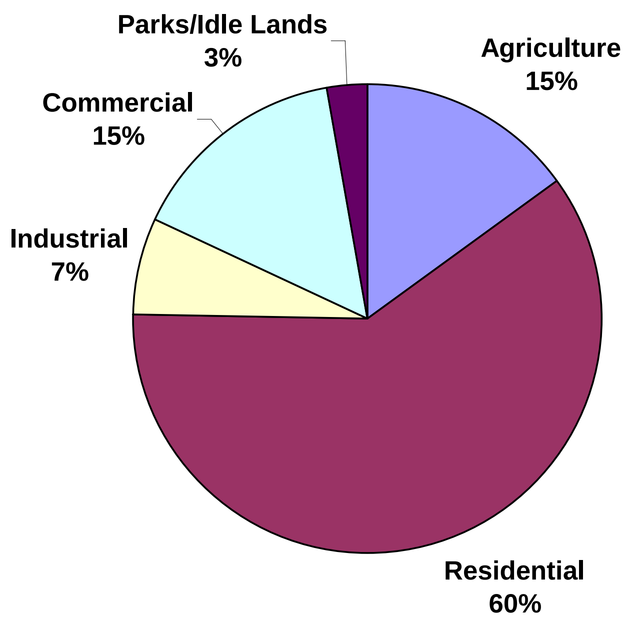
11	4.99	0.47	5.07	.37	1.02
12	25.24	2.40	48.17	3.53	1.91
14	7.41	.7	19.40	1.42	2.62
15	11.12	1.06	35.74	2.62	3.21
16	16.27	1.55	39.04	2.86	2.40
17	3.69	.35	11.95	.88	3.24
Total	**1051.84**	**100%**	**1364.73**	**100%**	**Ave = 2.02**

Sub-basin 2 is almost 700 acres and includes that area of Rice Lake north of the Hwy 48/53 interchange. It contributes more than 53% of the total annual phosphorous loading attributed to the City storm water system to Rice Lake. Sub-basin 2 drains into the Hospital Bay area of the lake, which may explain why Hospital Bay has so much vegetation. Sub-basin 1, at almost 130 acres, contributes more than 13.5% of the total phosphorous attributed to the city storm water sewer. Sub-basin 9, the third largest, contributes almost 8.75% of the total phosphorous. These three sub-basins encompass nearly 85% of the total acreage covered by the city storm water system and contribute more than 75% of the total phosphorous to the lake attributed to the City.

Another way to look at total loading is to determine which sub-basins contribute the most phosphorous per acre. Doing this helps to isolate hot spots within the sub-basins. The average per/acre loading for the entire city watershed is 2.02 lbs/acre. Sub-basins 1, 2, and 9 combined contribute approximately 1.44 lbs/acre, while sub-basins 6, 15, & 17 accounting for only 3.76% of the total acreage but contribute more than double the phosphorous per acre at an average of 3.19 lbs/acre. Sub-basin 6 drains the Fairgrounds and 15 and 17 drain the downtown area.

Type of land use within each individual sub-basin affects the overall phosphorous loading. Land use for this study was evaluated based on the following: agriculture, residential, industrial, commercial, and parks/idle lands. Figure 3 shows the percent of the total land use within the Rice Lake storm sewer drainage area.

Figure 3 – Land Use Within the 15 City Storm Water Sub-basins That Drain Into Rice Lake



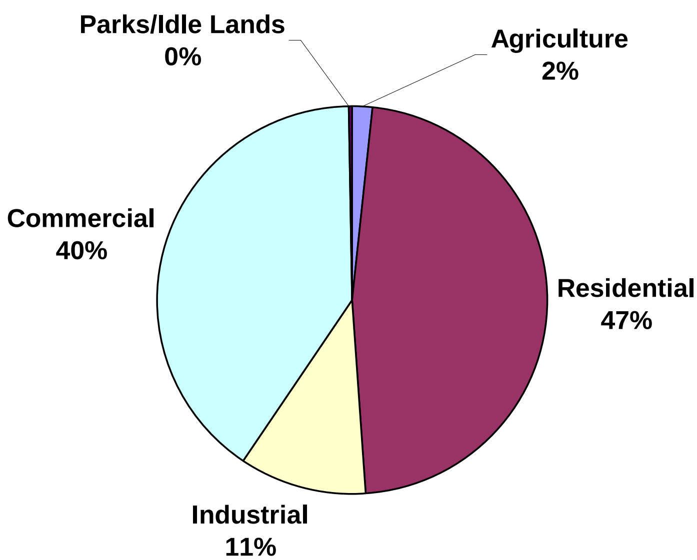
Default phosphorous loading export coefficients for an urban setting (Lin 2004) were used to calculate the total phosphorous load for each of the different land uses (Table 3).

Table 3
Export Coefficients Used in Calculating Total Phosphorous Loading From Different Land Uses Within an Urban Setting

Land Use	Urban Phosphorous Export Coefficient (kg/ha/year)
Agriculture	0.15
Commercial	3.85
Industrial	2.25
Parks/Idle Lands	0.15
Residential	1.14

Figure 4 shows the total phosphorous loading from each of the different types of land use. Residential accounts for 60% of land use and 47% of the total phosphorous loading. Commercial only accounts for 15% of the total land use with in the watershed, but contributes 40% of the total phosphorous loading. In those sub-basins where the major land uses are residential and commercial the percent of total phosphorous loading is high. Agriculture and parks/idle land accounts for 18% of the total land use, but only 2% of the total phosphorous loading. Industry accounts for 7% of the land use and 11% of the phosphorous loading per year.

Figure 4 – Total Phosphorous Loading (lbs) From Each Type of Land Use in That Area of the Rice Lake Storm Water Sewer System That Drains Into the Lake



Steps need to be taken to reduce the total amount of phosphorous entering the Rice Lake system on a yearly basis. Large actions including work in the Red Cedar River and Bear Creek sub-watersheds to reduce runoff and improved City of Rice Lake storm water planning would help do this. Smaller actions including shoreland restoration, buffer strips, rain gardens, street sweeping, and septic system maintenance would also help. Also, maintaining a healthy population of native plants throughout the lake complex is important (as evidenced by the Stump Lake and Clearwater

Bay areas of the lake system). It may also be possible to complete an alum treatment in the South Basin. Given the extended period of time that the South basin remains anoxic, binding the available phosphorous in the sediments so it could not be released back into the system may be beneficial. The rate of sedimentation in the South basin would need to be evaluated as would the retention time of that basin to determine how effective and long lasting an alum treatment could be.

Water coming in from the Red Cedar River is for the most part clean and clear. Water from Stump Lake is similar. Both sources carry phosphorous in their flows, but it is not until it reaches the Upper basin that a combination of available phosphorous, a slowing down of the flow, and a lack of significant plant growth causes significant algal blooms. More severe algal blooms limit light penetration further limiting native plant growth to a handful of species that can tolerate degraded water quality including coontail which then becomes one of the plants of concern that landowners want removed. Effective management needs to break this cycle and protect native plant species as best it can. Rather than take out all offending plants, management should concentrate on navigation and lake use issues and concentrate control measures in those areas that need it most. The late July 2008 plant survey did not locate any native plant beds that had a density over 1.5 on a 1-3 scale. This may be due, in part, to the current harvesting operations and limited water clarity, but it stands to reason to let native plants flourish, and then open up travel and convenience corridors if necessary.

Watershed Management Recommendations

Create a Farmer BMP Incentives Program similar to the one proposed for the Lower and Upper Turtle Lake Watershed. This Incentives Program would include incentives for incorporating best management practices including grassed waterways, fencing to keep livestock out of lake tributaries, feedlot and barnyard improvement projects, buffer strips, etc, and for increasing the total amount of crop land where "no till" agriculture is practiced.

Provide financial support for the Residential and Riparian Best Management Practices and Emergent Species Restoration programs started with the AIS Control Grant.

Provide a Lake District tax Levy credit based on BMP practices incorporated by land owners and the expected reduction in runoff.

Complete an evaluation of the Lower basin to determine if completing an alum treatment to bind existing phosphorous in the sediment in a form that can not be recycled into the lake during periods of anoxia.

Support storm water management goals and objectives established by the City of Rice Lake to reduce their contribution to total phosphorous loading to Rice Lake and the Red Cedar River.

Complete a Public Beach Study to determine if the current beach can be improved or moved to provide more public access to swimming in Rice Lake. Part of this study would be to determine if sources of Swimmers Itch could be identified and then controlled.

Complete a greater amount of Canada geese control in Rice Lake and remind riparian owners that mowed lawn and disturbed shoreline encourages use by Canada Geese.

Provide educational opportunities for all Lake District members to learn what processes are at work in Rice lake, how they can help to improve conditions on Rice Lake, and how they can get and stay involved in lake management activities.

This list of activities is not complete, but provide a good place to start. A Lake Protection Grant will be applied for in 2011 to help provide funding to implement these and other watershed improvements.

References

James, William 2001. Limnological Analysis of Rice Lake, Wisconsin. ERDC Eau Galle Aquatic Ecology Laboratory, Spring valley, WI, pp. 1-24.

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Olson, Nathan and Hanson, Dale 1993. Non-point Source Pollution Study of the Watershed of Rice Lake. Barron County Soil and Water Conservation Department, pp. 1-8.

MAP 1 – Water Quality Monitoring Sites in Rice Lake

MAP 2 – City of Rice Lake Stormwater Sub-basins with City Zoning

MAP 3 – City of Rice Lake Stormwater Sub-basins with Storm Sewer Outfalls

Appendix A – SEH Urban Phosphorous Load Estimates for 18 Sub-basins in the City of Rice Lake