WATER RESOURCES RESEARCH GRANT PROPOSAL

Title: Internal Mechanisms of Nutrient Loading in Ponds.

Focus Categories: SW, WQL, NU

Keywords: Ponds, Phosphorus, Water Quality, Stratification, Anoxia, Nitrogen, Urban Drainage, Radiotracers, Transport in Sediment and Water.

Duration: 3/00 - 3/01

Congressional District: 2nd

FY 2000 Federal Funds: Total $22,500   Direct $22,500   Indirect $0

FY 2000 Non-Federal Funds: Total $52,576   Direct $36,949   Indirect $15,627

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Technical Abstract

Supported by CTIWR/USGS (>99->00), we have been evaluating cryptic thermal stratification, anaerobic respiration, and re-mobilization of phosphorus in hyper-eutrophic Mirror Lake (summer Secchi depth ca. 0.5m). Temperature data collected with Onset TidBits (miniature thermistor/data loggers) have confirmed our three initial hypotheses: (1) daily solar heating extends into the sediments, (2) vertical thermal-density gradients cause water overlying sediments to become anoxic, (3) thermal and chemical gradients frequently de-stabilize, adding advection to diffusion of anoxic bottom water, nutrients, and metals into the photic zone. Not anticipated was the magnitude of daily heat budgets, the intensity of diurnal thermal-density gradients, and the dynamics they impose upon chemical and biological processes in the pond.

Daily excursions of water temperature during spring and summer reach D10^{0}C/12hours, and require measurement in time intervals of 10-15 minutes. In the same period, vertical

thermal gradients reach D10^{0}C/m, and require temperature measurements at depth intervals of 5-10cm. As examples of biochemical processes operating within those thermal dynamics, photosynthesis and respiration in Mirror Lake create daily dissolved oxygen concentrations cycling between saturation and twice saturation. Clearly, measuring rates of chemical and biological processes in Mirror Lake by changes in concentrations of dissolved reactants and products is beyond conventional methods. Fortunately, integrated and miniaturized electronic probes, micro-processors, and digital data loggers (used mostly in sewage treatment plants) are now available, and have the speed, capacity, and endurance to collect water quality data at rates required to understand both processes and predictability in ponds. We request one of those units (YSI/ISCO) for use in Mirror Lake. Portability of the equipment will allow collection of comparative data from Swan Lake (also a pond), as well, which is artificially aerated, relatively clear (Secchi>1m), and has aquatic macrophytes growing on the bottom.

Critical Regional/State Water Problem

Decades of good water quality and nutrient retention in ponds result in the accumulation of decades of external P from pond drainage basins, loading pond sediments. In the latter stages of pond succession and eutrophication, re-mobilization of P by anaerobic respiration enabled by micro-stratification, can produce very high fluxes of P to the water column (internal loading of P). These high fluxes can occur as event-like processes due to thermal instability driven by daily heating cycles. The magnitude of internal P-loading is likely closer in magnitude to decades of external input and is a function of sedimentation rate, sediment mixing depths, and the depth of sediment thermal stratification. The more significant the early success of ponds as a BMP, the more likely their eventual failure will be just as significant.

Ponds provide primary water quality improvement because dissolved phosphorus (PO_4 ^{3}) combines with oxidized iron (Fe^{+3}) to create insoluble compounds that can be buried in pond sediments. But, Fe^{+3} is chemically reduced to soluble Fe^{+2} in anoxic bottom sediments, making P mobile once more. In deeper lakes, oxygenated water below the photosynthetic zone recycles P back to the sediments. But in shallow ponds P released by sediments is taken up by photosynthetic algae blooms faster than it is returned to the sediments. Because residence times for water in ponds are short, a significant fraction of P released by sediments can be discharged downstream, creating poor water quality elsewhere. By the time effects of the P loading are apparent, little evidence may remain of the thermal gradients and anoxia that caused the internal P-loading, and the evidence of the controlling processes (micro-stratification and de-stabilization) no longer exist. Best Management Practices (BMPs) use ponds because they were thought to mimic the dynamics of lakes in retaining P. Differences in both scales and response times of small ponds suggest that BMPs involving ponds be re-examined.

Results and Benefits

Mirror and Swan Lakes (ca. 1.5m maximum depth) on the Storrs Campus of the University of Connecticut are typically mis-used urban ponds. Easily accessible to research facilities, they provide a rare opportunity to evaluate the use of ponds to remove nutrients and metals in runoff as well as the re-mobilization, internal loading, and export of excess nutrients and metals from aging ponds. Located on the campus of a major University the ponds are an ideal place to combine fundamental research with education and technology transfer.

Scheduled on time and space scales appropriate to ponds, the data to be collected and already collected from Mirror/Swan ponds (Figures 1,2,3) define and quantify pond processes and couplings among specific physical, chemical, and biological processes. The development of a mathematical model of pond processes (building on the first order model shown in Figure 4) constructed with those data can predict specific pond responses to external events, including responses of ponds over time (e.g. export of nutrients and metals). The model is to be generic for pond processes, and transferable to other ponds in other places, needing only measurements of a few pond-specific parameters (e.g. primary production, internal nutrient recycling, respiration redox reactions) . Mathematical models enable exploration of the error of predicted response, and of engineering safety factors within which the pond must operate. The sheer numbers of ponds currently in use as detention/retention basins suggest such a pond process model has extensive application, and will contribute to development of BMPs that specify maintenance for ponds rather than emergency retrofits.

Until in pond P loading is understood, defined in terms of its processes, and dynamically constrained by the time constants of the processes, a useful Best Management Practice (the use of ponds in urban/suburban landscapes) is questionable. Understanding the specific controls and driving forces for intermittent thermal stratification and internal P loading from pond bottoms will lead to better management of ponds for the same reasons that understanding *external* P loading from drainage basins led to effective management of lakes in the 1970s. Upon completion of this research, we will have demonstrated (or scientifically refuted) the role of micro-stratification and de-stabilization as a control process for internal P-loading in small ponds. Based on data obtained with last year=s funding, we are seeking additional funding through this and other appropriate avenues, including collaboration with the Connecticut Dept. of Environmental Protection (CTDEP) and Dept. of Transportation (CTDOT) in implementation and evaluation of BMPs in other ponds. Regardless of the outcome, our analytical techniques and the close interval sampling equipment installed in Mirror Lake will be available to colleagues in three Colleges (Liberal Arts & Science, Engineering, and Agriculture) within the University of Connecticut for demonstrations, environmental science laboratories and graduate student projects.