From: Ornberg, Kim [kornberg@seminolecountyfl.gov]
Sent: Thursday, June 26, 2008 9:48 AM
To: tlbusby@wildwoodconsulting.net; Gihring, Jennifer
Subject: Response to SJRWMD contracted peer review of the sed flux study
Hi All!
I wanted to send this official response to the critique (by ECT funded by SJRWMD) of the Sediment Flux Study (by HDR/HydroO2 funded by Sem. Co.). This was submitted back to SJRWMD shortly after we received the critique, but was not included or addressed by SJRWMD in it's documents or reports. Can you add it to the Sediment Reports folder on the ftp site? Thanks!

Kim

Review of the Review of the Lake Jesup Sediment Flux Study
Scott Lowe

- I should note that $HydrO_2$ is in fact the same Murphy and Hicks from the cited reference (Murphy and Hicks 1986).

- $HydrO_2$ was asked to report mainly on results, not the methodology, as I knew the methodology already. Nor were they asked to write anything on the external nutrient budget of the lake. The tubes were a new idea and so were discussed.

- The general methodology for using domes, or chambers, for in-situ DO and flux measurements has been around for several decades. The method was honed by EPA Region IV in particular, over a period of three decades, primarily by Phil Murphy and Del Hicks who used to work for EPA Region IV.

- After the pre-survey Phil Murphy noted to me that in all the years they had been doing this type of work, Lake Jesup had the most unconsolidated sediment they had worked with. He was concerned that even the chambers fitted with collars would sink. He thought that using long tubes, instead of relatively squat chambers, would help. I agreed that we should try this. These tubes did not exist and so they were made up just for the Jesup survey. This was purely an experiment that we hoped would work. As reported, the tube results were not great and should not be weighed heavily.

- Regarding the TkN results: Most of the N and P found in the TkN and TP results are associated with particulates. These settle out over the study period and so the final result is less than the initial, which gives a negative flux (flux from water to sediment), as would be expected with solids.

- Stirring: Usually a pump is used to induce gentle stirring in the chambers in order to mimic bottom water movement and hence attempt to get realistic in-situ diffusion. The trade off is that solids cannot be resuspended as they will be drawn into the samples, where they will throw off the resulting measurement substantially. In the case of Jesup the sediments were so flocculant that any mixing would have resuspended them, and so it was decided to not mix at all.

- Regarding the variation of initial values: these are not replicates but three chambers placed in fairly close proximity. Sediments are notorious for their spatial variability even over short distances, hence why three chambers are used at each site. This, unfortunately, is the nature of sediments, even under good conditions.

- The implication that the results are questionable was framed based on the measured variability, the lack of stations and some loading numbers. The variability is inevitable and does not represent bad data or errors. The lack of stations is what it is, the more data the better. Previous to this study the number of data points was zero. The Qual2k water quality model of Lake Jesup generated estimated fluxes close to what was measured before the study was done. Without the fluxes the water quality model cannot come close to reproducing the observed conditions in the lake.

General Comments on Sediment Flux Measurements
Scott Lowe

Diffusion and Resuspension

Nutrient fluxes and sediment oxygen demand is the product of a combination of resuspension and diffusive transfer. Resuspension is usually event driven and may cause a major release of nutrients during the event. It is not clear how large an impact resuspension events would have on a lake over the course of a year, compared to diffusive processes that occur continually. Certainly the solids that are resuspended will settle back out fairly quickly. Diffusive transfer applies only to dissolved constituents. Resuspension is usually taken to mean solids, but the turbulence generated during a resuspension event will also cause a transfer of dissolved material as will.

Diffusive Sediment Flux

The diffusion of oxygen and nutrient fluxes is related to pore water concentrations in the sediment, overlying water concentrations, and to the diffusion rate (see DiToro 2001 for the seminal review of the various physical, biological and chemical components of sediment fluxes –

624 pages devoted to the subject!). The pore water concentrations usually vary dramatically with depth. The oxygen profile in sediment, for example, decreases from the overlying water concentration at the sediment surface, to zero, in a few millimeters. This in turn defines the aerobic and anaerobic layers for the sediment. Despite its small depth, the aerobic layer plays a primary role in determining the fluxes of concern. Nutrients, such as nitrate, ammonia and phosphorus behave differently in each layer and there are large differences between the layers. If the overlying water DO concentration goes to zero, for example, then the aerobic layer disappears, and large nutrient and metal fluxes will be observed. The reactions that take place in the sediment, mineralizations and oxidations, are performed by bacteria and other micro-organisms.

The sediment continually receives new inputs of organic matter as solids settle out. This continues to drive the diagenesis that in turn results in the SOD and nutrient fluxes.

Diffusion Processes

The diffusion that drives the fluxes is due to the combination of various factors:

1. Molecular diffusion.

2. Biological activity – both at the sediment surface (bioirrigation) and within the sediment (bioturbation).

3. Turbulence at the sediment-water interface.

Biological activity and turbulence increase the in-situ diffusion rate anywhere from a factor of 5 to 50 over just molecular diffusion (DiToro 2001, Chapra et al 2005).

Sediment Core Based Methods

Given the above discussion it is easy to see that if one uses a small diameter tube driven into the sediment to extract a core, transports it back to a lab, and then proceeds to take measurements, that most of the factors listed above have been altered. This includes the sediment structure, the biology and the diffusion (other than perhaps the molecular diffusion). Can these factors be reconstructed in the lab? Possibly, but how would you know whether they have, or have not, been successfully duplicated? The study mentioned Moore (1998) used 1m long tubes that were 6.35 cm in diameter inserted 60 cm into the sediment, using a mallet if necessary, and Qu (2005) used 7 cm outside diameter cores driven 15 cm into the sediment.

The common rider to taking cores is that if they can be extracted, handled and transported with minimal sediment disturbance then, in theory, reasonable results can be achieved. To do this would require the use of very large diameter cores or using a large grab corer. The difficult part of the operation then becomes handling the large volumes – transporting them and setting up the lab component. Any cost advantage likely to be obtained over in-situ methods would probably be gone at this point.

Pore Water Profiles

Trying to measure in-situ pore water profiles is extremely difficult because of the very small depths involved if one tries to profile, or even delineate, the aerobic layer. Trying to construct pore water profiles from an extracted core will suffer both from the scale difficulty and the issue of sediment disturbance outlined above. The case noted from Lake Illawarra (in Wollongong, Australia, the town where I grew up – what are the chances!!) for example, used 2 cm intervals. I happen to know based on work we did a long time ago on the lake that the aerobic layer in Lake Illawarra is probably only about 1mm thick, at best.

In-Situ Chambers

In-situ chambers leave the sediment intact but compromise on the overlying water turbulence. Usually some mixing is generated in an attempt to match the observed velocities at the site but there is no guarantee that similar turbulence is created. This is also usually the most expensive method.

The Time Factor

In any method the longer the measurements take the more the system is compromised and the more it will drift from its in-situ state. In the case of flux chambers the measurements are done over a period of several hours. Even over this time frame the confined overlying water will be changing relative to unconfined water around it. Incubations, by their nature, take place over long periods of time, up to weeks. Extracting cores and transporting them also creates a time delay before measurements are even begun.

Comparison of Methods

Comparisons of SOD measurements between lab and in-situ chambers was performed in several TVA reservoirs by the EPA in 1983 (see Murphy and Hicks, 1986, for a summary). They concluded that the lab method, on average, predicted much lower SOD values than the chambers. In general there was no agreement between the lab and chamber data. This result has also been confirmed by other studies such as Edwards and Rolley (1965), Rolley and Owens (1967), Edburg and Hofson (1973) and Belanger (1979).

Miller-Way et al (1994) compared in-situ and ship board lab flux measurements of oxygen and nutrients, and found large differences. They used both box cores and diver extracted sediments to obtain undisturbed sediments. Ammonia matched the best with a 50% difference. SOD varied by a factor of five. The lab phosphorus flux was negative, indicating a flux into the sediment.

A Better Method?

All of this begs the question – is there a better approach? Can one simply measure concentrations above the sediment-water interface over a period of time and derive the flux rate from this? This would leave both the sediment and the overlying water undisturbed. The problem, of course, is that one has no way of isolating the effect of any concentration change that is observed. Presumably the biggest influence at any point will be the advective transport due to water motion. To take this out of the picture one would have to isolate a volume of water - and then one ends up with a chamber of some sort. What about if we injected a tracer into the sediment and measured its release? This would give us a good shot at the in-situ diffusion rate but we would lose any reactions that are taking place. What if we did two tracer injections and then placed a chamber over one. We would then be able to measure the diffusion rate in the open and compare it to the chamber. This would allow us to estimate the difference in actual diffusion taking place in the chamber while still collecting concentration data. Effectively this would help to adjust the chamber results to account for diffusion difference.

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