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ESTABLISHING THE NATURAL RANGE OF DISSOLVED OXYGEN LEVELS IN STREAMS OF THE SOUTHERN COASTAL PLAIN OF GEORGIA

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ABSTRACT

The majority of streams listed on the 2001 303(d) list in the Coastal Plain of Georgia are in violation of dissolved oxygen (DO) standards established by the Georgia Department of Natural Resources. The highest percentage of DO-impaired streams occurs in the southern Coastal Plain of Georgia (Ochlockonee, Suwannee, Satilla, and St. Mary's River Basin Group) where 61 of 67 or 91% of listed streams are in violation of the DO standard. The current Georgia DO standard for most designated uses is a daily average of 5.0 mg/L and a minimum of 4.0 mg/L. Research by University of Georgia and USDA-ARS scientists in 3 Coastal Plain watersheds indicates that low DO in Coastal Plain streams may be a natural condition for summer months. Consequently, it appears that the established State DO standard may not be applicable to Coastal Plain streams – particularly during the extended summer period. To address this issue, Georgia DNR-EPD is proposing a new DO standard which will be 90% of natural DO during critical flow conditions. Application of this new standard requires some means of establishing natural DO during critical flow conditions. Yet, an extensive data set which can be used to calculate this parameter for a wide range of streams is currently not available. To allow for a science-based standard, we initiated an extensive research program to establish the natural range of DO at critical flow conditions in the Coastal Plain of Georgia. The project contains monitoring and modeling aspects. Monitoring is taking place in the Ochlockonee, Suwannee, Satilla, and St. Mary's river basins.

KEYWORDS. Dissolved oxygen, Water quality, Georgia, Modeling, Monitoring

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INTRODUCTION

The majority of streams listed on the 2001 303(d) list in the Coastal Plain of Georgia are in violation of dissolved oxygen (DO) standards established by the Georgia Department of Natural Resources. The highest percentage of DO-impaired streams occurs in the southern Coastal Plain of Georgia (Ochlockonee, Suwannee, Satilla, and St. Mary's River Basin Group) where 61 of 67 or 91% of listed streams are in violation of the DO standard. The current Georgia DO standard for most designated uses is a daily average of 5.0 mg/L and a minimum of 4.0 mg/L. Under current legislation and standards, Total Maximum Daily Load (TMDL) management and implementation plans for the watersheds draining to DO-impaired streams in the Coastal Plain of Georgia must be developed at great expense to taxpayers. Eventual implementation of these plans may result in severe economic consequences.

It is commonly presumed that DO below the standard in slow moving streams is associated with increased biological activity resulting from N and P enrichment. This biological activity is generally excessive algal growth with dark respiration resulting in oxygen depletion. Globally, streams typically exhibiting such conditions have high exposure to sunlight and hard bottoms, such as gravel or rubble, which support surface-attached algal mats. Low DO conditions as a result of nutrient enrichment typically do not occur when the streams are heavily shaded or when bottom strata are non-solidified (sand or silt), both of which are common characteristics of small and medium size Coastal Plain streams. Yet it is these streams that are regularly listed in violation of DO standards.

Research by University of Georgia and USDA-ARS scientists in 3 Coastal Plain watersheds indicates that low DO in Coastal Plain streams may be a natural condition for summer months (Bosch et al., 2002a; 2002b). In fact, 4 years of data from the Piscola Creek watershed indicate that a "reference" stream typically has the lowest DO values of 9 monitored sites during the summer months (Vellidis et al., 1999). Several highly enriched streams in the midst of intensive livestock and row-crop production typically have considerably higher DO values during these months. It is hypothesized that a combination of high summer-time temperatures, low flows, and high loads of organic carbon contributed by riparian vegetation contribute to naturally low DO levels in Coastal Plain streams with otherwise good water quality. Consequently, it appears that the established State DO standard may not be applicable to Coastal Plain streams – particularly during the extended summer period.

To address this issue, Georgia DNR-EPD is proposing a new DO standard which will be 90% of natural DO during critical flow conditions. Application of this new standard requires some means of establishing natural DO during critical flow conditions. Yet, an extensive data set which can be used to calculate this parameter for a wide range of streams is currently not available. Consequently, the standard will be set by using mathematical models or other indirect means. To allow for a science-based standard, we initiated an extensive research program to establish the natural range of DO at critical flow conditions in the Coastal Plain of Georgia. The project contains monitoring and modeling aspects. Monitoring is taking place in the Ochlockonee, Suwannee, Satilla, and St. Mary's river basins (fig. 1) .

PROJECT DESCRIPTION

Because DNR-EPD had already made a significant investment in collecting water quality data in the Ochlockonee, Suwannee, Satilla, and St. Mary's River Basin Group and returned to this area for additional trend sampling during 2003, we began our assessment by evaluating the watersheds contributing to all established DNR-EPD sampling locations in the area. With this evaluation, we will attempt to categorize watersheds into 3 categories: predominantly forested, mixed forest and agricultural land use, and predominantly agricultural.

GIS techniques and satellite imagery are used to perform the land use analyses (fig 2). The analyses should result in watersheds of different scales within each category. The predominantly forested category will likely contain fewer and smaller watersheds. Watersheds similar in size and hydrologic characteristics will be paired both within and across categories. With this design, it is possible that we will also have nested watersheds. Any watershed that contains point sources or urban areas will be excluded from the study.

Predominantly forested watersheds are tentatively defined as those whose land use has been at least 65% forest for the past 30 years, have extensive and intact riparian forest buffers, and contain no concentrated livestock production. Conventional row crop agriculture will be accepted within predominantly forested watersheds provided it is not immediately adjacent to streams.

Mixed forest and agricultural land use watersheds are tentatively defined as those whose land use has been between 35 and 65% forest for the past 30 years, have riparian forest buffers in good condition, and contain few small concentrated livestock production units. Conventional row crop agriculture or pasture is likely to be the largest land use in this category.

Predominantly agricultural watersheds are tentatively defined as those whose land use has been less than 35% forest for the past 30 years and have limited riparian forest buffers. No limitations will be placed on agricultural activities. Final definitions will be adopted after discussions with DNR-EPD personnel.

Monitoring

Oxygen demand in the streams is likely to arise due to soluble organic materials, benthic materials, and respiration by aquatic plants. Sampling and analyses are conducted in order to quantify these demands in each stream. We began 3 years of intensive bi-weekly monitoring of water quality and hydrologic parameters within the watersheds and at the watershed outlets at 50 locations during August 2003. The water parameters to be evaluated are listed below. The parameters include those that could potentially affect DO. Simultaneously, we are evaluating and characterizing the watersheds

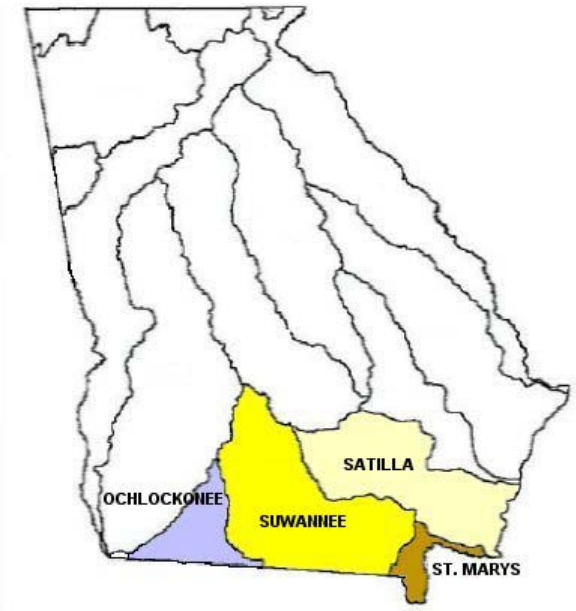

Figure 1. Map of Georgia showing the Ochlockonee, Suwannee, Satilla, and Saint Mary's river basins in which the project will be conducted.

to establish the dynamics that affect DO within each watershed. The parameters we are measuring are given immediately below:

Bi-Weekly Water Quality Measurements

- DO
- pH
- conductivity
- TOC
- BOD_5
- NO_3+NO_2, NH_4, TN
- PO_4, TP
- chlorophyll a
- TSS – Total Suspended Solids
- temperature
- depth
- flow velocity (biweekly only at small streams – major streams and rivers will be measured seasonally; flow rate will be calculated)

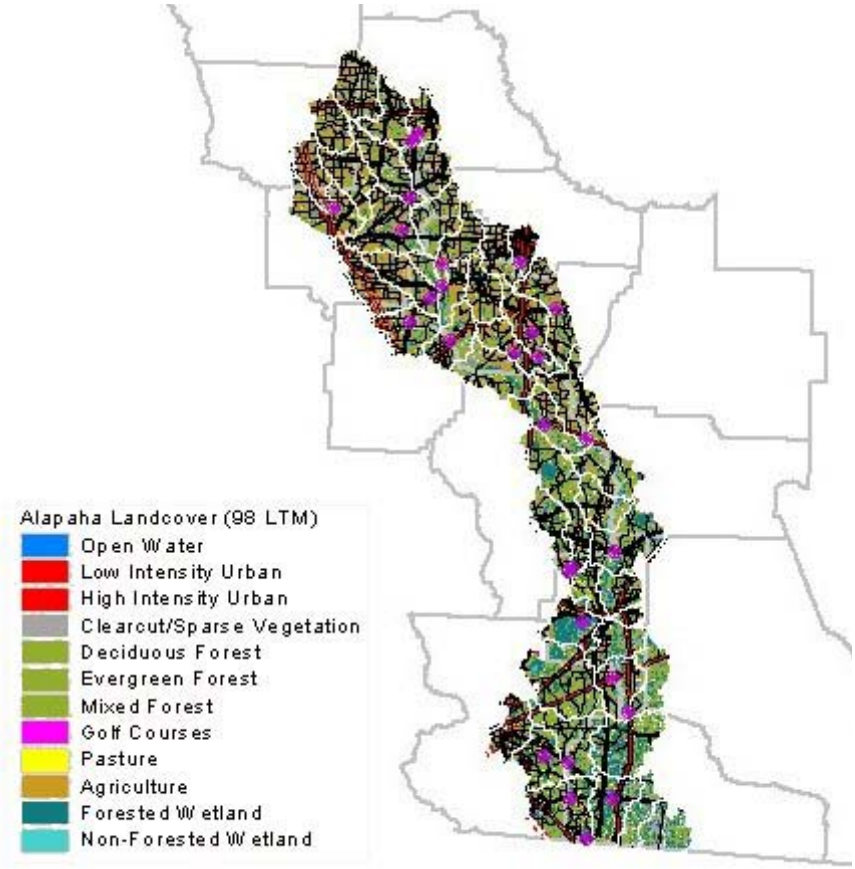

Figure 2. . Landcover of the Alapaha River 8-digit HUC developed from 1998 LandSat Thematic Mapper data. The Alapaha River is a major tributary of the Suwanne River.

Other Measurements

- stream characterization (morphology, etc. done annually)
- long term BOD (quarterly or semiannually)
- benthic and periphyton respiration (quarterly or semiannually by respirometer)

After 3 years of monitoring, we expect to have an extensive database from which to establish the natural range of DO at critical flow conditions. In Georgia, critical flow conditions have traditionally been defined as a stream's seven-day, ten-year minimum flow or "7Q10". A stream's 7Q10 is a statistical figure that reflects the lowest seven-day running average of a stream's flow with a recurrence frequency of once in ten years.

If critical flow values have not been measured directly, they can be calculated using standard hydrologic recurrence interval calculation techniques from available hydrologic data. If the available data is insufficient, data from the Little River Research Watershed (LRRW) in the

headwaters of the Little River 8 digit hydrologic unit can be used to determine low flow conditions for coastal plain watersheds. Long term data (up to 30 years) from 8 gaged streams in the LRRW can be used to determine critical flow values and other low-flow parameters for watersheds ranging in size from one square mile to 133 square miles. Alternatively, critical flow values can be estimated from USGS values for similar, or larger, watersheds in the region.

Modeling

Although 3 years of monitoring and existing DNR-EPD trend monitoring data may provide natural DO at critical flow conditions for some streams, it is most likely that this parameter will be estimated using extrapolation, modeling, or a combination of these techniques for most streams using the measured DO data. The technique that will ultimately be used for developing the parameter will be selected in coordination with DNR-EPD personnel.

One approach is to use a DO sag model. Reaeration of streams is primarily due to mixing and diffusion across the air water interface. Additional O_2 can be added during daylight hours by photosynthetic algae. These same algae can deplete oxygen during the night due to respiration. Reaeration coefficients can be estimated by calibration of an oxygen sag model utilizing measured oxygen demands and measured DO concentrations in the streams. The calibrated values can be compared to other measured values or to literature values based upon stream depth and velocity to make sure that they are reasonable. The calibrated DO sag model can then be utilized to predict stream DO concentrations during critical flow periods.

Initial assessment of streams listed for DO impairment indicates that the majority of those listed are headwater tributaries. Generally, the main reaches of the rivers are above the current DO standards. Is this a function of aeration associated with higher flow velocities? If so, what is causing low DO in the tributaries? Is it just low velocity or are other factors involved? To answer these questions we are identifying the largest stream listed for DO impairment in each of the Upper Ochlockonee, Alapaha, and Satilla watersheds. We then move to the next established downstream sampling location that does not show impairment and begin an intensive water quality monitoring program in the entire watershed contributing to that stream reach in order to quantify the dynamics that affect DO within each watershed.

We have included all established DNR-EPD trend monitoring locations within the delineated watersheds and will add more sampling locations as needed. Some of the issues we will address within these watersheds are organic carbon loads, benthic oxygen demand, primary production, reaeration, etc.

PROJECT OUTCOME

At the end of the project, we anticipate having a 3-year database of DO and physical, chemical, biological, and hydrologic parameters that could potentially affect DO at up to 50 locations within the Ochlockonee, Suwannee, Satilla, and St. Mary's river basins. More importantly, we expect to have data-based estimates of natural DO at critical flow conditions for study area streams.

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REFERENCES

1. Bosch, D., R. Lowrance. G. Vellidis, J. Sheridan, and R. Williams. 2002a. Dissolved oxygen and stream flow rates: Implications for TMDLs. In A. Saleh (ed) *Proceedings of the Total Maximum Daily Load (TMDL) Environmental Regulations Conference,* pp. 92-92. ASAE, St. Joseph, Michigan.
2. Bosch, D., R. Lowrance. G. Vellidis. 2002b. Dissolved oxygen concentrations in three coastal plain watersheds: Implications for TMDL's In A. Saleh (ed) *Proceedings of the Total Maximum Daily Load (TMDL) Environmental Regulations Conference,* pp. 606-610. ASAE, St. Joseph, Michigan.
3. Vellidis, G., R Lowrance, P. Gay, J. Sheridan, D. Bosch. 1999. Water quality of Piscola Creek watershed. ASAE Technical Paper No. 99-2131. ASAE, St. Joseph, MI. 13 pp.