LAKE JESUP
SEMINOLE COUNTY, FLORIDA
In situ ASSESSMENT
Of
SEDIMENT NUTRIENT FLUX ASSESSMENT
And
SEDIMENT OXYGEN DEMAND

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LAKE JESUP
SEMINOLE COUNTY, FLORIDA
In SITU ASSESSMENT OF
SEDIMENT NUTRIENT FLUX & SEDIMENT OXYGEN DEMAND
SEPTEMBER 25-29, 2006

INTRODUCTION

As part of their support to Seminole County, Florida, related to assessment of Total Maximum Daily Load (TMDL) of nutrients to Lake Jesup, HDR Engineering, Inc. requested that $HydrO_2$, Inc. conduct an *in situ* assessment of sediment nutrient flux from the lake bed sediments. Specifically, field efforts conducted under subcontract by $HydrO_2$ to HDR consisted of *in situ* measurement of sediment nutrient flux at five locations distributed throughout the lake. $HydrO_2$ personnel have long standing experience in the development, refinement, and implementation of *in situ* techniques for acquisition of these types of data. The Plan of Study (POS) detailing the tasks and methods associated with the nutrient flux assessment is incorporated into this report as Appendix A. However, modifications to the assessment approach presented in the POS were dictated by findings during reconnaissance activities which revealed sediment characteristics in portions of the lake to be unsuitable for *in situ* chamber deployment. The modifications, developed and discussed with Seminole County and HDR prior to the field study, are presented subsequently in the Methods section of this report.

This report describes the reconnaissance findings conducted by $HydrO_2$ and Seminole County personnel on September 18, 2006, and nutrient flux assessments conducted by this same team during the period September 25-29, 2006

STUDY APPROACH

At initiation of study planning, the HDR project engineer and $HydrO_2$ personnel discussed the potential problematic character of the lake bed sediments of Lake Jesup. Accordingly, using various maps of the lake bed sediments and bathymetric charts, $HydrO_2$ and Seminole County personnel conducted a reconnaissance of the lake one week in advance of the field study. The goal of the reconnaissance was to select five representative locations for potential nutrient flux measurements. During the recon, profiles of dissolved oxygen (surface to bottom) were conducted at seven locations to determine lake-bottom dissolved oxygen resources available for *in situ* chamber incubation and maintenance of aerobic condition within the chambers throughout the incubation time. At these same locations, dives were made by $HydrO_2$ personnel to assess sediment characteristics, tactically due to zero visibility, as well as collection of sediment cores for visual observation on deck. An *in situ* chamber was deployed to assess penetration and settling of the chamber into the soft substrate. Dissolved oxygen resources were deemed adequate for potentially long incubation times at all locations. Findings from the reconnaissance activities confirmed that the lake bed consists predominately of an unconsolidated stratum of very "fluid" sediment (floc), over soft mud. The vertical thickness of the floc layer varied by location. One location between the northeastern lake shore and Bird Island exhibited a relatively thin (approximately 4 inch) layer of floc over hard clay. The remaining sites consisted of loose floc over soft mud, each varying in thickness. Accordingly, it became evident during the recon that SOD/Nutrient Flux chamber (Murphy & Hicks, 1986)[1] deployment would be possible at three locations with the remaining reconnaissance sites requiring an alternate technique due to the greater depth of the unconsolidated sediments.

SAMPLING LOCATIONS

As specified in the Plan of Study (Appendix A), five locations were selected in Lake Jesup for sediment nutrient flux determination. Station locations are depicted in Figure 1. GPS coordinates and general sediment descriptions are as follows:

TABLE 1
STATION COORDINATES AND DESCRIPTION

STATION	LATITUDE	LONGITUDE	DESCRIPTION
1	28° 44.489'	81° 13.459'	Water depth 4-5 feet; approx. 4-6 inches unconsolidated sediment ("floc") over soft mud
2	28° 42.875'	81° 15.892'	Water depth 7-8 feet; approx. 12-15 inches floc over soft mud; stiff, thin layer at approx. 24" within soft mud layer, then more soft mud.
3	28° 43.094'	81° 12.371'	Water depth 5-6 feet; approx. 6 inches of "floc" over grey mud w/ layer of snail shells
4	28° 44.667'	81° 11.361'	Water depth approx. 4 feet; approx 15 inches floc over soft mud; stiff, thin layer at approx. 24" within soft mud layer, then more soft mud.
5	28° 44.190'	81° 12.576'	Water depth 3-4 feet; approx. 4-6 inches of floc over hard clay; dense layer of snail shells (live and dead.

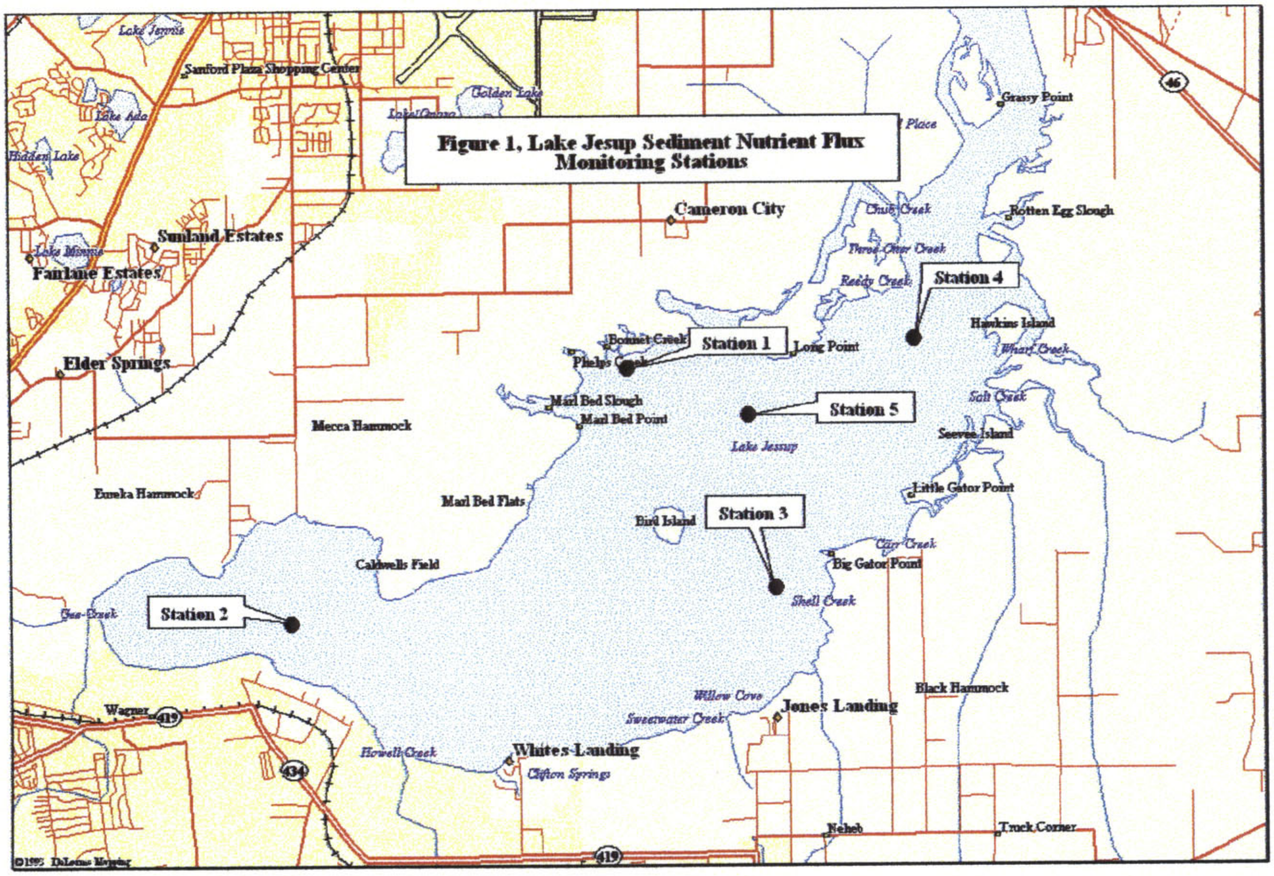


Figure 1, Lake Jesup Sediment Nutrient Flux Monitoring Stations

TASKS and METHODS

To assess sediment nutrient flux rates, $HydrO_2$ typically uses an *in situ* chamber method developed and published by $HydrO_2$ personnel (Murphy & Hicks, 1986). $HydrO_2$ personnel have successfully used this method in other waterbodies for determination of sediment nutrient flux. In addition to sediment nutrient flux, this method also provides for measurement of sediment oxygen demand (SOD). Monitoring of SOD, even when not the primary parameter, is required to determine the DO resource available to sustain aerobic conditions within the enclosures during the deployment period. At each sampling station, three replicate *in situ* chambers were deployed in contact with the sediment. An identical chamber but with a sealed bottom, was deployed concurrently with the sediment contact chambers to measure water column processes, only. In extremely soft sediments such as Lake Jesup, depth of penetration of the chamber must be controlled to avoid settling of the chamber that could literally result in burial of the chamber beneath the sediment/water interface if not controlled and confirmed by divers. This can be accomplished in most cases by fitting the chamber with a supplemental extended "collar" (See cover photograph). This approach proved effective at Stations 1, 3, and 5. However, extensively deep and fluid "floc" atop soft, unconsolidated mud at Stations 2 and 4 called for an alternate approach in an attempt to measure sediment nutrient flux under these less suitable conditions of sediment structure. Discussion and concurrence with HDR and Seminole County personnel led to the fabrication and deployment of aluminum "tubes" at Stations 2 and 4. The tubes, approximately 10.5 inches (27mm) in diameter by 48 inches ((122 cm) in length, enclosed a $0.057m^2$ area of sediment. Volume of the tube above the sediment/water interface was dependent upon depth of penetration and, thus, varied slightly with each tube deployment. Depth of penetration (generally approximating 24 inches at each station) for volume calculations was measured specifically and recorded on site at each station for each individual tube. As with the *in situ* chamber method, a "blank" tube enclosure isolating 20 liters of water unaffected by sediment processes was deployed concurrently at each tube station to address water column nutrient cycling and water column respiration for adjustment of nutrient flux and SOD rates. In all cases, both with chambers and tubes, observed conditions at depth in the lake led to the decision to forego mixing via pumps and diffusers within the enclosures in order to better simulate the quiescent ambient conditions at the lake bottom and to avoid sediment re-suspension and its potential effect on nutrient flux and sediment oxygen demand rates. Gentle mixing near the sampling port prior to extraction of the final samples was accomplished manually by a diver while maintaining the seal integrity of the enclosures. All-in-all, the mechanics of the tube assessment of nutrient flux closely resembled that of the *in situ* chambers, with the exception that the tubes provided a greater stratum of water between the sediment/water interface and the sealed top of the tube, than exists in the height-restricted chambers. This resulted in an increased volume-to-surface area ratio for the tubes versus the chambers as well as sample extraction at a greater vertical distance, approximately 20-23 inches, above the sediment/water interface in the tubes versus approximately 10 inches in the chambers. These variables relative to the experimental tubes appears to have impacted comparability of the tube data, resulting in caution regarding its utility as discussed in the following results.

RESULTS

Sediment Nutrient Flux

Target analytes for sediment nutrient flux measurements were ammonia (NH_3), Total Kjeldahl Nitrogen (TKN), Nitrite and Nitrate ($NO_2 + NO_3$), Total Phosphorous (TP), and Total Dissolved Phosphorous (DP). Sediment nutrient flux calculations and results are presented in Tables 3-7. Most notable of the parameters measured were the flux rates associated with NH_3 and DP. At the *in situ* chamber stations (Stations 1, 3, and 5) flux of these nutrients were consistently from the sediment toward the water column (positive flux), with the exception of DP at Station 3. At the tube Stations 2 & 4, flux of DP was, likewise, positive while NH_3 flux was negative (from the water column to the sediment). Flux rates and direction for TKN and TP are less definitive which, based on experience, is not uncommon for these parameters due to the variable nature of the organic nitrogen components associated with TKN and the sorption of phosphorous to suspended and settable particulate in the TP measurements.

Table 2 presents a summary of ammonia and total dissolved phosphorous loadings for all five stations with the associated means. Including the results of the experimental tube approach, which were inconsistent with the more widely used *in situ* chamber method, there is a considerable net gain of NH_3 and DP to the waters of Lake Jesup from the lake bed. A cursory extension of the mean flux for NH_3 and DP rates/m^2 (Table2) to a presumed total lake area of 69,700,000 m^2 (16,000 acres) reveals loadings of 3,122,560 gm/day (6877 lbs/day) for ammonia and 250,920 gm/day (553 lbs/day) for dissolved phosphorous. Considering the experimental nature of the tube measurements, and their inconsistency with the *in situ* chamber method results, these loadings are potentially a very conservative estimate. With removal of the tube results from the mean calculations, mean rates swell to 7,116,370 gm/day (15,675 lbs/day) for NH_3 and 327,590 gm/day (722 lbs/day) for dissolved phosphorous. By either of the above measures, the lake bed is a considerable source of nutrients to the waters of Lake Jesup.

In decisions regarding whether to include the tube measurements within the data set that will ultimately be used in modeling sediment contributions to the nutrient loading of Lake Jesup, several factors warrant consideration. First, as previously mentioned, the inconsistency of the tube results compared to the results of the reliable *in situ* chamber method, coupled with the relative similarity in sediment characteristics among the five stations, allows for pause when considering the utility of the tube data. Logically, there is little basis for the thought that the direction of nutrient flux should be spatially different within the main body of the lake under conditions of similar water column and sediment characteristics as present during the study. Secondly, physical features associated with the tubes and the sampling approach may not have accurately captured the actual flux at the sediment/water interface. For instance, in the attempt to assure sampling within the tubes above the floc layer, coupled with the facts that the tubes were of a fixed length and divers could not penetrate the tubes any deeper than approximately two feet into the soft mud, a vertical lens of water approximately two feet in height remained above the sediment/water interface. Samples were extracted from the top of the tube, which generally was approximately 24 inches above the sediment surface. Samples from the *in situ* chambers were extracted much nearer sediment/water interface due to the inherent design of the chamber. With the decision not to mechanically mix neither the chambers nor the tubes so as to simulate ambient conditions, as well as to avoid re-suspension, the quiescent conditions within the large vertical stratum within the tube may not have presented a sample representative at the top of the tube that was a true measurement of the flux of nutrients at the sediment/water interface. Additionally, the extended vertical height of the water within the tube could have incorporated phytoplankton not generally present deeper in the water column nearer the sediment/water interface. As such, nutrient cycling within this more extensive stratum may have played a role in the processes effecting concentrations of the biologically reactive ammonia and dissolved phosphorous. Lastly, dissolved oxygen concentrations within the tubes at Station 4 were considerably above ending concentrations for other overnight incubations at other stations, raising the question of potential leaks in each tube caused by a dense hyacinth mat observed at this location that tangled with the tubes mooring and floats overnight, possibly placing tension on the surface cap.

None of the above speculation is conclusive and, thus, remains only suggestive. The use of tubes to address nutrient flux in extremely unconsolidated sediments such as Lake Jesup exhibits promise as an approach to overcome the problematic nature of unconsolidated substrates, but additional work is the only route to validate or negate the possibilities discussed above. Additional modifications specifically aimed at developing an on-site ability to adjust and control the height of the water column within the tube, thereby reducing the volume-to-surface area ratio, as well as permitting sampling nearer to the sediment/water interface, is a requirement learned from this effort. In conclusion, however, with or without the tube data included, the overall analysis clearly reveals the lake bed to be a notable source of ammonia and dissolved phosphorous to the water column in Lake Jesup.

TABLE 2
LAKE JESUP, SEMINOLE CO., FL
MEAN FLUX RATES
GM/M2/DAY

	Station Means	
SITE	**NH3**	**Dissolved P**
1	0.0209	0.0149
2	-0.0758	0.0023
3	0.1416	-0.001
4	-0.0064	0.0014
5	0.1439	0.0003
Note: Positive Nutrient Flux is From Sediments to the Water Column		
Lake Avg (all stations)	**0.0448**	**0.0036**
Lake Avg (Stations 1,3,5)	***0.1021***	***0.0047***

	NUTRIENT FLUX TO WATER COLUMN		
	NH3		**Dissolved P**
BASE ON AVG - ALL STATIONS	3,122,560	gms/day	250,920
	6878	lbs/day	553
BASE ON AVG of STA. 1,3, & 5	7,116,370	gms/day	327,590
	15,675	lbs/day	722

(Estimate for 16,000 acre lake => (16,000 acres)x(43560ft2/acre)x(0.1m2/ft2) =69,700,000 m2)

Sediment Oxygen Demand

The *in situ* chamber SOD methodology employed by $HydrO_2$ facilitates the assessment of sediment nutrient exchange (NUTX) along with sediment oxygen demand. Initial monitoring of dissolved oxygen concentrations within the chambers and tubes was necessary in order to establish the oxygen decay rate which governs length of incubation. Nutrient flux sampling initiated under aerobic conditions must be completed prior to anoxic conditions occurring within the enclosure. Typically, dissolved oxygen monitoring for SOD rate determination occurs over a 90-180 minutes period initiated at deployment of the chambers. However, the unconsolidated character of Lake Jesup sediments coupled with wind prevented monitoring of this duration at Stations 2, 4, and 5. In order to remain precisely positioned on station, with the various lines and cables tending from the boat to the chambers, a 5-point anchoring array was deployed at each station. However, with measured wind speeds as little as 10-15 mph, anchor drag through the unconsolidated sediment resulted in the boat shifting to the extent that it became necessary to extract the DO probes early, stopper the DO port, and detach from the chambers or tubes at Station 2, 4, and 5. Limited but sufficient data were obtained at the *in situ* chambers Stations 1, 3, and 5 to determine SOD rates over a time sequence initiated at deployment. Overnight incubation of tubes at Station 2 permitted SOD rate calculations. However, no SOD rates are reported for Station 4 due to wind driven boat drift immediately at deployment as well as the potential and questionable impact to the tubes and their DO concentrations during the night by a hyacinth mat previously mentioned. Measured rates are presented in Table 8. At Stations 3 and 5 *in situ* chamber rates are reported for the abbreviated initial monitoring period, as well as the extended overnight incubation where only an initial and final dissolved oxygen concentration was used for rate calculations. At each of these two stations, the short period SOD rate is greater than the overnight SOD rate, as expected. Based on experience, during long period incubations, as the dissolved oxygen resource within the chambers is diminished to low concentrations, oxygen decay rates begin to slow. The short versus overnight incubations at Stations 3 and 5 exhibited these same apparent influences with short term versus overnight rates of 1.26 vs 0.78 and 2.11 vs 1.63 $g/m^2/day$, respectively, in conjunction with final DO concentrations generally near 0.5 mg/L at Station 3 and 1.5 to 2.0 mg/L at Station 5.

REFERENCES

1/ Murphy, P.J. and D.B. Hicks, 1986. In-situ method for measuring sediment oxygen demand, *in* Hatcher, K.J., ed., Sediment oxygen demand—Processes, modeling, and measurement. University of Georgia, Institute of Natural Resources, Athens, Georgia, p. 307-322.

TABLE 3
SEDIMENT NUTRIENT FLUX RATE
STATION 1

SITE #1 9/25/06

SOD Chambers

LAB/FIELD DATA

Chamber	Collection Time	NH3	TKN	NO2-NO3	T-P	Diss P
Rep		mg/l	mg/l	mg/l	mg/l	mg/l
O Initial	1410 reset	0.0091	3.2	0.0052	0.16	0.0393
O Final	1800	0.009	3	0.0052	0.15	0.0265
1 Initial	1035	0.009	3.5	0.0052	0.17	0.015
1 Final	1800	0.041	3.2	0.0052	0.16	0.0246
2 Initial	1045	0.009	3.1	0.0052	0.15	0.0168
2 Final	1800	0.046	3	0.0052	0.15	0.0286
3 Initial	1035	0.014	3.2	0.0052	0.15	0.013
3 Final	1800	0.025	2.9	0.0052	0.14	0.0105

FLUX (mg/l)

Chamber	Incubation Period Minutes	NH3	TKN	NO2-NO3	T-P	Diss P
O	230	-0.0001	-0.2	0	-0.01	-0.0128
1	445	0.032	-0.3	0	-0.01	0.0096
2	435	0.037	-0.1	0	0	0.0118
3	445	0.011	-0.3	0	-0.01	-0.0025

NET SEDIMENT FLUX (GM/M2/DAY)

Chamber		NH3	TKN	NO2-NO3	T-P	Diss P
1		0.024774	-0.07718	0	0	0.017288
2		0.029291	0.078952	0	0.007895	0.019422
3		0.008567	-0.07718	0	2.14E-17	0.007949

NOTE: Positive Nutrient Flux rate is From Sediments To The Water Column

TABLE 4
SEDIMENT NUTRIENT FLUX RATE
STATION 2

SITE #2 9/26-27/06

Tube Chambers

LAB/FIELD DATA

Chamber	Collection Time	NH3	TKN	NO2-NO3	T-P	Diss P
Rep		mg/l	mg/l	mg/l	mg/l	mg/l
O Initial	9/26/06 1645	0.028	3.4	0.0052	0.1	0.00786
O Final	9/27/06 0910	0.023	3.2	0.0052	0.094	0.01
1 Initial	9/26/06 1650	0.24	4.1	0.0052	0.16	0.00783
1 Final	9/27/06 0905	0.077	3.7	0.0052	0.12	0.00935
2 Initial	9/26/06 1655	0.06	3.8	0.0052	0.13	0.00594
2 Final	9/27/06 0900	0.037	3.6	0.0052	0.11	0.0126
3 Initial	9/26/06 1700	0.21	4.4	0.0052	0.17	0.0119
3 Final	9/27/06 0855	0.12	3.7	0.0052	0.14	0.0131

FLUX (mg/l)

Chamber	Incubation Period Minutes	NH3	TKN	NO2-NO3	T-P	Diss P
O	985	-0.005	-0.2	0	-0.006	0.00214
1	975	-0.163	-0.4	0	-0.04	0.00152
2	965	-0.04	-0.2	0	-0.02	0.00666
3	955	-0.09	-0.7	0	-0.03	0.0012

NET SEDIMENT FLUX (GM/M2/DAY)

Chamber		NH3	TKN	NO2-NO3	T-P	Diss P
1		-0.13086	-0.16564	0	-0.02816	-0.00051
2		-0.02796	0	0	-0.01118	0.00361
3		-0.0686	-0.40356	0	-0.01937	-0.00076

NOTE: Positive Nutrient Flux rate is From Sediments To The Water Column

TABLE 5
SEDIMENT NUTRIENT FLUX RATE
STATION 3

SITE #3 9/27-28/06

SOD Chambers

LAB/FIELD DATA

Chamber	Collection Time	NH3	TKN	NO2-NO3	T-P	Diss P
Rep		mg/l	mg/l	mg/l	mg/l	mg/l
O Initial	9/27/06 1145	0.023	4	0.0052	0.12	0.00594
O Final	9/28/06 0855	0.027	3.8	0.0052	0.11	0.0148
1 Initial	9/27/06 1103	0.027	4	0.0052	0.12	0.00783
1 Final	9/28/06 0900	0.55	4.4	0.0052	0.11	0.0163
2 Initial	9/27/06 1150	0.036	4.4	0.0052	0.14	0.00729
2 Final	9/28/06 0845	0.48	4.3	0.0052	0.12	0.0123
3 Initial	9/27/06 1140	0.035	4	0.0052	0.13	0.00959
3 Final	9/28/06 0850	0.66	4.7	0.0052	0.13	0.0115

FLUX (mg/l)

Chamber	Incubation Period Minutes	NH3	TKN	NO2-NO3	T-P	Diss P
O	1270	0.004	-0.2	0	-0.01	0.00886
1	1317	0.523	0.4	0	-0.01	0.00847
2	1245	0.444	-0.1	0	-0.02	0.00501
3	1270	0.625	0.7	0	0	0.00191

NET SEDIMENT FLUX (GM/M2/DAY)

Chamber		NH3	TKN	NO2-NO3	T-P	Diss P
1		0.135342	0.156465	0	0	-0.0001
2		0.121376	0.027586	0	-0.00276	-0.00106
3		0.167934	0.243383	0	0.002704	-0.00188

NOTE: Positive Nutrient Flux rate is From Sediments To The Water Column

6
SEDIMENT NUTRIENT FLUX RATE
STATION 4

SITE #4 9/28-29/06

Tube Chambers

LAB/FIELD DATA

Chamber	Collection Time	NH3	TKN	NO2-NO3	T-P	Diss P
Rep		mg/l	mg/l	mg/l	mg/l	mg/l
O Initial	9/28/06 1135	0.034	4.8	0.0052	0.21	0.0103
O Final	9/29/06 1000	0.028	3.7	0.0052	0.13	0.0116
1 Initial	9/28/06 1155	0.035	4.7	0.0052	0.2	0.00148
1 Final	9/29/06 1005	0.022	4.1	0.0052	0.15	0.0117
2 Initial	9/28/06 1150	0.04	4.9	0.0052	0.19	0.00598
2 Final	9/29/06 1010	0.031	4.1	0.0052	0.15	0.0107
3 Initial	9/28/06 1045	0.048	5.2	0.0052	0.22	0.00668
3 Final	9/29/06 1010	0.022	3.9	0.0052	0.14	0.00666

FLUX (mg/l)

Chamber	Incubation Period Minutes	NH3	TKN	NO2-NO3	T-P	Diss P
O	1345	-0.006	-1.1	0	-0.08	0.0013
1	1320	-0.013	-0.6	0	-0.05	0.01022
2	1320	-0.009	-0.8	0	-0.04	0.00472
3	1405	-0.026	-1.3	0	-0.08	-2E-05

NET SEDIMENT FLUX (GM/M2/DAY)

Chamber		NH3	TKN	NO2-NO3	T-P	Diss P
1		-0.00506	0.361482	0	0.021689	0.006449
2		-0.00217	0.216889	0	0.028919	0.002473
3		-0.01202	-0.12017	0	0	-0.00079

NOTE: Positive Nutrient Flux rate is From Sediments To The Water Column

TABLE 7
SEDIMENT NUTRIENT FLUX RATE
STATION 5

SITE #5 9/28-29/06

SOD Chambers

LAB/FIELD DATA

Chamber	Collection Time	NH3	TKN	NO2-NO3	T-P	Diss P
Rep		mg/l	mg/l	mg/l	mg/l	mg/l
O Initial	9/28/06 1540	0.018	4.4	0.0052	0.16	0.0121
O Final	9/29/06 0800	0.037	4.8	0.0052	0.18	0.011
1 Initial	9/28/06 1620	0.024	4.7	0.0052	0.18	0.0154
1 Final	9/29/06 0830	0.61	4.6	0.0052	0.13	0.0168
2 Initial	9/28/06 1625	0.1	4.8	0.0052	0.19	0.0181
2 Final	9/29/06 0845	0.53	4.6	0.0052	0.14	0.0145
3 Initial	9/28/06 1630	0.087	5.1	0.0052	0.18	0.0129
3 Final	9/29/06 0835	0.35	4.7	0.0052	0.16	0.0139

FLUX (mg/l)

Chamber	Incubation Period Minutes	NH3	TKN	NO2-NO3	T-P	Diss P
O	980	0.019	0.4	0	0.02	-0.0011
1	970	0.586	-0.1	0	-0.05	0.0014
2	980	0.43	-0.2	0	-0.05	-0.0036
3	965	0.263	-0.4	0	-0.02	0.001

NET SEDIMENT FLUX (GM/M2/DAY)

Chamber		NH3	TKN	NO2-NO3	T-P	Diss P
1		0.200753	-0.17703	0	-0.02478	0.000885
2		0.144035	-0.21027	0	-0.02453	-0.00088
3		0.086839	-0.28472	0	-0.01424	0.000747

NOTE: Positive Nutrient Flux rate is From Sediments To The Water Column

Table 8. Sediment Oxygen Demand (SOD) Rates
Replicates and Means
Lake Jesup, Seminole, County, Florida
September 25-29

Station	Rep	Average Rate of Change (mg/L/min)	Adjusted Avg.[1] Rate of Change mg/L/min	SOD $gmO_2/m^2/hr$	Mean SOD $gmO_2/m^2/hr$ ($gmO_2/m^2/day$)	s[2]	CV[3] (%)	Water Column R mg/L/min	Water Temp (°C)
1	1 2 3	.0064 .0065 .0076	0.0059 0.0060 0.0071	0.085 0.087 0.103	0.091 (2.2)	0.0098	10.7	0.0005	29.5
3	1 2 3	0.0057 0.0044 0.0047	0.0044 0.0031 0.0034	0.064 0.045 0.049	0.053 (1.26)	0.010	19.0	0.0013	29.0
3 overnight incubation	1 2 3	0.0042 0.0043 0.0039	0.0023 0.0024 0.0020	0.033 0.035 0.029	0.032 (0.78)	0.003	9.4	0.0019	
5	1 2 3	0.0093 0.0143 0.0090	0.0048 0.0098 0.0045	0.069 0.130 0.065	0.088 (2.11)	0.036	41.4	0.0045	26.0
5 overnight incubation	1 2 3	0.0086 0.0079 0.0075	0.0053 0.0046 0.0042	0.077 0.066 0.061	0.068 (1.63)	0.008	12.0	0.0033	
2 tubes overnight	1 2 3	0.0050 0.0047 0.0036	0.0018 0.0015 0.0004	0.060 0.048 0.013	0.040 (0.97)	0.024	60.5	0.0032	28.7

1/ Adjusted average obtained by subtracting water column respiration from average rate of change in each chamber

2/ s = standard deviation

3/ CV = coefficient of variation as percent

Photo 1. Retrieval of "blank" chamber used for water column respiration and nutrient cycling.

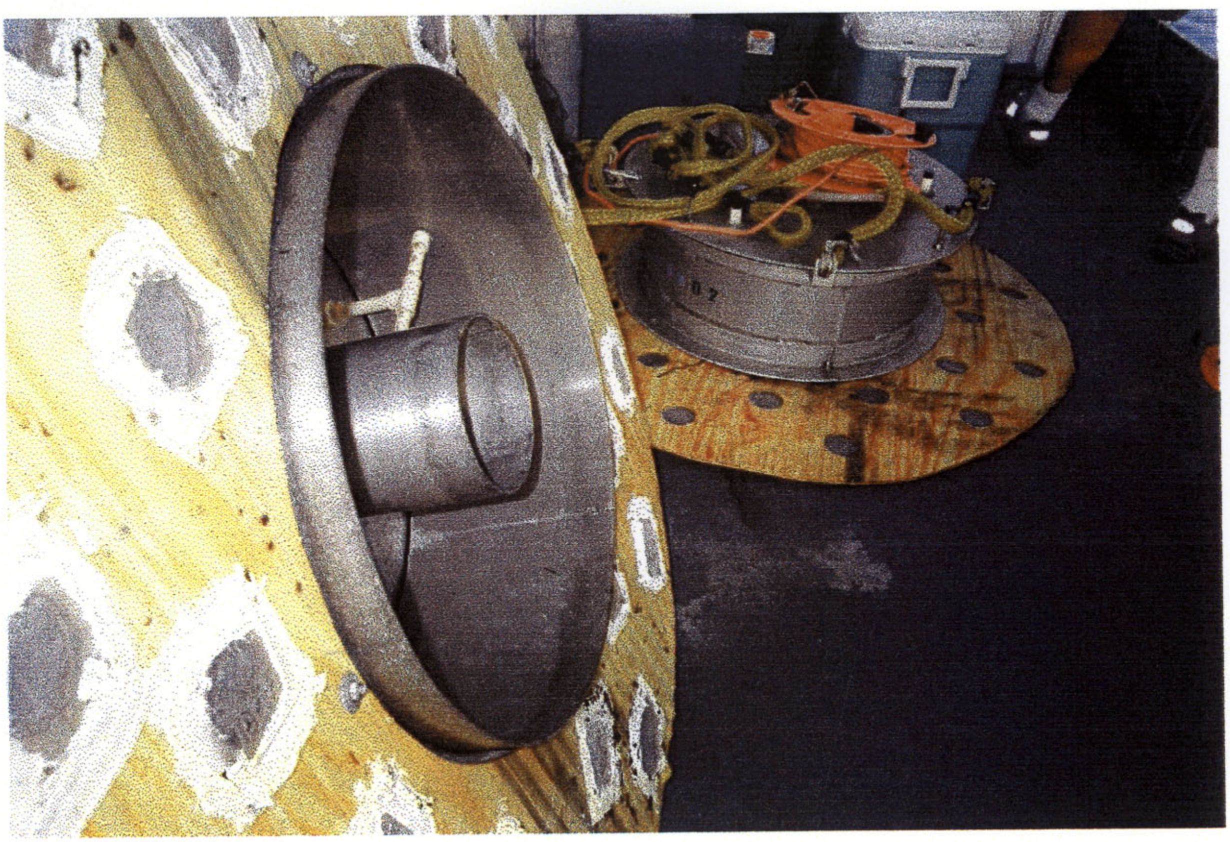


Photo 2. In situ chambers fitted with "collar" for soft substrates

Photo 3. Ms. Gloria Eby, Seminole Co., biologist inspects tubes to be used for nutrient flux measurements.

Photo 4. Full boat with tubes and chambers. Note that plastic bucket extensions have been removed from tubes to reduce length for sampling.

Photo 5. Sample tracking and custody paper work.


Photo 6. Ms. Shannon Wetzel conducting DO profiles during recon.

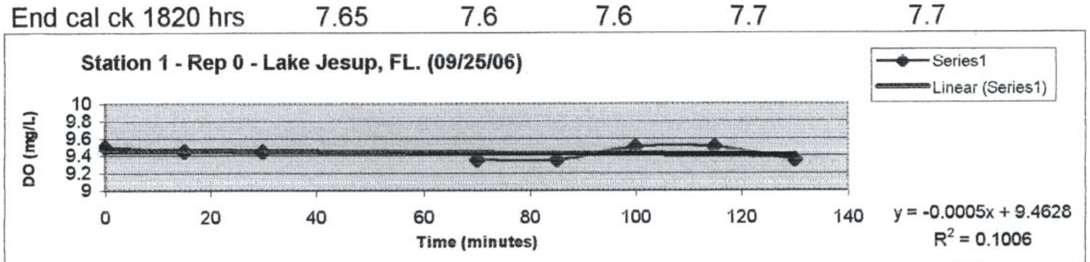
Photo 7. $HydrO_2$ crew.

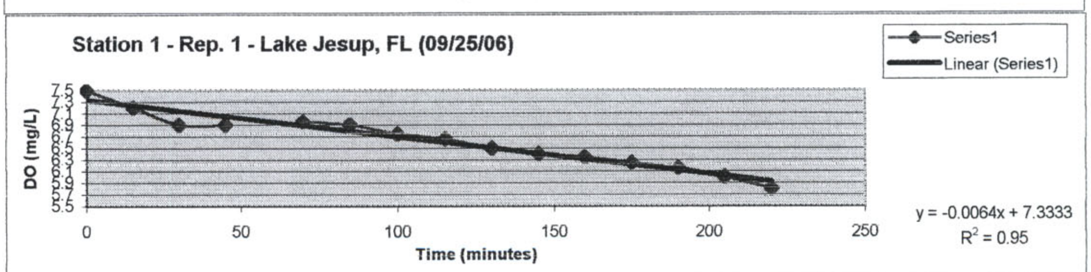
Photo 8. Curious visitor (8-10 ft. gator) observing nutrient flux measurement or just looking for some "nutrients".

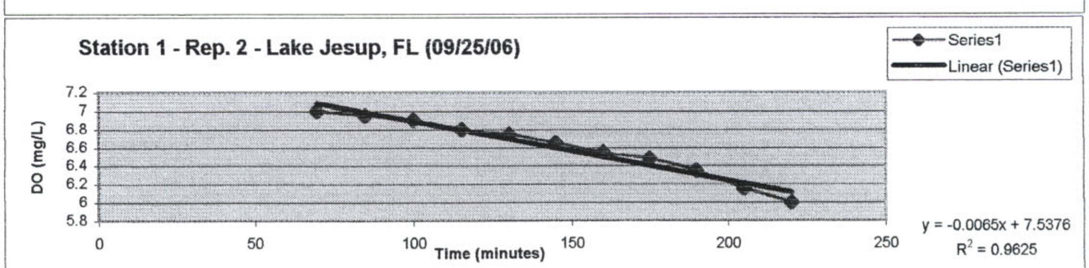
APPENDIX A
SOD DATA AND REGRESSION

FIGURE 2
STATION 1 - LAKE JESUP, SEMINOLE CO., FL
SEDIMENT OXYGEN DEMAND
SEPTEMBER 25, 2006

Time	Minutes	Rep 0	Rep 1	Rep 2	Rep 3	Ambient
1120	0	9.5	7.5		7.46	7.6
1135	15	9.45	7.2		7.38	
1150	30	9.45	6.9		7.27	7.7
1205	45		6.9		7.1	7.5
1220	60					7.9
1230	70	9.35	6.95	7	6.93	8.1
1245	85	9.35	6.9	6.95	6.8	
1300	100	9.5	6.75	6.9	6.65	8.5
1315	115	9.5	6.65	6.8	6.56	8
1330	130	9.35	6.5	6.75	6.45	8.25
1345	145		6.4	6.65	6.32	7.9
1400	160		6.35	6.55	6.24	8.15
1415	175		6.25	6.48	6.11	7.9
1430	190		6.15	6.35	5.98	7.8
1445	205		6	6.15	5.9	7.8
1500	220		5.8	6	5.77	7.5
1515	235		**Average water temperature 29.5C**			
1530	250		End Cal. Winklers 7.7 & 7.65			
End cal ck 1820 hrs		7.65	7.6	7.6	7.7	7.7







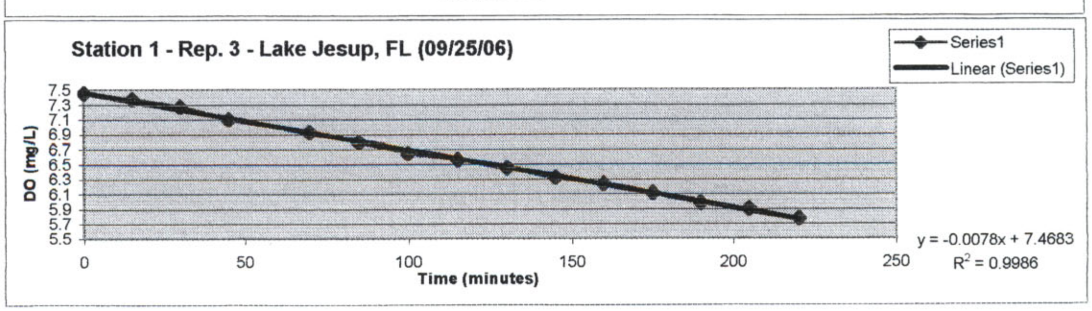
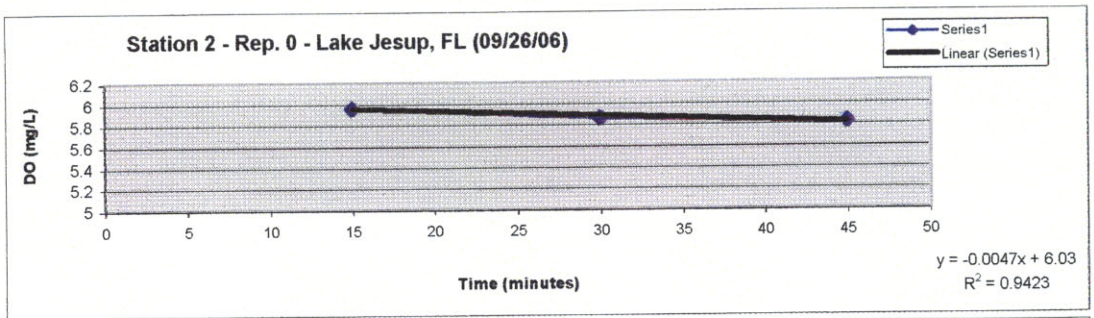
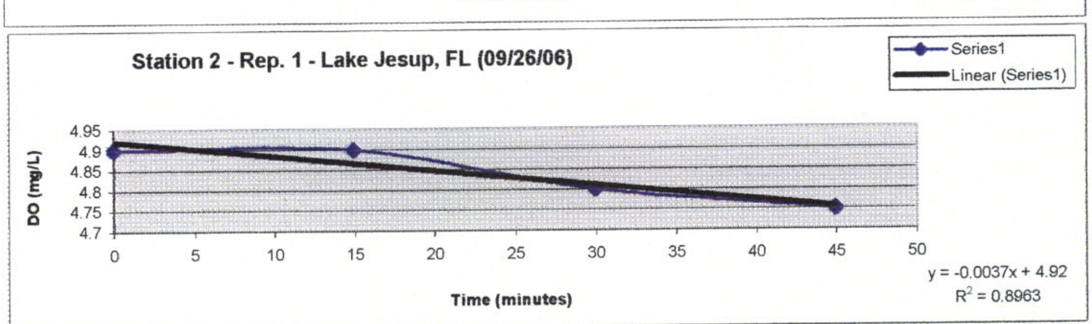


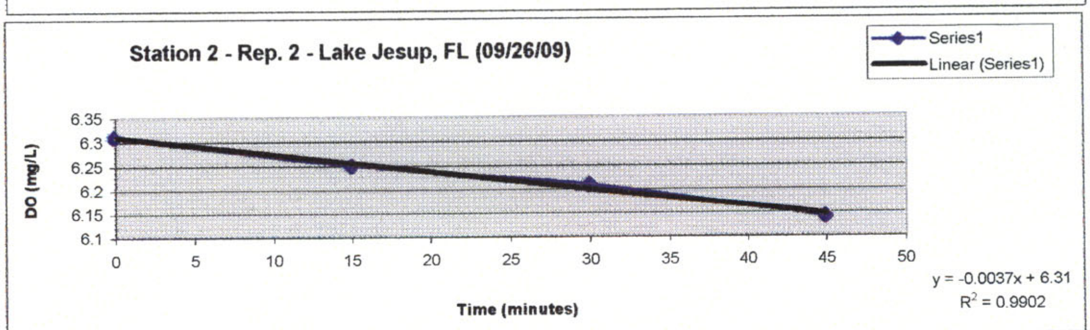
FIGURE 3
STATION 2 - LAKE JESUP, SEMINOLE CO., FL
SEDIMENT OXYGEN DEMAND
SEPTEMBER 26, 2006

Time	Minutes	Rep 0	Rep 1	Rep 2	Rep 3
1250	0		4.9	6.31	5.9
1305	15	5.97	4.9	6.25	5.775
1320	30	5.87	4.8	6.21	5.7
1335	45	5.83	4.75	6.14	5.6
1350	60				5.5

Anchors broke loose in wind; abort SOD measurement
Tubes redeployed for nutrient flux sampling
Average water temperature 29 C







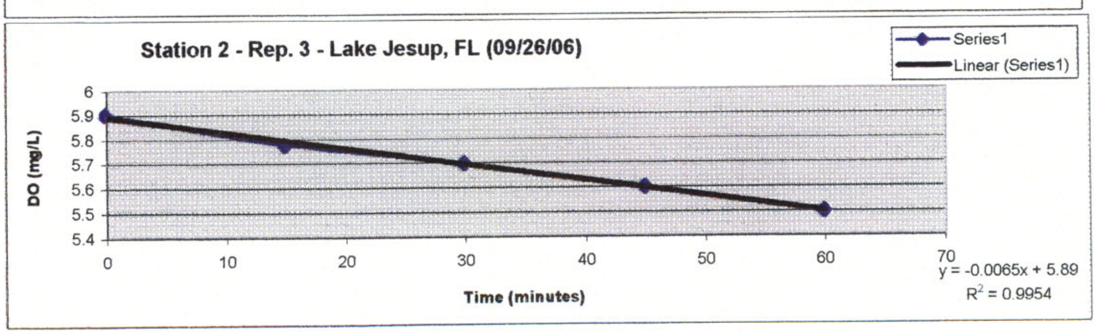
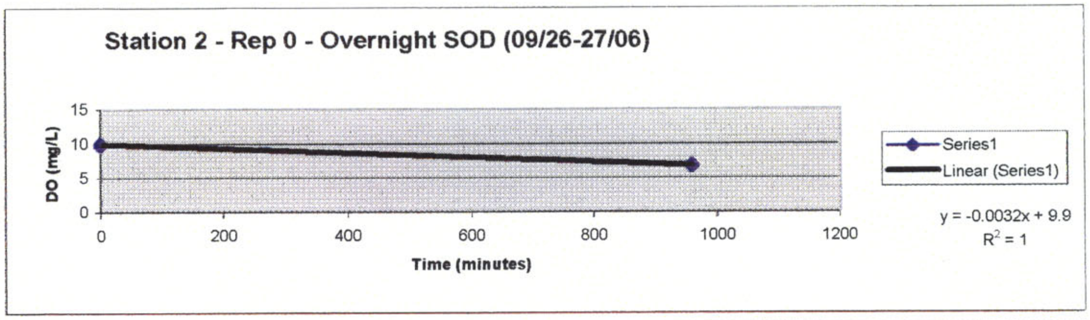


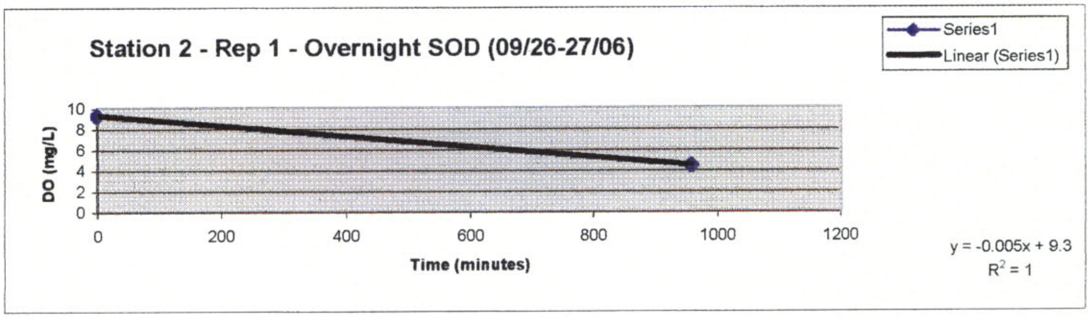
FIGURE 4
STATION 2 - LAKE JESUP, SEMINOLE CO., FL
SEDIMENT OXYGEN DEMAND
for OVERNIGHT INCUBATION OF TUBES
SEPTEMBER 26- 27, 2006

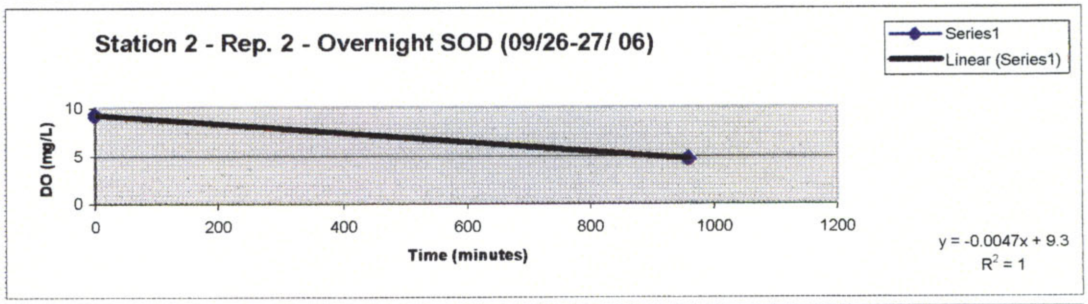
Date	Time	Minutes*	Rep 0	Rep 1	Rep 2	Rep 3
9/26/2006	1646	0	9.9	9.3	9.3	8.2
9/27/2006	850	960	6.8	4.5	4.75	4.75

* 960 minutes is avg. incubation time tubes.

Anchors broke loose in wind during initial start on 09/26/06.
Tubes redeployed for nutrient flux sampling late afternoon 09/26/06
and incubated overnight until morning of 09/27/06.
SOD calculated from initial and final DO concentrations for incubation period.
Average water temperature 29 C







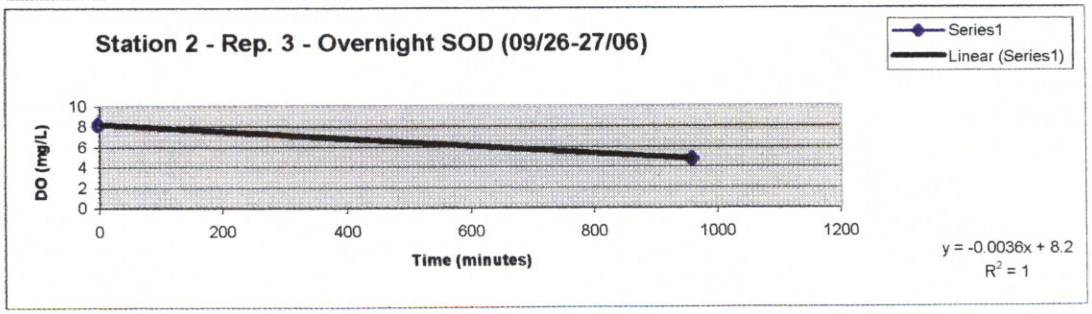
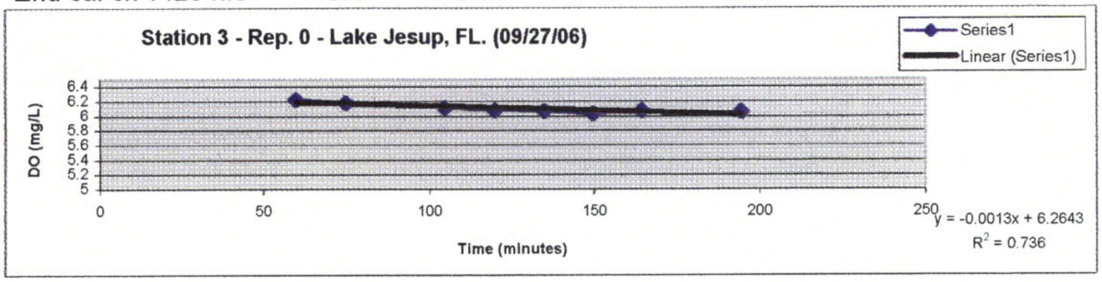


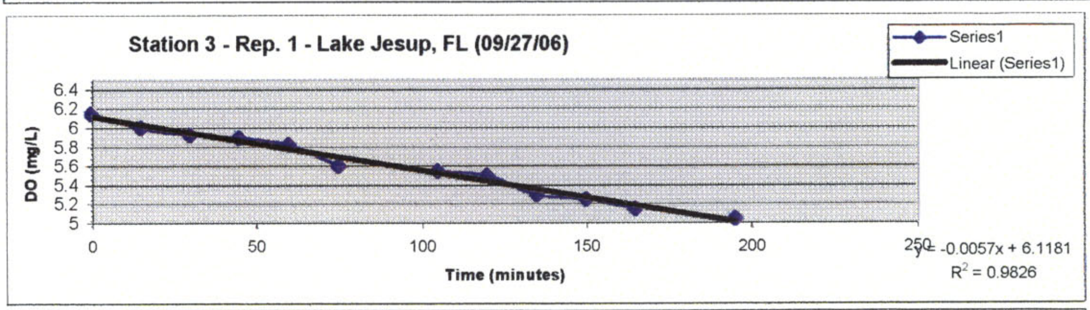
FIGURE 5
STATION 3 - LAKE JESUP, SEMINOLE CO., FL
SEDIMENT OXYGEN DEMAND
September 27, 2006

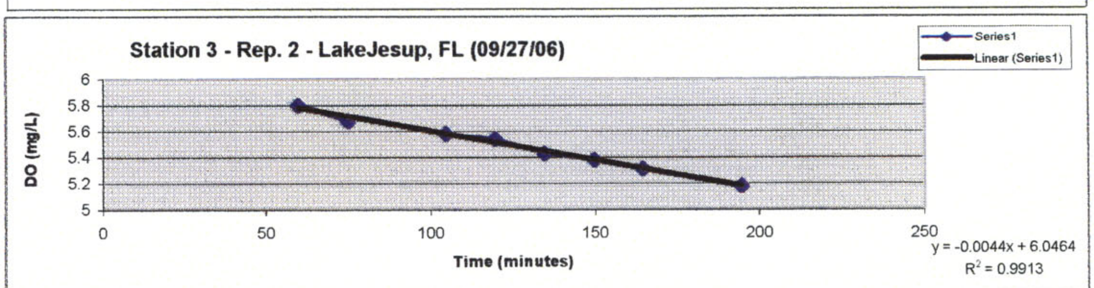
Time	Minutes	Rep 0	Rep 1	Rep 2	Rep 3
1105	0		6.15		
1120	15		6		
1135	30		5.925		
1150	45		5.9		
1205	60	6.23	5.825	5.8	5.7
1220	75	6.18	5.6	5.68	5.65
1235	90				
1250	105	6.11	5.55	5.58	5.4
1305	120	6.08	5.5	5.54	5.4
1320	135	6.07	5.3	5.43	5.3
1335	150	6.03	5.25	5.38	5.2
1350	165	6.08	5.15	5.31	5.18
1405	180				
1420	195	6.06	5.05	5.18	5.1

Avg. water temp. 29.0 C

End cal ck 1420 hrs 6.4 6.55 6.45 6.55 Winkler 6.50 & 6.50







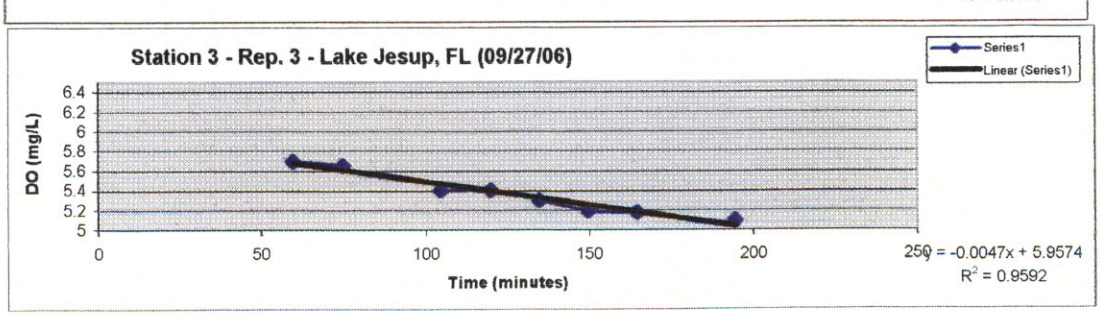
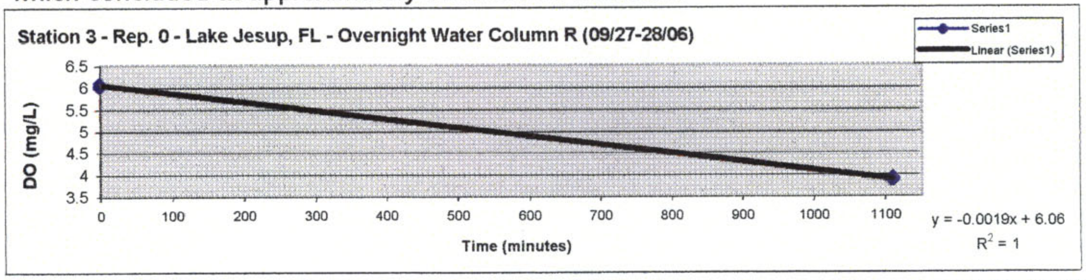


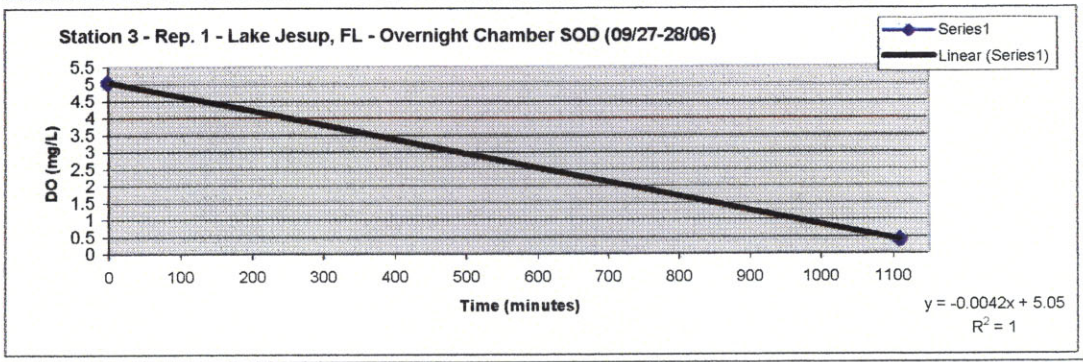
FIGURE 6
STATION 3 - LAKE JESUP, SEMINOLE CO., FL
SEDIMENT OXYGEN DEMAND
for OVERNIGHT INCUBATION OF TUBES
SEPTEMBER 27- 28, 2006

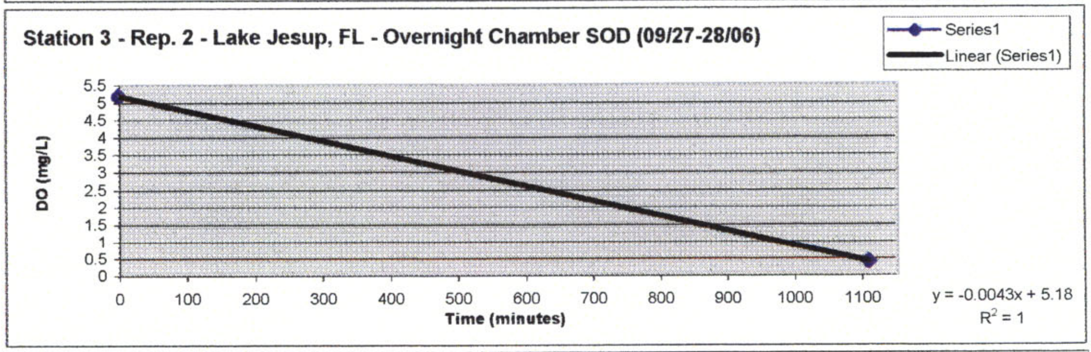
Date	Time	Minutes*	Rep 0	Rep 1	Rep 2	Rep 3
9/27/2006	1420	0	6.06	5.05	5.18	5.1
9/28/2006	845	1110	3.9	0.4	0.4	0.8

*1110 minutes is avg. incubation time tubes.

Chambers secured and detached from boat and incubated overnight.
Times represent beginning and end of overnight incubation period.
SOD calculated from initial and final DO concentrations for incubation period which concluded at approximately 0845 hrs on 09/28/06.







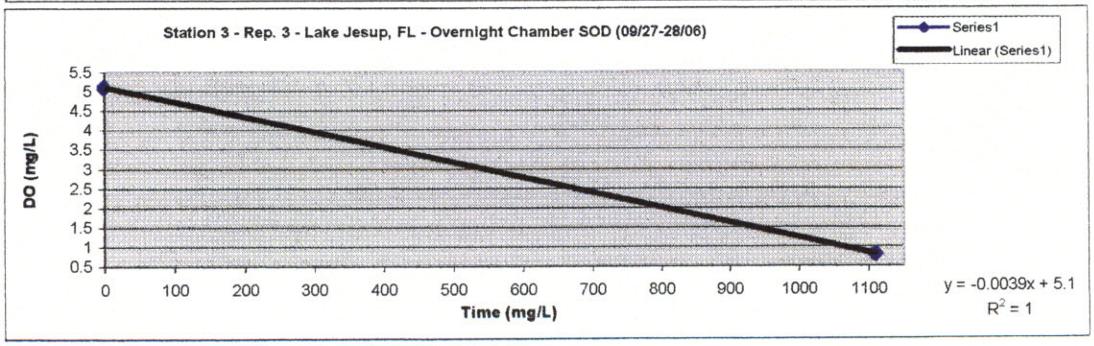


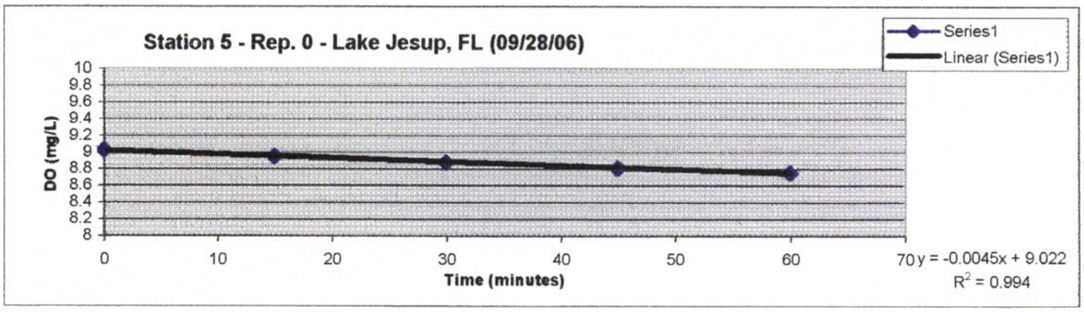
FIGURE 7
STATION 5 - LAKE JESUP, SEMINOLE CO., FL
SEDIMENT OXYGEN DEMAND
September 28, 2006

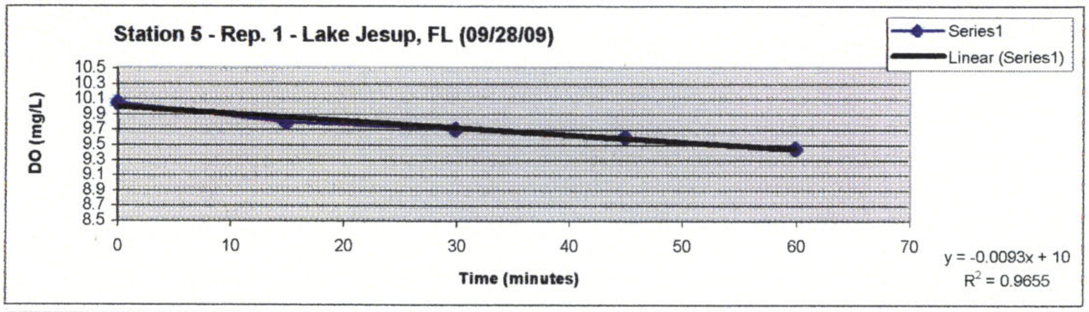
Time	Minutes	Rep 0	Rep 1	Rep 2	Rep 3
1635	0	9.03	10.05	9.77	
1650	15	8.95	9.8	9.6	9.3
1705	30	8.88	9.7	9.4	9.2
1720	45	8.81	9.6	9.15	9.05
1735	60	8.76	9.45	8.92	8.9

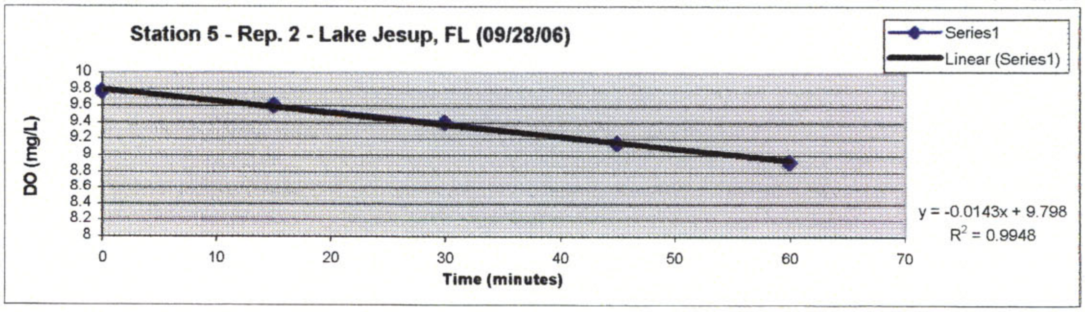
SOD monitoring terminate after 1 hour due to increased winds causing boat shift due to anchors dragging thru muck.

Avg. water temp. 26 C (Cool front moved thru during night of 9/27/06)

End cal ck 1825 hrs 6.6 6.65 6.6 6.57 Winkler 6.6 & 6.6







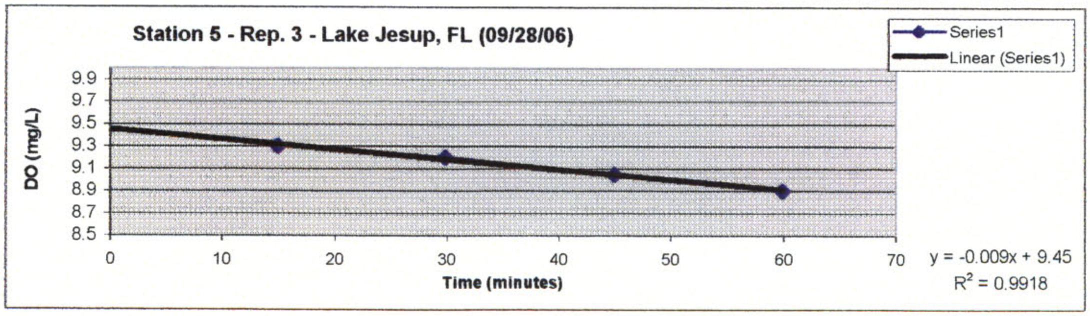


FIGURE 8

STATION 5 - LAKE JESUP, SEMINOLE CO., FL

SEDIMENT OXYGEN DEMAND

for OVERNIGHT INCUBATION OF TUBES

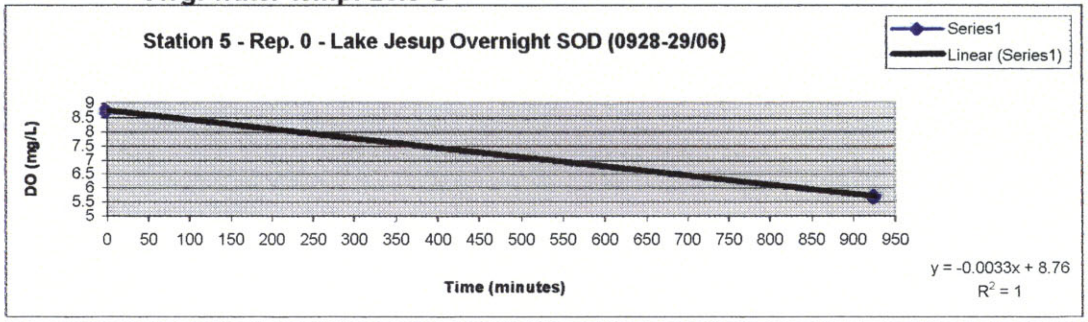
SEPTEMBER 28- 29, 2006

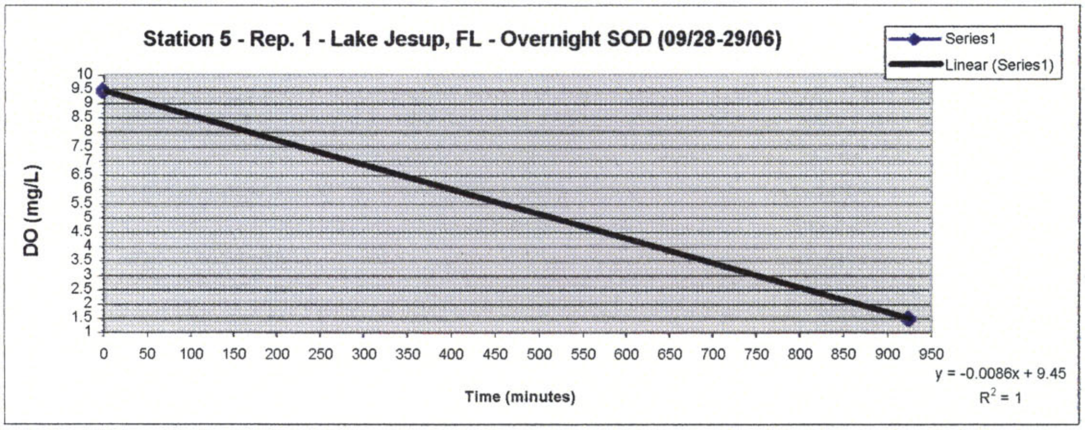
Date	Time	Minutes*	Rep 0	Rep 1	Rep 2	Rep 3
9/28/2006	1735	0	8.76	9.45	8.92	8.9
9/29/2006	830	925	5.7	1.5	1.6	2

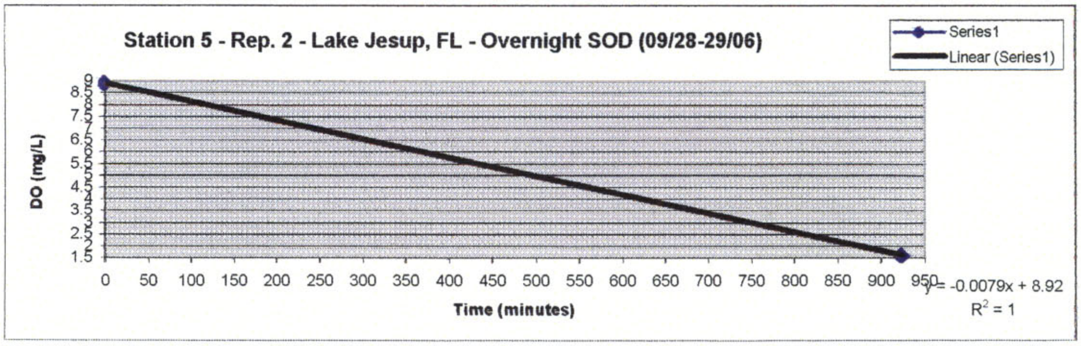
* 925 minutes is avg. incubation time tubes.

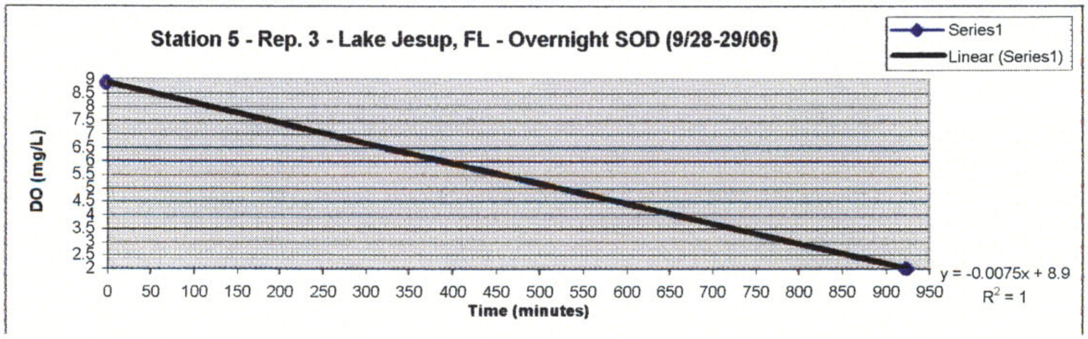
Anchors began loosening by wind after 60 minutes incubation.
Chambers secured and detached from boat and incubated overnight.
Times represent beginning and end of overnight incubation period.
SOD calculated from initial and final DO concentrations for incubation period which concluded at approximately 0830 hrs on 09/29/06.

Avg. water temp. 26.0 C









APPENDIX B

PLAN OF STUDY
LAKE JESUP
SEMINOLE COUNTY, FLORIDA
SEDIMENT NUTRIENT FLUX
SEPTEMBER 2006

INTRODUCTION

Seminole County, through their water quality modeling consultant, HDR/LMS has requested the assistance of HydrO_2, Incorporated in the assessment of sediment nutrient flux rates in Lake Jesup. HydrO_2 will be working under subcontract to HDR/LMS. Resulting data will be used as a model input parameter by LMS as they assist the County in modeling nutrient loading from various sources into Lake Jesup.

STUDY APPROACH

Specifically, the planned study will target five (5) lake bed locations spread spatially thru Lake Jesup. At the selected locations, sediment nutrient flux will be assessed using the *in situ* chamber method described later in this plan of study. To assist in selection of station locations, the primary study effort will be preceded by a reconnaissance of the lake by personnel from HydrO2, HDR/LMS, and Seminole County. Existing sediment maps depicting sediment composition and depth, available through Seminole County, will guide the reconnaissance activities aimed at selecting sediment nutrient flux sites that will address sediment variability within the lake. Reconnaissance activities will also assist in the determination of suitability of sediments for deployment of *in situ* chambers as well as dissolved oxygen resources adequate for extensive chamber incubation times necessary for nutrient flux determinations.

TASKS & METHODS

To assess sediment nutrient flux rates, an *in situ* chamber method developed and published by HydrO_2 personnel (Murphy & Hicks, 1986) will be used. HydrO_2 personnel have successfully used this method in other waterbodies for determination of sediment nutrient flux. Sediment nutrient flux, along with sediment oxygen demand (SOD), is important in evaluation of sediment processes effecting dissolved oxygen and nutrient loading. The importance of such data to model development is equaled by the difficultly of its acquisition in areas such as Lake Jesup where unconsolidated sediments can be problematic.

Since the *in situ* chamber SOD methodology employed by HydrO_2 facilitates the additional assessment of sediment nutrient exchange (NUTX) along with sediment oxygen demand, both parameters will be reported. SOD rates must be monitored during *in situ* nutrient flux determinations in order to assure that experiments initiated under aerobic conditions remain aerobic throughout the data acquisition phase. The addition of the NUTX component to the SOD methodology requires extraordinarily extended incubation times (generally 8 or more hours). As incubation times become shorter, the requirement for lower level nutrient analysis with high precision is increased. Accordingly, successful accomplishment of NUTX will require dissolved oxygen resources sufficient to sustain the experiment over a time period adequate to achieve measurable analytical differences in beginning and ending nutrient concentrations. Hence, the laboratory analytical capabilities with high precision will enhance the potential for success of sediment nutrient flux measurements.

Seminole County's laboratory will provide analytical services in support of the study. Target analytes are as follows: TKN, NH3, NO2 + NO3, TP, and DP.

Details of the assessment approach are presented in the following module. Anticipated on-site field activities are tentatively scheduled for the period mid to late September 2006.

DELIVERABLES

Seminole County's environmental analytical laboratory will provide analytical results to HDR/LMS who will supply the data to $HydrO_2$ for calculation of nutrient flux rates. $HydrO_2$ will provide a tabular presentation of sediment nutrient flux rates and SOD rates to HDR/LMS, along with a narrative description, and lat/long, of sampling stations. Deviation from the methods described in the following Module 1, will also be noted.

MODULE 1
SEDIMENT NUTRIENT FLUX w/ SEDIMENT OXYGEN DEMAND (SOD)

1.1 Module Objective

To provide field measurements of sediment nutrient flux accompanied by sediment oxygen demand (SOD) at 5 locations within Lake Jesup.

1.2 Anticipated Module Activities

Sediment Nutrient Flux (NUTX) and Sediment Oxygen Demand (SOD) rates will be measured using the *in situ* chamber method (Murphy & Hicks, 1986). This method involves the deployment of opaque chambers over bottom sediments for time periods during which the rate of oxygen consumption is continuously monitored with calibrated and stirred dissolved oxygen probes positioned in each chamber. Three replicate sediment contact chambers 64 liters in volume, incorporating 0.27 m^2 of bottom sediment are effectively sealed to bottom sediments, with the enclosed water volume mixed in an annular flow pattern via a pump and diffuser arrangement to simulate ambient over-bottom mixing. Data is manually logged, typically at 15-minute intervals. Regression analysis of acquired data points yields the oxygen decay rate within each chamber, which must be corrected for the respiration rate associated with the 64 liters of water within each chamber to arrive at the effective sediment oxygen demand. The oxygen respiration rate attributable to this water volume is accounted for by concurrent deployment of a forth chamber identical in dimensions to the sediment chambers but totally enclosed with a chamber bottom, and purged and filled with bottom water. The water column respiration rate acquired with this "blank" chamber is subtracted from each sediment contact chamber rate to arrive at the SOD rate. Continuous on-station examination of data from each chamber allows the scientists to identify potential problems and conduct corrective actions during the course of the deployment, thus enhancing confidence in the effectiveness of the measurements before departing the station. Monitoring of SOD rates within the chambers is necessary in order to assure maintenance of ambient aerobic conditions during nutrient flux assessment. If conditions in lake bottom waters at the time of study are anoxic, then assurance that the assessment conditions remain anoxic throughout chamber incubation must, likewise, be validated.

NUTX measurements, the primary parameter of focus for this study, will be conducted concurrent with SOD measurements by the extraction of water samples (500 to 1000 mls based upon analytical requirements) with a special sampling device at the beginning and end of the incubation period. Initiation of the incubation period will occur early morning of each day and conclude near dark. Taking into account time required for meter calibration, 4-point anchoring, and chamber deployment/retrieval, this daily schedule should result in chamber incubation times approximating 9-10 hours, provided that lake bottom water dissolved oxygen concentrations are adequate to sustain the incubation times for this duration in conjunction with the SOD rate. Since nutrient cycling will also be occurring within the 64 liters of water contained within each chamber, extraction of water samples from the blank chamber will serve as a water column control for adjustment of sediment contact chamber rates.

1.3 NUTX & SOD Monitoring Requirements

The following procedures will be employed for conducting field measurements of sediment nutrient flux and SOD:

- Calibrate dissolved oxygen meters according to $HydrO_2$ SOP and maintain a record of calibration.

- Diver deploys chambers and assures chamber-to-sediment seal. The blank chamber will be deployed first and purged with bottom water while remaining chambers (3) are deployed. Blank chamber should be located in a position from remaining chambers to avoid potential for recruiting resuspended sediments into blank chamber, or otherwise the purging and sealing of the blank chamber will be accomplished before deployment of the sediment contact chambers.

- Following chamber deployment, allow approximately 20 minutes for settling of any potentially resuspended sediments during deployment. Install probes and engage circulation pump. Terminate purging of blank chamber when probe is installed.

- Extract initial water samples for nutrient analysis from all chambers

- Deploy ambient probe.

- Record monitoring data at 15-minute intervals for a time period sufficient to determine SOD rates, followed by continuance of DO recordings at 0.5 hour increments throughout the incubation time in order to monitor DO concentrations within each chamber.

- At the end of the incubation period, which will either be at day's end or when DO concentrations within the chamber become critical to maintenance of aerobic conditions, extract final water sample from each chamber for determination of ending nutrient concentration.

- Recheck operation of circulation pump at termination of the experiment. Once experiment is completed, recheck calibration of instruments and record results.

2.5 <u>QA/QC Requirements</u>

Sampling protocol will follow $HydrO_2$ Standard Operating Procedure (SOP) manuals and instrument manufacturers' calibration specifications.

Three replicate sediment contact chambers will be deployed concurrently. Cursory field calculation of SOD rates will be conducted during the incubation at each station in order to anticipate length of incubation under aerobic conditions. DO probes may be temporarily extracted from each chamber, with the chamber probe orifice subsequently sealed, for checking probe calibration. Success of SOD measurements will be governed by end calibration of DO probes being according to $HydrO_2$ SOP requirements. Success of nutrient flux determinations must await analytical processing of samples. All samples will be stored on ice prior to transfer to the laboratory where processing, including and any required filtering, will be conducted.

<u>References</u>

Murphy, P.J. and D.B. Hicks, 1986. In-situ method for measuring sediment oxygen demand, *in* Hatcher, K.J., ed., Sediment oxygen demand—Processes, modeling, and measurement. University of Georgia, Institute of Natural Resources, Athens, Georgia, p. 307-322.