**MEMORANDUM**

October 1, 2020

To: Tracy Marinello, Florida Defenders of the Environment

From: E. Allen Stewart III P.E.

Re: Preliminary engineering analysis of a proposed nutrient removal and recovery in-lake Managed Aquatic Plant System (MAPS)[[1]](#footnote-1) oriented around water hyacinth cultivation in Newnans Lake, Alachua County, Florida.

**SUMMARY**

Proposed, as an initial demonstration project and pilot study, is a two year, in-lake operational Managed Aquatic Plant System (MAPS) program, to include a fifty-six acre enclosure within the boundary of the 6,600 acre Newnans Lake near Gainesville, Florida. The enclosure of approximate rectangular dimension of 2,033 ft. x 1,200 ft. shall serve as containment for a standing crop of water hyacinths (*Eichhornia crassipes [Mart] Solms* or *Pontederria crassipes*), which are to be cultivated through periodic harvesting of a portion of the standing crop. The harvesting and ultimate removal of these enclosed plants from the lake’s watershed will result in substantial removal of nitrogen and phosphorus from the lake sediment’s legacy storage and will augment the nutrient reduction requirements associated with Newnans Lake Total Maximum Daily Load or TMDL[[2]](#footnote-2) [[3]](#footnote-3), while serving to impede the development of Cyanobacterial (Blue-Green Algae) blooms. This program is intended to be complimentary to efforts associated with the Orange Creek Basin Management Action Plan (BMAP)[[4]](#footnote-4), not as a replacement of the proposed actions presently delineated within this BMAP.

The enclosure is to be constructed of floating boom specifically designed for containment of floating aquatic plants, to include a 12” to 18” ballasted skirt, secured to the lake bottom with screw anchors or other equivalent methods. The enclosure shall be positioned within the lake to be close enough to the shoreline to reduce harvest transfer distance. Attendant with and contiguous to the enclosure shall be an in-lake processing barge which will facilitate chopping of the harvest to provide volume reduction and subsequent pumping of the chopped biomass to ensure efficient delivery to a shore-based windrow composting facility.

A starting crop of at least 500 wet tons of healthy water hyacinths cleared of other invasive plants and free of pests such as the hyacinth weevil (*Neochetina sp.*) and the hyacinth moth (*Sameodes sp.*) shall be placed within the enclosure and permitted to expand to about 80% surface coverage (45 acres), resulting in a standing crop of about 3,903 wet tons at a wet density of 4.0 lb.ft-2. Harvesting shall be done through a bid secured agreement with an experienced aquatic plant harvesting contractor (Contractor), who will employ Kelpin type harvesters, or equivalent machinery, to accommodate the removal, processing and conveyance of as much as 500 wet tons per week of whole hyacinths from the enclosure to the shore-based facility. The Contractor shall also assume responsibility for facility construction, operation and maintenance; for operation of the shore-based composting facility; and for all aquatic plant harvesting needs for the entire lake, with the intent of eliminating herbicide application.

It is anticipated that the harvesters and ancillary equipment dedicated to managing the hyacinth crop should be capable of removing and processing as much as 500 wet tons of hyacinths per week, with an expected annual harvest from the enclosure of 15,800 wet tons per year, resulting in the production of about 1,200 tons of final compost at 40% moisture. The net annual nutrient removal projected from the MAPS operation, exclusive of the harvesting done outside the enclosure, is 4,744 pounds of phosphorus and 47,444 pounds of nitrogen. Preliminary engineering consideration for the MAPS facility is presented in the last section of this text.

Within this memorandum is presented a review of the nutrient dynamics within Newnans Lake, including comments related to the historical influences of nutrient recycling within the lake and a proposed application, with preliminary engineering considerations, of in-lake cultivation of water hyacinths as a Managed Aquatic Plant System (MAPS) to provide a number of environmental reclamation services including:

* Augmenting the planned nutrient reduction as delineated within the TMDL[[5]](#footnote-5) and the Basin Management Action Plan (BMAP)[[6]](#footnote-6) from watershed sources by reducing stores of available nitrogen and phosphorus within the lake sediments;
* Documenting to the extent practical the rate of recycling of nutrients from the sediments within the water column, with the ultimate goal of contributing to achieving the TMDL in-lake concentration targets for total phosphorus (0.062 mg.L-1) and total nitrogen (0.97 mg.L-1) [[7]](#footnote-7) ;
* Enhancing fish and wildlife habitat through elimination of herbicide use within the lake through replacement with a mechanical harvesting/processing program to be employed both for cultivation of a contained water hyacinth crop and for managing aquatic plant growth within the lake boundaries;
* Impeding the development of Cyanobacterial blooms through shading, nutrient reduction and allelopathy[[8]](#footnote-8);
* Investigating and establishing feasibility and long-term cost effectiveness of recovering nutrients within a harvested biomass of water hyacinths to produce a soil (compost) product of value to local agricultural activities;
* Coordinating with the four involved agencies—The Florida Department of Environmental Protection (FDEP), the Florida Fish and Wildlife Conservation Commission (FWC), the Florida Department of Agriculture and Consumer Services (FDACS) and the St. Johns River Water Management District (SJRWMD)—as well as research groups such as the University of Florida Institute of Food and Agricultural Sciences (IFAS) to assess the value of recovered products; the effectiveness of the aquatic plant management efforts; and the status of the phytoplankton community including the presence of Cyanotoxins within the lake.
* Serving as a research and development facility for refinement of the in-lake MAPS technology which could be incorporated into other Basin Management Action Plans (BMAP) and potentially provide genesis for a promising agricultural enterprise which can offer new, high quality jobs while facilitating water quality enhancement and effective nutrient recovery and reuse.

It should be noted that a MAPS program such as that detailed within this review is congruent with the stated strategy within the Newnans Lake BMAP[[9]](#footnote-9):

*“The extent to which nutrient recycling acts as a nutrient load in Newnans Lake could significantly affect the effectiveness of nutrient load reduction projects”* pg. 49

*“A number of future studies have been identified to improve the scientific understanding of the impact on water quality of internal nutrient recycling, external nutrient loadings, and the historical alteration of wetlands. Future studies include the following:*

*• Internal recycling rates (i.e., TP movement between lake sediments and the water column), and*

*• A literature review to document the effects of aquatic plant management,*

*including options for improving management strategies to restore and protect water quality and promote natural lake functions.”* pg. 52

**PERSONAL HISTORY**

I believe the first time I saw Newnan’s Lake was around 1953 when I was close to 8 years old[[10]](#footnote-10). I was accompanying my older brother who collected snakes around the Gainesville area. We parked near the Hawthorne Road bridge over Prairie Creek and walked around the lake shoreline to catch brown water snakes which rested within the gnarled cypress trunks and knees. The water was dark brown but rather clear. I would return to the lake many times after that, even after my family moved from Gainesville in 1956. I also remember Lake Wauberg where the University of Florida had set up a recreational area. Here also the water was dark brown but clear. I spent many hours swimming in Lake Wauberg. I do not ever recall these lakes in heavy algal blooms until many years later when in 1976 I did some sampling and sediment analysis on Lake Wauberg. The lake was in an algal bloom at that time.

I do remember during the fifties the abundance of water hyacinth in the area’s waters, although I do not recall seeing large expanses of hyacinths in either Newnans Lake or Lake Wauberg. In some areas such as Paynes Prairie and Lake Alice the hyacinths grew so tall and thick you could walk over them. We often would find black swamp snakes and Allen’s swamp snakes (now crawfish snake) curled up in the roots, along with a myriad amphibians such as sirens, and an abundance of invertebrates. While I do not recollect massive growths of hyacinths on Lake Newnan, I understand that it became necessary to apply herbicides in the sixties to control them, and that herbicide use on the lake has continued over the following years.

The positive influence of these memories of Newnans Lake and of the vibrancy of natural Alachua County play no small part in my sustained interest in the restoration and protection of Florida’s environmental resources. So, while now retired after a 40+ year career as a biologist and environmental engineer, I still feel compelled to offer whatever support I can to efforts to improve the ecological stability of impaired surface waters in Florida such as Newnans Lake. As stated in several of my earlier communications I do not seek, nor would I accept any monetary or other type of payment for any such support.

**TECHNICAL REVIEW**

Recently several people brought to my attention the challenges associated with implementing the Basin Management Action Plan (BMAP) for the Orange Creek Basin[[11]](#footnote-11), which includes Newnans Lake and its watershed. In developing the Newnans Lake TMDL through the FDEP, the investigators[[12]](#footnote-12) found that the phosphorus dynamics were driven largely through recycling from the sediments to the open water and that significant amounts of both nitrogen and phosphorus are stored within the sediments—amounts much greater than what would be expected from accumulated watershed contributions alone. Consequently, in the assessment of loadings it was estimated that of the incoming loads to the lake of 315,510 lb.yr-1 of nitrogen and 25,732 lb.yr-1 of phosphorus, about 74% of the nitrogen load (226,515 lb.yr-1) was from internal sources within the lake, while 59% of the phosphorus load (13,478 lb.yr-1) was from internal sources within the lake. External loading to the lake from the watershed was calculated as 88,995 lb.yr-1 nitrogen and 12,254 lb.yr-1 phosphorus. The TMDL for the lake was set at 85,470 lb.yr-1 nitrogen and 10,942 lb.yr-1 phosphorus, which equates to a target removal rate of 230,040 lb.yr-1 nitrogen and 14,808 lb.yr-1 phosphorus. The dilemma of course is that the removal requirements exceed the incoming loads from the watershed by 141,045 lb.yr-1 nitrogen and 2,554 lb.yr-1 phosphorus, making reduction of internal loading essential for achieving the TMDL targets.

In 2010 the St. Johns River Water Management District (SJRWMD) completed a supplementary study to the TMDL to establish Pollutant Load Reduction Goals (PLRG).[[13]](#footnote-13) The report like the TMDL report established pollutant reduction needs for Newnans Lake. The findings were somewhat similar to, but higher than, those reported within the 2003 TMDL report[[14]](#footnote-14), with a recommendation for an in-lake total p hosphorus concentration of 0.068 mg.L-1 and total nitrogen of 1.294 mg.L-1, which could be accomplished by setting allowable annual loading at 277,767 lb.yr-1  nitrogen and 14,764 lb.yr-1 phosphorus. It is interesting that this report mentions nitrogen fixation as a source of nitrogen but does not mention internal loading of phosphorus from the sediments. Included in the report is the suggestion that if the phosphorus concentration is reduced, then Cyanobacteria will not have the selective advantage they now enjoy, and therefore nitrogen fixation will be either greatly reduced or eliminated. This may be somewhat presumptive. It is not clear why phosphorus recycled from the sediments was not discussed within the report.

Sediment deposition rates were noted within the report at 1.61 mg.m-2.yr-1 for nitrogen and 0.12 mg.m-2.yr-1 for phosphorus[[15]](#footnote-15). These rates represent about a fourfold increase when compared to historical nitrogen rates reported in the document, and a two fold increase when compared to historical phosphorus rates.

Investigations into the nature of the Newnans Lake sediments within the profundal zone[[16]](#footnote-16) in 1992 gives some valuable insight into the role of sediments in phosphorus dynamics[[17]](#footnote-17). Within this study the 137*Cs* horizon corresponding to the circa 1954 nuclear testing provided indication that recent accretion of a highly organic sediment was represented within the first 20-60 cm. This zone was also characterized by a high phosphorus content, averaging around 0.3% on a dry weight basis (3 mg.g-1) as well as a high nitrogen content, averaging about 3.0% (30 mg.g-1) on a dry weight basis. Also within this zone organic content on a dry weight basis was about 50% within the recent sediments, with the dry bulk density comparatively low at about 30-90 mg.cm-3.

The implication provided by this sediment data is that increased nutrient loading over the past 60 years has been extensive and has facilitated the development of hypereutrophic condition. However the phosphorus and nitrogen content in the deeper sediments (below 60 cm) are also very high in phosphorus, nitrogen and organic content, which is suggestive of a non-anthropogenic source of phosphorus and nitrogen. Phosphatic soil deposited just above the Hawthorn formation during the Miocene and Pliocene epochs (circa 5.5 to 23 million years ago) would be suspected as a significant source of phosphorus, and such is suggested by Odum in his 1953 analysis of phosphorus levels throughout Florida waters.[[18]](#footnote-18) Alachua County does contain such deposits and the abundance of phosphorus throughout the sediment column associated with Newnans Lake suggests these deposits may be highly influential on the lake’s phosphorus dynamics. Coincidentally, in 1976 when I did sediment sampling on nearby Lake Wauberg I found the vertical distribution of phosphorus within the sediment profile to be similar to Newnans Lake[[19]](#footnote-19). My comments at that time were:

*“Lake Wauberg… is highly eutrophic, even though loading from the watershed appeared to be low….. It appears that sediments may play a significant part in loading the lake with phosphorus. What may be the case in Lake Wauberg is the presence of some natural phosphorus deposit which through bacterial action has been rendered biologically available in recent years.”*

This same can be presumed for Newnans Lake, with these natural phosphorus deposits being the Miocene/Pliocene phosphate rich formations. These phosphate deposits typically are in the form of apatite, hydroxyapatite and fluorapatite. All of these are rather recalcitrant and resist weathering processes such as dissolution or hydrolysis. However this weathering does occur slowly, and can be accelerated often by changes within the sediments as they become buried with higher organic content. These changes include reduction in pH and Redox potential which occurs quite often in the deeper strata, particularly if there is extensive biological activity. As a result, with weathering, soluble phosphate can be generated, and subsequently dissolve within the surrounding pore water. Diffusion can then facilitate upward migration of phosphate to equilibrate with the lower concentration within the pore water in the upper strata, and eventually release into the lake water column where it becomes available for primary productivity (photosynthesis). Considerable study of phosphorus behavior in lake sediments has been conducted, much of it targeted at the Great Lakes in the early seventies as part of the Great Lakes Water Quality Agreement[[20]](#footnote-20). As a result of these studies, we have a much better understanding of the processes involved in the movement of phosphorus within lake sediments, but there remains a need to expand this understanding. The following footnote references would be worth a review for those wishing to explore this subject in greater detail.[[21]](#footnote-21) [[22]](#footnote-22) [[23]](#footnote-23)

Within the 2010 report by SJRWMD[[24]](#footnote-24), in-lake concentrations of phosphorus and nitrogen was noted to increase substantially after 1991, changing from an average of about 2.00 mg.L-1 total nitrogen and 0.100 mg.L-1 total phosphorus from 1967 to 1991, to an average of close to 4.00 mg.L-1 total nitrogen and 0.180 mg.L-1 after 1991. The Chlorophyll-a levels increased similarly, consistently exceeded 100 µg.L-1 after 1991, a concentration well into Hypereutrophic conditions. The Newnans Lake watershed is largely forested and wetlands with smaller areas of urban/suburban, commercial and industrial. Agriculture is mostly limited to silviculture. While land uses have changed somewhat since 1991, they did not change dramatically. It is reasonable then to suspect other factors beyond just watershed inputs as primary contributors to the increased nitrogen and phosphorus levels after 1991. It is reasonable to expect the phosphorus is generated through increased release from the sediments, while increased nitrogen may be a result of nitrogen fixation by Cyanobacteria responding to increased phosphorus levels, although resolubilization of sediment held nitrogen could also be a factor.

The storage of phosphorus as a legacy from historical and existing activities within the watershed has become recognized as a potential source of excess phosphorus levels within Florida lakes and has complicated development and administration of BMAPs. Like Newnans Lake, Lake Okeechobee has shown substantial increases in phosphorus levels since the early seventies[[25]](#footnote-25), when total phosphorus was about 0.045 mg.L-1. Presently phosphorus levels are nearly 0.150 mg.L-1, or about a threefold increase. It should be noted that increases in phosphorus loading do not always result in immediate increases in concentration within the water column, as much of the influx is initially delivered to the sediments where it is associated with organic mud. This accumulated phosphorus has been identified as legacy phosphorus which eventually can redistribute available phosphorus to the water column. Legacy phosphorus within Lake Okeechobee and its watershed presently amounts to 110,000 metric tons of available phosphorus, enough to release 500 metric tons a year to the lake water column for 200 years, as identified by the University of Florida (UF) Water Institute[[26]](#footnote-26) . This is an obvious impediment to meeting the TMDL for Lake Okeechobee of 149 tons per year, which is recognized within the UF report:

*“Beyond existing and planned approaches, the substantial reservoir of legacy phosphorus in the Northern Everglades[[27]](#footnote-27) watersheds will necessitate new and more aggressive strategies to combat the mobility of phosphorus.”*

Reddy et. al.[[28]](#footnote-28) conducted studies on these organic sediments in Lake Okeechobee and calculated that the phosphorus loading rates from the sediments to the water column are as large as 0.7 mg-P.m-2.d-1 for the mud zone and 1.1 mg-P.m-2.d-1 for marsh sediments. As the mud zone amounts to about 200,000 acres of the lake area, the annual sediment contribution from the mud zone alone can be estimated at about 207 metric tons of phosphorus per year.

Because the Okeechobee Basin (Northern Everglades) is largely agriculture, it is not difficult to determine the original source of this legacy phosphorus. However, Newnans Lake has a rather natural watershed, with limited phosphorus loading. There are three reasonable potential sources of legacy phosphorus in Newnans Lake, these being:

* Increased dissolution and hydrolysis of the underlying natural phosphate deposits
* Storage within the lake of incoming phosphorus loads over an extended time period
* Release from necrotic vascular plant issue (e.g. Water Hyacinths) as a result of large scale herbicide application

Increased dissolution and hydrolysis is indeed possible, but there is no evidence as to why after 5,000 years + of the lake’s existence, it would all of a sudden start dissolving the underlying phosphate rock at a significantly higher rate.

Long term phosphorus storage within the lake sediments is possible, and in fact was suggested by Odum in his 1953 paper[[29]](#footnote-29), in which he noted

*“The waters entering Newnans Lake …show a drop from 0.247 to 0.117 ppm*

*(mg.L-1).”*

In this case the 0.247 mg.L-1 was a value from Hatchet Creek at SR26 near the influent to Newnans Lake, while 0.117 mg.L-1 was the value at the Prairie Creek outlet. While the 1953 Hatchet Creek value is higher than that currently documented (by about 0.130 mg.L-1), it needs to be recognized that pollution control efforts where minimal in 1953, and it would not be surprising that there would be discharges which would not be allowed today. The difference noted between input and outputs (0.130 mg.L-1) indicate an in-lake storage of about 14,000 lb.yr-1, or over 23 years (to 1976), about 320,000 pounds of phosphorus, or a rate of about 0.65 mg-P.m-2.d-1. This is just a rough estimate, as Odum relied upon single grab samples, and there is no indication as to how many years this accumulation occurred or what the actual average accretion rate was over this period. But this phenomenon is not much different than that noted within Lake Okeechobee, and other hypereutrophic lakes in Florida.

One way to test the Odum based hypothesis is by estimating phosphorus accretion rate based upon sediment information as reported by Gottgens and Crisman[[30]](#footnote-30). Using the mean 137*Cs* horizon at a sediment depth of 40 cm, and a dry bulk density of 63 g.cm-3 , with phosphorus content on a dry weight basis of 0.30%, over the 38 year period 1954 to 1992, assuming the profundal zone is about 2,500 acres, then about 43,000 lb. yr-1 of phosphorus are added to the sediments. This is three times the rate estimated from the Odum values.

The implication is that there may be other sources of phosphorus. The underlying mineral deposits as noted may be one source, but it is also possible that phosphorus held within the vascular aquatic plant standing crop could be a source. For example, 500 acres of water hyacinth, as referenced in a report of invasive plant management programs to the Florida House of Representatives[[31]](#footnote-31) as the amount of floating vegetation targeted for herbicide application on Newnans Lake for the period 2001-2002, contains about 2,178 dry tons assuming a wet crop density of 4 lb.ft-2 and a solids content of 5%. Using a dry weight phosphorus content of 0.30%, the 500 acres holds about 13,000 pounds of phosphorus. Considering this, depending upon how many acres of plants were destroyed and how much necrotic tissue was allowed to remain within the lake over the 60+ year period, the additional phosphorus loading from herbicide use could be significant. It is noteworthy that the amount of phosphorus within the water column of Newnans Lake is about 14,300 pounds presently, an increase by about 6,700 pounds from pre-1991. The destruction of 500 acres of water hyacinths over a short period of time would almost double the phosphorus mass and concentration within the lake’s water column.

Nutrient release as a result of herbicide use within Florida’s surface waters has become an issue of discussion in recent years. I mentioned this within a blog presented on my PASOP website ( <https://www.pasop.org/herbicide-policy> ), and discussed it recently with managers with the Florida Fish and Wildlife Conservation Commission (FWC) during an review of a proposal I submitted in January of this year to a request for information (RFI) related to alternative approaches to aquatic plant management.[[32]](#footnote-32)

In August, 2020, after learning of a Cyanobacterial bloom in Little Orange Lake, located within the Orange Creek Basin, I reached out to David Whiting, Deputy Director of the Division of Environmental Assessment and Restoration for the Florida Department of Environmental Protection (FDEP)[[33]](#footnote-33). On August 12, 2020, after an initial conversation with Mr. Whiting I sent him an inquiry via email:

*“Thanks for taking the time to discuss with me the possible relationship between herbicide application and the occurrence of blooms of Blue-Green Algae. While, as best I have been able to determine, there is no indication anyone has established a direct relationship between these two, it does seem quite possible that herbicide use and the resulting nutrient release from necrotic plant tissue could elicit Blue-Green algal production. As noted during our conversations we have recently seen blooms develop in both Little Orange Lake and Lake Hatchineha following extensive herbicide application.”*

Mr. Whiting responded on August 17, 2020.

*“Regarding your concern about pesticide treatment of aquatic plants resulting in algal blooms, I think it is possible, but that it probably depends on a lot of factors (e.g., temperature, time of year, level of treatment, proportion of lake treated, whether there is flow in and out of the lake…).  Given that Little Orange Lake has experienced a cyanobacteria bloom, I do think that should be taken into consideration by FWC when determining what additional aquatic plant management activities should be performed on the lake this year.”*

In 1972 Putnam, Brezonik and Shannon[[34]](#footnote-34) suggested that herbicide application could well have been an important factor in the hyper eutrophication of Lake Apopka.

*“A hyacinth eradication program employing herbicides over the last 20 years has left a flocculent bottom layer of undecomposed plant residues. These unconsolidated sediments according to a recent Federal Water Quality Administration report (1968) cover 90 percent of the lake bottom”*

It is reasonable then to believe that as with Lake Apopka and other impaired lakes in Florida, herbicide use on Newnans Lake over the years could be a significant factor in promoting extensive Cyanobacteria production within the Lake. A comprehensive in-lake MAPS program would be designed to eliminate herbicide use within these lakes, while addressing the need to reduce the influence of sediment held legacy nutrients. The proposed Newnans Lake program would provide valuable insight into the design and operational requirements needed to make such a statewide comprehensive plan viable and cost effective.

**PRELIMINARY ENGINEERING CONSIDERATIONS**

**Introduction**

Legacy nutrients are those that accumulate and are temporarily sequestered within lake sediments and/or watershed soils, and which under certain conditions can be released into the lake water column. These legacy nutrients have proven problematic for those responsible for developing TMDL’s and implementing BMAP’s. This was expressed rather clearly by the Blue-Green Algae Task Force in their recent consensus report[[35]](#footnote-35).

*“Legacy nutrients, i.e. nitrogen and phosphorus sequestered in soils, groundwater and sediments, contribute also to excessive nutrient loading of surface waters throughout the state*.” pg.1

*“Legacy nutrients….are a concern in the South Florida landscape, and the task force recommends that their contribution to loading figure prominently in the Lake Okeechobee, Caloosahatchee and St. Lucie River and Estuary BMAPs. The task further recommends that projects with the demonstrated potential to expedite legacy nutrient removal merit special attention and be designated as priority projects.” pg. 3*

While the attention of the Task Force was directed primarily to Lake Okeechobee and its outlets (Caloosahatchee and St. Lucie Rivers), their assessments certainly have statewide applicability. Newnans Lake is an example in which loading from legacy nutrients is an important nutrient load contributor, and such has been recognized within the TMDL report for the lake.[[36]](#footnote-36)

There can be identified four available methods of reducing the influence of legacy nutrients—these being:

* external “kidney” type treatment system;
* in-lake MAPS systems;
* Dredging;
* and in-situ sequestration or immobilization.

A brief description of each of these options is included below.

1. **External “kidney” type treatment systems**. The use of an external treatment unit which receives water from the impaired water body; treats it; then returns the treated water to that body at a lower nutrient concentration. The advantage offered by these external systems is the stability and operational flexibility of a fixed shore-based facility. Such units could employ biological, chemical or physical treatment, or a combination of these. These type of systems are presently in operation in a few areas around Florida.
   1. For example, in Indian River County, Florida, impaired surface water from a canal system is treated though a MAPS process known as an Algal Turf Scrubber® (ATS™) in series with a downstream lake/wetland system before being returned to the canal system. This facility has been in operation for about 10 years, and relies upon frequent harvesting and removal of the biomass associated with the ATS™ to ensure sustainability. A video of this facility (Egret Marsh Stormwater Park) can be viewed at [https://vimeo.com/375731448?ref=fb-share&fbclid=IwAR1fCVnlhNdI33XZXBu3MkXkrJv8sJF\_q2yg1-j1ng8R0w19TQFSwmyoM6o](https://gcc02.safelinks.protection.outlook.com/?url=https%3A%2F%2Fvimeo.com%2F375731448%3Fref%3Dfb-share%26fbclid%3DIwAR1fCVnlhNdI33XZXBu3MkXkrJv8sJF_q2yg1-j1ng8R0w19TQFSwmyoM6o&data=02%7C01%7Cjsteinle%40sfwmd.gov%7Cee543410a5a24266d4d708d775a24e20%7Cd23f7173b3864e918ce7052a18d65341%7C0%7C1%7C637107212296985403&sdata=ODwwqP33kp%2FzkdudUAKvZSx06HezrG9wUByhVSrH%2FeU%3D&reserved=0). A large scale external system involving MAPS is envisioned in the PASOP blog at <https://www.pasop.org/implementing-maps> .
   2. In addition to MAPS based treatment, passive wetland systems can be used as external “kidney” systems as well. However, these passive wetlands, such as the Stormwater Treatment Areas (STA) in South Florida do not include aggressive periodic removal of plant production, and in fact use herbicides at times in an effort to reduce invasive species such as cattails. Wetland systems certainly can be effective, but periodic removal of accumulated plant residuals is suggested. If such removal were incorporated into the operational strategy, these wetlands would be considered MAPS facilities.
   3. Physical/Chemical technologies are another treatment option for this   
      “kidney” approach. The St. Johns River Water Management District (SJRWMD) is presently testing an innovative process developed by Phosphorus Free Water Solutions of Lakeland Florida <https://phosphorusfree.com/> . This process results in a calcium phosphate by-product which has reuse potential.
2. **In-lake MAPS Systems** such as that proposed within this text, involves nutrient removal and aquatic plant management through cultivation of aquatic plants within the lake itself. The in-lake system can be oriented around contained floating systems as proposed within this text, or management of expansive production of invasive plants, such as hydrilla. The in-lake MAPS offers several benefits, as note in the Summary on page 1 of this proposal. To reiterate, some of these include:
   1. Augmenting the planned nutrient reduction as delineated within the TMDL;
   2. Enhancing fish and wildlife habitat through elimination or extensive reduction of herbicide use within the lake;
   3. Impeding the development of Cyanobacterial blooms through shading, nutrient reduction and allelopathy
3. **Dredging** can be effective in eliminating the sediment sources of nutrient loading. The Corps of Engineers completed a dredging project in 1,600 acre Lake Trafford in 2010[[37]](#footnote-37) which resulted in reduced nutrient levels. Dredging however is expensive and requires extensive land for dredge spoil storage. The cost for the Lake Trafford project was about $23 million or about $14,000 per acre.
4. **Sequestration and Immobilization:** In the UF Water Institute report[[38]](#footnote-38) a reference is made to “immobilization of legacy P by chemical amendments”. However there was no reference to the methods or field experiences. Addition of Aluminum Sulfate (Alum) to a lake can immobilize soluble phosphorus within the sediment pore water, but it does not lend itself to recovery and reuse. In addition, there is question as to whether the immobilization can be reversed in the future as the sediment environment changes. There are also concerns regarding impacts upon the sediment and lake ecology.

Each of these may have application, depending upon specific situations and costs. Of course it is feasible that one or more could be used in combination.

**Preliminary Engineering**

***Initial Sizing with HYADEM model***

Using water hyacinths to manage and recover nutrients as an in-lake MAPS is not a new concept. In fact Mayan cultures some 1,000 years ago used the nutrient rich organic soils created by the decomposition of aquatic plants within canals to establish sustainable agricultural techniques.[[39]](#footnote-39) In more recent times in 1977, two South African researchers, C.F. Musil and C.M. Breen [[40]](#footnote-40) presented a case for using the harvesting of in-lake hyacinths to improve water quality in eutrophic lakes. More recently, the Chinese have used contained hyacinths, much as proposed in this text, within some of their reservoirs to remove and recover nutrients, and to impede the production of Cyanobacteria[[41]](#footnote-41), as noted in Figure 1 (see PASOP blog at <https://www.pasop.org/the-chinese-apply-water-hyaicnths> ).

Figure 1

Confined Water Hyacinth Facility, Caohai China[[42]](#footnote-42)



In their study, Musil and Breen[[43]](#footnote-43) developed a first-order kinetics model based upon the Michaelis-Menten[[44]](#footnote-44) relationship to estimate specific growth rate considering both nitrogen and phosphorus as the limiting nutrient. This model was modified by Stewart et. al.[[45]](#footnote-45) in 1987 and put into an Excel Spreadsheet. This model has been successfully used in sizing hyacinth systems in terms of nutrient removal and harvest needs. A modified version of this model---Hyacinth Design Model or HYADEM-- was used to size the in-lake system proposed in this text, as shown in Table 1. The input values used in this model and the results of the model run are similar to past operations, including a facility done jointly in the S-154 basin of Lake Okeechobee for FDACS, FDEP and the South Florida Water Management District (SFWMD).[[46]](#footnote-46)

The modeling indicates a 56 acre enclosure will result in an annual harvest of 15,815 wet tons (791 dry tons), with an annual removal of 47,444 lbs. of nitrogen and 4,744 pound of phosphorus. Theoretically the in-lake concentrations of total nitrogen will be reduced from 4.24 mg.L-1 to 3.66 mg.L-1 and total phosphorus from 0.186 mg.L-1 to 0.128 mg.L-1. However, it should not be expected that during the first year of operation that in-lake concentrations will be reduced to these levels, as sediment recycling could well replenish the nutrients removed through the harvested hyacinth. The extent to which sediment recycling occurs will provide insight into how long it might take to reduce sediment legacy contributions. Note that on page 5 of this report, the estimated sediment phosphorus contribution is 13,478 lb.yr-1, so should this 56 acre pilot prove effective in nutrient removal and recovery, it would be anticipated that for full scale operation, the enclosed area would need to be expanded substantially—perhaps to 200-400 acres, depending upon system performance during this demonstration project.

Also, it is the intent to apply the water hyacinth cultivation as a means of impeding Cyanobacterial production. Based upon personal field experience I can attest to the antagonism between Cyanobacteria and water hyacinths. When hyacinths are introduced to a water body in a Cyanobacterial bloom, they must overcome the stresses associated not only with allelopathy, but also the high daytime pH values typically attendant with these blooms. However, if a seed crop of hyacinths can be established then they can combat the Cyanobacteria through light deprivation (shading) and counter allelopathy. To establish a crop of water hyacinths in Newnans Lake, an initial crop must be confined to a restricted area and allowed to expand within the 56 acre enclosure. As 56 acres only represents 1% of the lake surface, it is not likely that this coverage will be sufficient to eliminate Cyanobacterial blooms throughout the lake, but reductions within the vicinity of the enclosure is likely. I have in my experiences found that about 10% coverage the hyacinth crop should effectively control Cyanobacterial blooms. This of course is anecdotal. This proposed demonstration project will give more solid evidence regarding this issue.

**Infrastructure Considerations**

Required infrastructure operational support for operational support will include

* 56 acre hyacinth cultivation enclosure
* Barge Module for chopper and pumping system
* HDPE Force Main
* On shore material receiving/composting facility
* Road Access and Boat Ramp



Table 1

Newnans Lake in-lake Hyacinth Cultivation Area Sizing HYADEM

***HYACINTH CULTIVATION ENCLOSURE:*** This enclosure will be designed to contain the cultivated hyacinth crop. It is envisioned as a floating boom system with a chain ballasted 12” to 18” skirt. The enclosure will be secured to the bottom by appropriately spaced screw anchors, or equivalent anchoring system. The anchoring system and the boom shall be designed to resist the forces associated with a wind driven crop of about 3,500 tons pushing against the boom enclosure. The intent is that the enclosure system will be able to sustain a fixed location through the 2 year operational period. The boom system shall be fitted with disconnect plates which would allow opening access for the harvester.

The boom system shall be specifically developed for containing floating aquatic plants, such as that supplied by American Marine, Inc. of Cocoa, Florida (<https://www.elastec.com/products/floating-boom-barriers/invasive-aquatic-plant/> ).

***CHOPPER/PUMPING PROCESSING BARGE and HDPE FORCE MAIN:*** An assembled fixed position barge, such as those provided by Damen Shipyard. Gorinchem, Netherlands, or approved equivalent, would serve to support the necessary conveyors, choppers, pumps, power pack, as well as needed appurtenances—See Figure 2 for typical site arrangement.

One possible site location is shown as Figure 3, recognizing this will likely change once a detailed site analysis has been completed.

Figure 2

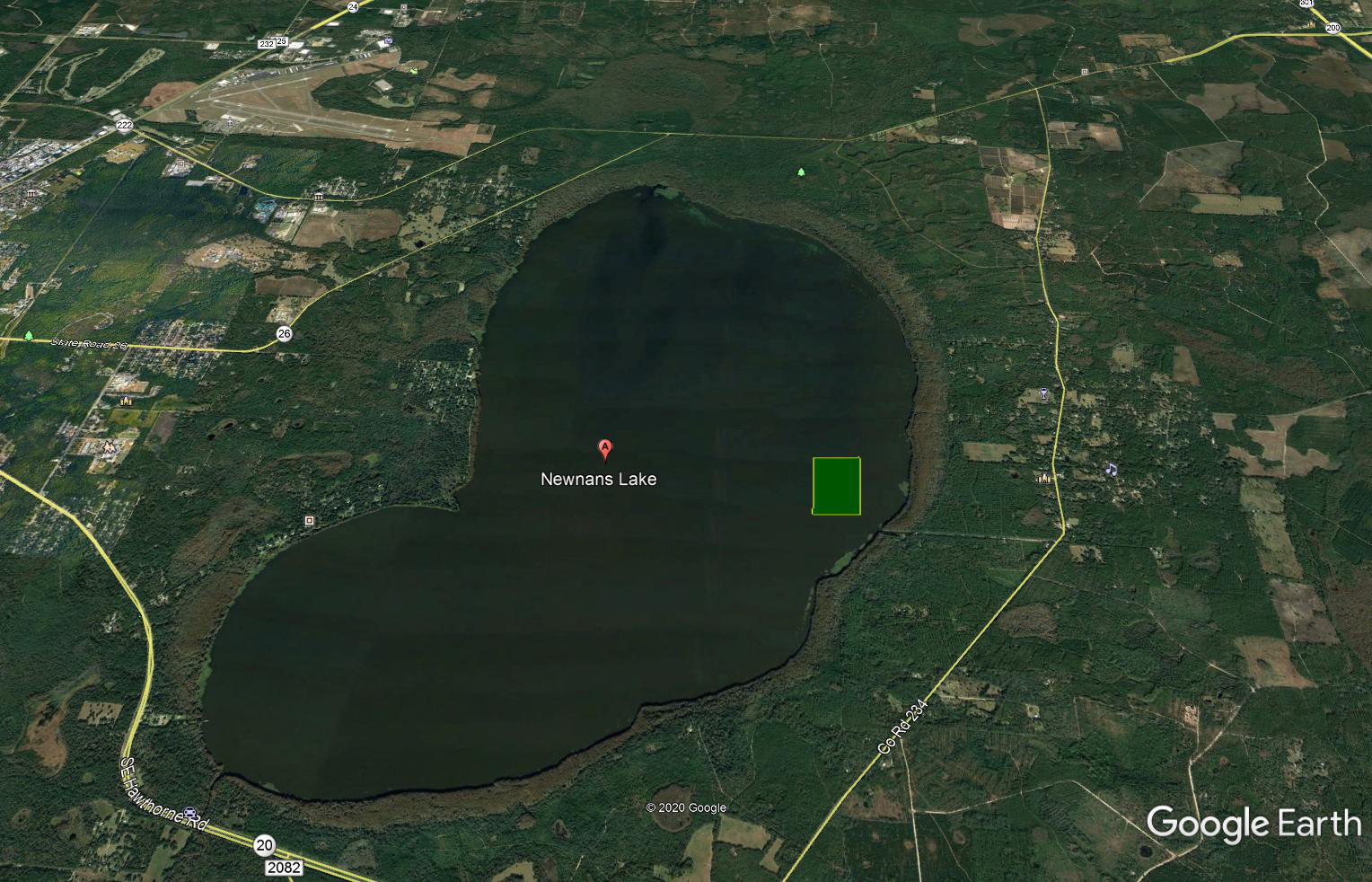
Typical Damen Modular Barge Set-Up



The Chopper/Pumping Processing Barge would be equipped with a conveyor which accepts feed from the harvester and delivers the material into a chopper system. This arrangement would be similar to that shown as a land-based system in Figure 4. The chopper system could be a forage chopper modified to accept wet material, as shown in Figure 4.This chopper increases the wet density of whole plants at about 540 lb.yd-3 to a homogenous chopped material of average particle size of ¼” at about 1,600 lb.yd-3, or about a 67% volume reduction. This chopped material is about 95% water, but much of this is intercellular water. Nonetheless it can be pumped, and we have done this well over a thousand feet with a progressive cavity (e.g. Moyno) pump.

Figure 3

Possible Site Location Proposed Demonstration Project



**Newnans Lake (circa 6,600 acres)**

Chopper/pump Processing Barge

Receiving/Composting Facility

56 acre water hyacinth cultivation enclosure

Road Access

HDPE Force Main

Boat Ramp

Figure 4

Conveyor and Hyacinth Chopper at S-154 project, Okeechobee, Florida (2005) photo by HydroMentia, Inc.



Other positive displacement pumps such as diaphragm pumps or peristaltic pumps may also be considered or even certain types of centrifugal pumps. It is possible some additional carrier water will be needed to reduce fiction losses and ensure movement into the pump intake.

As it is anticipated that about 400 wet tons of hyacinths will be harvested weekly from the enclosure, and if this harvesting is done in two-8 hour days using two harvesters, the rate of delivery to the chopper would approach 25 tons per hour. The conveyor and chopper would have to be sized accordingly, and consideration would have to be given to loading and unloading times as well as transport times.

At 20 tons per hour at 1,600 lb.yd-3 it can be calculated that the pumping rate without carrier water would be 84 gpm. If an equal amount of carrier water is used, the rate would be at 168 gpm. Assuming a reasonable distance of 2,500 feet to the receiving station, a delivery rate of 180 gpm, and a low Hazen-Williams coefficient of 60 to account for friction associated with moving the chopped plant particles, a six inch HDPE pipe would provide a velocity of over 2 fps with a friction loss of about 33 ft. or about 14.3 psi. This is a rather modest pumping demand, and could be provided using a Moyno progressive cavity pump as an example. The Moyno series 2000 HS can be equipped with a bridge breaker, which will help ensure the material moves efficiently into the pump intake. As noted, carrier water might help improve pumping performance. This water could be recycled through a return line so that excess water does not enter into the composting process. A pump design specialist would need to formalize the layout of the pumping system, and some field testing may be helpful before final selection is made.

The hyacinth slurry force main could be of HDPE of an SDR suitable for expected pressures. The pipe could be laid directly to the lake bottom and on the floor of the cypress wetlands before being buried as it encounters dry land. It could be secured to the bottom with ballast at a frequency sufficient to prevent serious lateral movement or flotation. Air and vacuum relief valves would be needed to protect performance and the integrity of the piping system. A Kamloc type connector station would need to be designed to facilitate easy connection to the pumping system.

A power station will be required on the barge. This could be a gasoline, diesel or natural gas powered hydraulic system which would drive the conveyor, chopper and pump station.

Regarding harvesting done outside the enclosure as required to facilitate effective aquatic plant management throughout the lake, the work plan will be developed by FWC and the Contractor shall adjust the operation accordingly. As enclosure harvesting is expected to require only 2 days per week, the remaining days can be dedicated to lake aquatic plant management. It will be the responsibility of the Contractor to provide harvesting, transport and processing needs for this work. If the enclosure infrastructure, such as the processing barge and force main as well as the composting area are used, it will be necessary to isolate the enclosure harvest from the open lake harvest.

***ON-SHORE MATERIAL RECEIVING/COMPOSTING FACILITY:***The on-shore facility shall be designed to receive the pumped hyacinth slurry; facilitate the storage and surface drainage of this slurry; using equipment such as a skid loader or front end loader to move the slurry to a composting row and mix the slurry with bulking material, such as chopped straw, as necessary to establish a compost design mix; create a compost windrow and mix the windrow as appropriate throughout the initial composting period (see Figure 5); provide an area for final aging and storage of compost and for loading onto dump trucks as needed for transport of the final product outside the Newnans Lake basin. A water source and water distribution system will also be required. Windrow composting should not generate offensive odors if operated properly. However, the site should be sufficiently removed from residential areas so equipment noise and visual aesthetics do not become problematic.

Regarding sizing considerations, the composting process is very effective at reducing volume of the feed material. Based upon experiences at S-154[[47]](#footnote-47) and other facilities, about 25% of the volatile solids will be oxidized and about 94% of the moisture, as shown in table 2. The result is a compost product of about 40% moisture and a bulk density of about 1,200 lb.yd-3 after about 90 days. The initial feed material is at about 1,600 lb.yd-3. A First In First Out (FIFO) analysis, considering a windrow 5 ft. high and a cross sectional area of 60 ft-2, a weekly harvest of 400 wet tons with a volume of about 500 yd3, or 13,500 ft3, which will require about 227 linear feet of space or 2,700 ft2, the final product would amount to 50 tons of material with a volume of about 83 yd3 or 2,250 ft3, which will require about 37.5 linear feet of space or 450 ft2 , if it assumed a linear daily decline in square footage required over a 90 day periods, about 18,000 ft2 will be the maximum area required for rows. If this is doubled to accommodate harvest from outside the enclosure, and then expanded by 50% to allow vehicle access to the rows, then a total composting area which should be set aside is estimated at 54,000 ft2, or about 1.15 acres. Doubling this to 2.30 acres will allow storage, final curing, a receiving lagoon and equipment storage and refueling. It is anticipated the composting facility would not require electrical power, although it would be convenient if available. Pumps and power tools can be run from generators.

Table 2

Typical Compost Batch from Chopped Water Hyacinth[[48]](#footnote-48)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Content | Beginning Batch #2 | | Finished Batch #2 | |
|  | % | Total Pounds | % | Total Pounds |
| Total Weight pounds | - | 52,883 | - | 6,589 |
| Moisture | 91 | 48,111 | 45.2 | 2,978 |
| Total Dry Weight | - | 4,772 | - | 3,611 |
| Phosphorus dw | 0.26 | 12.2 | 0.36 | 12.9 |
| Nitrogen dw | 2.30 | 110 | 3.21 | 116 |
| Ash | - |  | 60.2 | 2,174 |
| Potassium dw | - |  | 1.11 | 40 |
| Sulfur dw | - |  | 0.33 | 12 |
| Calcium dw | - |  | 3.72 | 134 |
| Magnesium dw | - |  | 0.55 | 20 |
| Sodium dw | - |  | 0.18 | 6 |
| Iron dw | - |  | 0.70 | 25 |
| Copper dw | - |  | 0.0013 | 0.005 |
| Manganese dw | - |  | 0.040 | 1 |
| Zinc dw | - |  | 0.011 | 0.40 |
| pH units | - |  | 8.0 | - |

The Compost market in Florida was evaluated by the University of Florida [[49]](#footnote-49) in a 2005 study. The total compost market in Florida was noted to be about 42 million tons annually, with in-state production at only 5.5 million tons, so there is opportunity to move the material produced through this proposed project, pending favorable analysis. Moving the 1,600 tons produced annually out of the watershed should not be difficult.

Figure 5

Typical windrow composting operation for harvested aquatic plants

photo by HydroMentia, Inc.



***ROAD ACCESS and BOAT RAMP:*** There are several existing boat ramps around the lake. The ramp at Owens Illinois Park on the east side of the lake is comparatively remote in terms of residential areas, although the ramp would have to be widened and modified to accommodate the harvesters. However, use of the ramp would be minimal as the harvesters would stay on the lake permanently unless they needed repair or replacement. Smaller service boats might need to be launched at the ramp on a more frequent basis. The site layout shown in Figure 3 is oriented around the Owens Illinois Park. Obviously final site selection will need to be included as part of design, and will require open public involvement.

There is a reasonable access road coming to the park from CR 234. A spur could be built from this road for accessing the receiving/composting area. As only about 1,200 tons of compost would be produced each year, or about 120-16 cy dump truck loads would be required, or perhaps on average one truck every 3 days. Disruption to the area would be negligible. The truck traffic could be reduced further if live-bed trucks were used.

**Operational Strategy**

Once the enclosure is completed the Contractor will locate and obtain permitting for transport of about 500 wet tons of fresh water hyacinths. To the extent practical, the plants should be free of pests and pathogens, such as the hyacinth weevil (*Neochetina sp*.) and the hyacinth moth (*Sameodes sp*.). The introduced crop should be constrained within a section of the enclosure and the restraints expanded as the crop expands. During grow-out, dead material and older plants should be removed to ensure the standing density is uniform. Throughout the project, including the grow-out period, pests such as the mentioned weevil or moth may become problematic. There are biological controls available to manage these, including BTI and predatory nematodes such as *Heterorhabditis sp.* The use of conventional synthetic pesticides will not be allowed. It is anticipated that under present nutrient levels, grow-out to 45 acres will take about 130-140 days. During grow-out some harvesting may be needed to enhance crop health, so the harvesters as a minimum should be available.

It is expected that weekly harvesting from the enclosure will be done with a paddlewheel driven harvester such as the Kelpin harvester shown in Figure 6. A YouTube video at <https://www.youtube.com/watch?v=JrLXcDadKIM> shows a 70 foot Kelpin Harvester removing a very dense (200 wet ton per acre) stand of water hyacinths. It is anticipated the density of the enclosure hyacinths will be at about half this value. While the final logistics will be determined by the Contractor as part of the bid package, it is likely that two of the 70 foot Kelpin units could handle the weekly harvest within two days, including transport time to the chopper/pumping barge.

Figure 6

Typical Kelpin Harvester

photo by Texas Aquatic Harvesting



It is possible the Kelpin harvester will be able to use its conveyor to direct feed into the chopper units. To help expedite the operation, discharge from the conveyor will need to go into a holding area, which would feed the material into the modified forage choppers, which should be able to handle at least 20 wet tons per hour. The chopper discharge will deliver material to a wet well which facilitates feed into the pumping system while providing some storage in case the chopping rate exceeds the pumping capacity. The modified forage chopper, such as that shown in Figure 4, will be custom designed and fabricated, which requires engineers and fabricators with experience with managing wet crops.

The receiving compost station will require 1-2 experienced operators for moving the material into windrows; mixing with bulking agent; monitoring weights and volumes; establishing storage and finishing piles; mixing working windrows; receiving and loading; and general maintenance and clean-up. Depending upon how much material is received from outside the enclosure; one of the composting station operators could be part time.

**Monitoring Strategy**

A monitoring program should be developed which provides reliable data to allow the following determinations:

* The mass quantity of the wet enclosure harvest
* Sampling at a frequency which gives statistical confidence of wet harvest quality to include moisture content and wet bulk density for each enclosure harvest.
* Sampling at a frequency which gives statistical confidence of dry harvest quality for each enclosure harvest to include as a minimum on a dry weight basis percent protein, phosphorus, nitrogen, carbon, ash, calcium, potassium, magnesium, manganese and iron, with screening for heavy metals on a monthly basis.
* The mass quantity and quality of bulking agent added to each windrow of enclosure harvest.
* The mass quantity of the finished compost for each enclosure harvest
* Sampling at a frequency which gives statistical confidence of compost quality for each enclosure harvest to include as a minimum percent moisture and wet bulk density and on a dry weight basis percent phosphorus, nitrogen, carbon, ash, calcium, sodium, potassium, magnesium, manganese and iron, with screening for heavy metals on a monthly basis.
* Continuous In-situ water quality at two stations—one near the enclosure and one at a remote site, to include temperature, pH, DO, and conductivity.
* Field sampling at the two sites for turbidity, secchi depth and chlorophyll-a during daylight hours once weekly.
* Weekly 24 hour composite sampling at mid depth at the two stations for TKN-N, Nitrate-Nitrite-N, Ammonia-N, Total Phosphorus, ortho-phosphorus, total suspended solids, color, chlorophyll-a, TOC, and TDS.
* Weather Station at the Composting station for air temperature, rainfall and wind speed/direction.
* Monthly qualitative analysis of phytoplankton at two sites.
* Weekly photographs pre and post-harvest
* Sediment cores to be taken at the two lake stations once every six month, to be sampled at 2 cm intervals over top 10 cm for percent solids, percent dry weight organic carbon, phosphorus, and nitrogen.
* Other parameters to include flow rates at gauging stations and lake water level, and sampling as needed of drain waters which might be collected at the compost station.
* In-lake harvest quantity and quality shall be determined per directions from FWC.
* Harvest efficiency for enclosure harvesting in terms of man hours per harvest and area and per wet ton delivered to compost station. To include equipment run time, fuel use, down time, transfer time, break downs, etc.
* Periodic monitoring of by-catch associated with enclosure harvesting both quantitative and qualitative.
* FWC to conduct annual fish and wildlife surveys within the enclosure area and areas within the lake.

The operational period will be for two years, with the final report to include:

* Total wet harvest and dry enclosure harvest for each harvest and annual totals.
* Total phosphorus and nitrogen removed through enclosure harvest and percent capture within compost.
* Average man-hours per wet ton harvested and processed.
* An evaluation of quality and value of the finished compost.
* General review of aquatic ecology, including the fishery, within the vicinity of the enclosure.
* Comments and recommendations.

**Implementation and Funding**

There are several implementation models, as listed below, which could work to satisfy the intent and schedule of the project. Obviously this will be a multidisciplinary effort, and should be of specific interest to the four agencies mentioned—FDEP, FWC, FDACS and SJRWMD. Therefore joint participation and funding would be optimal, although it may be helpful to have a lead agency to administer the contract(s).

1. Private Contractor to provide Design, Build and Operate (DBO), meaning most aspects of the project are managed by the Contractor. This way the agencies get one price and one point of accountability. Initial bid specifications for procurement of the DBO Contractor will be developed jointly by the involved agencies and their engineering and technical consultants. The DBO Contractor could be the Harvesting Service Provider, but it may be some other private entity.
2. Several separate contracts bid and administered by the agencies, who shall assign a project manager to oversee construction and operation—e.g. design and bid; construction; equipment supply; operational service; monitoring and analysis services.
3. Two primary contracts--Design and Construction as one contract, and Equipment Supply and Operations as a second contract, using groups such as IFAS to conduct the monitoring and analysis.

**Final Comments**

This memorandum is introductory, and the concept proposed and the calculations provided are based partly upon my experiences and somewhat upon established engineering. I encourage reviewers to check my assumptions and calculations and if there are questions—which there should be—we can discuss these in detail at future meetings. I believe the approach delineated within this proposal clearly shows how overlapping of interests of the four agencies mentioned can be mutually beneficial, and addresses several basic questions such as

* Can in-lake MAPS assist in reduction of legacy nutrients in lakes and contribute to improved water quality and to meeting the TMDL? (FDEP/SJRMWD)
* Can combining in-lake MAPS with comprehensive aquatic plant mechanical harvesting of non-cultivated plant biomass within the lake allow elimination of herbicide application within the lake? (FWC)
* Can agricultural products such as compost or liner mix be developed from the harvested plants from the in-lake MAPS? (FDACS)

1. Managed Aquatic Plant Systems (MAPS) represent a variant of typical agriculture, for the primary intent is not to maximize productivity of the targeted crop as with conventional agriculture, but rather to maximize reduction of pollutants from an impaired water source through an on-going harvesting and processing strategy. In other words, MAPS operations do not involve adjustment of nutrient levels in the feed water to ensure high levels of crop production and quality, but rather involve adjustment of crop selection and operational strategies to ensure high rates of nutrient reduction from the raw feed water, such as a nutrient enriched, impaired surface water. With conventional agriculture the crop is the primary product, while with MAPS, enhanced water quality is the primary product. This approach represents a significant paradigm shift from the general acceptance of agriculture as a net pollutant contributor, to the reality that there are forms of agriculture that can offer substantial net pollutant removal and recovery. [↑](#footnote-ref-1)
2. Total Maximum Daily Load per section 303(d) of the Clean Water Act—PL92-500 [↑](#footnote-ref-2)
3. Final Nutrient Total Maximum Daily Load For Newnans Lake, Alachua County, Florida, Xueqing Gao and Douglas Gilbert Watershed Assessment Section Florida Department of Environmental Protection 2600 Blair Stone Road, MS 3555 Tallahassee, FL 32399-2400. ,September 22, 2003 [↑](#footnote-ref-3)
4. FINAL 2007 ORANGE CREEK BASIN MANAGEMENT ACTION PLAN For the Implementation of Total Maximum Daily Loads Adopted by the Florida Department of Environmental Protection for Newnans Lake, Orange Lake, Lake Wauberg, Hogtown Creek, Sweetwater Branch, Tumblin Creek, and Alachua Sink Developed May 8, 2008 by the Orange Creek Basin Working Group in Cooperation with the Florida Department of Environmental Protection Division of Water Resource Management Bureau of Watershed Management Orange Creek Basin Adoptable BMAP [↑](#footnote-ref-4)
5. Ibid, pg. 1 footnote 3 [↑](#footnote-ref-5)
6. Ibid, pg. 1 footnote 4 [↑](#footnote-ref-6)
7. Ibid, pg. 1 footnote 3 [↑](#footnote-ref-7)
8. Allelopathy refers to the chemical inhibition of one plant (or other organism) by another, due to the release into the environment of substances acting as germination or growth inhibitors. [↑](#footnote-ref-8)
9. Ibid, pg. 1, footnote 4 [↑](#footnote-ref-9)
10. For those of you interested in Florida History, Newnans Lake is named for the notorious character Daniel Newnan. In 1812, just after the time when the Alachuan Seminoles and their Spanish allies defeated a group of so-called “Georgia patriots” at Twelve Mile Swamp and pushed most of them out of Florida, one of the patriots, Daniel Newnan, made one last effort to inflict revenge on the Alachuans. In a surprise raid probably in the vicinity of Hatchet Creek, he and about 110 men attacked the Alachuan leader Payne and his entourage who were on their way to St. Augustine to meet with the Spanish Governor. Newnan had made a big mistake, and soon found himself surrounded by Alachuan and Black Seminole warriors. He and a few of his men barely made it back unharmed to Ft. Picolata on the east side of the St. Johns River. While the raid was a failure, during the encounter Newnan managed to mortally wound the Alachuan leader Payne (hence Payne’s Prairie), who died of his wounds a few months later. Payne was a charismatic leader and diplomat who had the intellect and experience needed to establish a political and military solution to American encroachment into Florida. His death brought an end to that possibility, and the brutal Seminole wars followed shortly after his passing. [↑](#footnote-ref-10)
11. Ibid., pg. 1, footnote 4 [↑](#footnote-ref-11)
12. Ibid, pg. 1, footnote 3 [↑](#footnote-ref-12)
13. Di, J.J., D. Smith, C. Lippincott, and E. Marzolf (2010) Technical Publication SJ2010-1 POLLUTANT LOAD REDUCTION GOALS FOR NEWNANS LAKE. St. Johns River Water Management District Palatka, Florida [↑](#footnote-ref-13)
14. Ibid, pg. 1, footnote 3 [↑](#footnote-ref-14)
15. This may be an error, and may actually be mg.m-1.d-1  [↑](#footnote-ref-15)
16. The profundal zone is the deeper regions of the lake which are separate but typically contiguous to the near shore littoral zone. [↑](#footnote-ref-16)
17. Gottgens, J.F. and T.L Crisman (1992) Sediments of Newnans Lake characteristics and pattern of redistribution following a short drawdown [Phase II] University of Florida, Dept. of Env. Eng and Sciences, Gainesville, Fl. For St. Johns River Water Management District Project :10-43-6420-3103-DIST-31500-SWIM. pp:21-28 [↑](#footnote-ref-17)
18. H.T. Odum (1953) Dissolved Phosphorus in Florida Waters Department of Biology, university of Florida , Gainesville,Florida pg. 7. [↑](#footnote-ref-18)
19. E.A. Stewart III (1976) A Study of Differences in Vertical Phosphorus Profiles Within the Sediments of Selected Florida Lakes as Related to Trophic Dynamics [↑](#footnote-ref-19)
20. The U.S. and Canada first signed the Great Lakes Water Quality Agreement in 1972. It was amended in 1983 and 1987. In 2012, it was updated to enhance water quality programs that ensure the “chemical, physical, and biological integrity” of the Great Lakes. [↑](#footnote-ref-20)
21. Williams, J. D. H. and Mayer, T. "Effects of Sediment Diagenesis and Regeneration of Phosphorus ~with Special Reference to Lakes Erie and Ontario." In Nutrients in Natural Waters, pp. 281-315. Edi ted by J. R. Kramer and IL E. Allen. New York: John Wiley and Sons, 1972. 37.. [↑](#footnote-ref-21)
22. Williams, J. D. H.; Syers, J. K.; and Harris, R. F. "Adsorption and Desorption of Inorganic Phosphorus by Lake Sediments in a 0.1 M NaCl System ." Environmental Science and Technology 4 (1965): 517-519. [↑](#footnote-ref-22)
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24. Ibid ,pg 5.footnote 13 [↑](#footnote-ref-24)
25. Total Maximum Daily Load for Total Phosphorus Lake Okeechobee, Florida Prepared by: Florida Department of Environmental Protection 2600 Blairstone Road Tallahassee, FL 32303 [↑](#footnote-ref-25)
26. Options to Reduce High Volume Freshwater Flows to the St. Lucie and Caloosahatchee Estuaries and Move More Water from Lake Okeechobee to the Southern Everglades An Independent Technical Review by the University of Florida Water Institute, 2015 [↑](#footnote-ref-26)
27. The Northern Everglades Watershed is Lake Okeechobee and its expansive drainage basin to the north. [↑](#footnote-ref-27)
28. Reddy, K.R., Y.P. Sheng, and B.L. Jones. 1995b. Lake Okeechobee phosphorus dynamics study, volume 1, summary. Report, South Florida Water Management District, West Palm Beach, FL. [↑](#footnote-ref-28)
29. Ibid, pg 6 footnote 17 [↑](#footnote-ref-29)
30. Ibid, pg 6, footnote 17 [↑](#footnote-ref-30)
31. The Committee on Environmental Protection report to Florida House of Representative, 1999, REVIEW OF INVASIVE PLANT MANAGEMENT PROGRAMS [↑](#footnote-ref-31)
32. E. Allen Stewart III (2020) Response to Request for Information (RFI) non-herbicide treatment and removal of aquatic plants from Florida Waters (FWC 19/20-22) For more information on this RFI contact Matt Phillips, Section Leader FWC, Invasive Plant Management Section 3800 Commonwealth Blvd.  MS 705 Tallahassee, Florida 32399 (850) 617-9430 [↑](#footnote-ref-32)
33. Mr. Whiting may be reached at (850) 245 8191. [↑](#footnote-ref-33)
34. Putnam, H. D.; Brezonik, Patrick L.; and Shannon, Earl E.(1972) Eutrophication Factors in North Central Florida Lakes. U.S. Environmental Protection Agency Papers. 260.[*http://digitalcommons.unl.edu/usepapapers/260*](http://digitalcommons.unl.edu/usepapapers/260) [↑](#footnote-ref-34)
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36. Ibid, page 1, footnote 3 [↑](#footnote-ref-36)
37. <https://apps.sfwmd.gov/webapps/publicMeetings/viewFile/10437> [↑](#footnote-ref-37)
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43. Ibid, pg 13, footnote 36 [↑](#footnote-ref-43)
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